MODERNIZATION AND THE EVOLUTION OF IRRIGATION PRACTICES IN THE RIO DULCE IRRIGATION PROJECT, SANTIAGO DEL ESTERO, ARGENTINA

UNA TAREA DE TODOS

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Dit onderzoek is uitgevoerd binnen de onderzoeksschool CERES

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Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus,
Prof. Dr. M.J. Kropff,
in het openbaar te verdedigen
op maandag 18 december 2006
des namiddags te vier uur in de Aula

MODERNIZATION AND THE EVOLUTION OF IRRIGATION PRACTICES IN THE RIO DULCE IRRIGATION PROJECT, SANTIAGO DEL ESTERO, ARGENTINA. UNA TAREA DE TODOS. Wageningen University. Promoter: Vincent, L.F., - Wageningen: Daniel Prieto, 2006, p.292+xx.

ISBN: 90-8504-545-2

PROPOSITIONS

1. If the final goal of irrigation is to contribute to people's development, farmers' irrigation practices and their interactions with other components of the irrigation system and with their own production styles should never be ignored. *(This thesis)*

2. The criticism of modernization is not in its pursuit of change but in the prescriptive character of its application, and how this prescription becomes the vehicle for worldwide dissemination of a standard 'modern' set of hard and soft technologies assumed to achieve efficacy, efficiency and water productivity under every context, independent of local experiences and local conceptualization of irrigation systems. *(This thesis)*

3. Interdisciplinary approaches to irrigation research, such as the socio-technical approach, have proved to be very effective to explore and understand diversities and specificities of real situations. However they can sometimes be somewhat superficial to help on construction of alternative strategies to improve them if they do not have an even and strong development of all their component disciplines, and participatory involvement in design of future interventions.

4. Performance assessment can be designed on long term objectives to help policy makers, and on short term objectives to help managers, but to help people it should also provide understanding of how and why users behave as they do and such indicators are so far less developed.

5. It is a capital mistake to theorize before one has data. (Sir Arthur Conan Doyle, "Scandal in Bohemia" The Adventures of Sherlock Holmes, published in The Strand Magazine 1891)

6. Science and technology revolutionize our lives, but memory, tradition and myth frame our response. (Arthur M. Schlesinger, Jr., born October 1917)

7. What we know is a drop of water, what we do not know is the ocean. (Isaac Newton, 1642-1727)

8. The one thousand mile journey starts with the first step. (Lao-Tzu)

Propositions attached to the thesis
Modernization and the Evolution of Irrigation Practices in the Rio Dulce Irrigation Project: Una Tarea de Todos

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18 December 2006

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Glossary and abbreviations

ACA	Actual Cropped Area
Administrador	Head of the Administration board of Comuneros (see footnote 1.14 pag. 27)
AE&TI	Agro-ecological system and technological infrastructure (see page 13)
APAZ IV	Water User Association for Zone IV of the PRD
APAZ V	Water User Association for Zone V of the PRD
A&EE	Agua y Energía Eléctrica (Water and Electric Power) Federal Government agency in charge of national irrigation issues before 1992
B1 – TTS	Sampled Sub Tertiary unit within PRD
Boleta de Riego	Daily register of irrigation in comuneros
Caudal	Empirical discharge unit commonly used in PRD
Comunero/a	Water course that distribute water directly to the farms
CRD	Corporación del Río Dulce. Provincial autartic agency in charge of the extension service in the initial phase of PRD
CROPWAT	FAO developed software for calculations of crop water requirements and irrigation requirements for crops, cropping pattern and water courses
C-TDR	ComuneroTime Delivery Ratio
DPI	Dirección Provincial de Irrigación. The name of the provincial irrigation agency before 1968
EAP	Agriculture Production Units.
ED	Entrepreneur Diversify Production System

EE	Entrepreneur Production System in Expansion within PRD
F- TDR	Time Delivery Ratio at farm level
FAAM	Mechanized Familiar Agriculture – Alfalfa Production System
FAO	Food and Agriculture Organization from United Nations
FAV	Familiar Agriculture-Vegetables Production System
F-TDR	Time Delivery Ratio to the Farms
F-WDR	Water Delivery Ratio to the Farms
IA	Irrigated Area
IMT	Irrigation Management Transfer
INDEC	Instituto Nacional de Estadística y Censo
INTA	National Institute for Agriculture Technology
INTA-EEASE	INTA - Santiago del Estero Experimental Station
JS	Sampled Tertiary Unit within PRD
MAA	Smallholder Agriculture Alfalfa Production System
MAAM	Mechanized Smallholder Agriculture Alfalfa Production System
MC	Small holding cotton production System
MCM	Million of cubic meters
MS	Smallholder Subsistence Production System
NT	Not typify Production Systems
O&M	Operation &Maintenance
PRD	*Proyecto del Río Dulce*
PRETA	Permiso revocable eventual Temporario Anual. Temporary Water Right
PROSAP	Programa de Servicios Agropecuarios Provinciales. A BIRF – World Bank funded program for modernization of Provincial Agriculture Services
PSA	Programa Social Agropecuario. A Federal Program for small loans and economic subsidize for smallholding farmers.
PWR	Permanent Water Rights
RAMSAR	Convention on Wetlands
RIFA	Relative Active Farms
RIMSIP	International Farming Systems Research Methodology Network
RIS	Relative Irrigation Supply
RS	Sampled Tertiary unit from the Suri Pozo Secondary network
RWS	Relative Water Supply
S&CS	State and Institutions of Civil Society (see page 13)
SARCC	*Sociedades de Agricultores Regantes* de Canales *Comuneros* (*Comuneros* Water Users Associations
SMFN	Sampled Tertiary unit from the San Martín Secondary canal network.
TCA	Total Cropped Area
TCA	Total Cropped Area
TDR	Time Delivery Ratio
TTC	Tertiary Canal from La Cuarteada Secondary Canal
TTS	Sampled Tertiary unit from the Simbolar Secondary network
TU Delft	Technical University of Delft
TWRA	Total Water Righted Area
UER	Unidad Ejecutora de Riego. Provincial Irrigation Agency in charge of PRD operation from 1992.
UNDP	United Nations Development Programme
WAU	Water User Associations
WDC	Water Delivery Capacity
WDR	Water Delivery Ratio

WR	Water Right
WRAP	Water Righted Area of Active Parcels

Preface

To do a PhD was not a reflexive decision to get a degree that would improve my livelihood and my family situation. Actually the decision to do a PhD in the second half of my professional life was highly motivated by the need to improve my knowledge of tools to help me to understand the complexity of large-irrigation systems. It was also my conviction that such a deeper knowledge was essential to contribute to the *knowhow* needed to improve irrigation and the livelihood of people in Santiago del Estero. It would be a long period of technical and social engagement with water management.

I made the first contact with the IWE group for a PhD in early 1995 and was fortunate and grateful to receive a 'sandwich' scholarship from Wageningen University: but I could only make the project concrete at the beginning of 1998. The student desk surprised me and my family by offering to rent flat 272 at Pomona, Wageningen - the same flat where 15 years before I had lived with my wife and my eldest son during our M.Sc studies. Soon I discovered that it was not a coincidence but a kind sign of friendliness by Ankie Lamberts from the student desk, an old friend of my wife Cristina and myself since she started her career as secretary of the Soil and Water M.Sc course within the International MSc program in Wageningen. This kind gesture helped us to feel at home again.

Unfortunately the road to the PhD was not as easy as that promising beginning. The original main topic of my 1995 research project needed to be updated as the complexities of the Proyecto Rio Dulce (PRD) became clearer, and I discovered the sociotechnical and other research approaches. Furthermore, the fact that the there was no conventional water scarcity and/or tail enders problems and/or social conflicts among large and small farmers within PRD, led most of my interlocutors to conclude that PRD was a water-rich project without serious irrigation problems, and left me alone in this search. Construction of the research proposal was indeed then initial stage of a learning process, but a learning process that only started for myself when I realized - after reading Checkland (1981) - that I was leading as many managers, with a complex and hard-to-define problem. This learning process followed a long and difficult evolutionary path that evolved - as the PRD - with the contribution of many people, many hours of reading and many hours of far away glances though the Nieuwlanden windows, or delving into my own former work.

If preparation of the research proposal was a hard intellectual process, the field work back in Santiago del Estero from late 1998 was no softer, for two main reasons: it has to be done at the time of one of the most serious financial crises of Argentina and my Institute, and it became a less than a part time job due my involvement in routine tasks, and my own limitations to concentrate my work on the PhD research. This explains why my field work programmed for 1999-2000 extended to 2002.

No less difficult has been the processing stage of all the information collection, and the final stage, the writing process of the thesis. The processing of the large amount of information collected required hard work, concentration and continuous cross-checking to guarantee the quality of the information. However, my limited skill in fluent English made the writing process a very time-consuming and many times a frustrating process.

Materialization of this thesis therefore required the support and involvement of many people that consciously or not helped me along this long process. First of all I should mention my family, my wife Cristina and my sons Salvador, Nicolás, Manuel and recently my daughter-in-law Natalia. I can find no words to acknowledge all they have done to support my work. I am clear that the effort of most of them has been almost greater than mine in this long period. For that reason I wish to apologize for all the hours that we should have been together but which I spent working on evenings, week-ends and even holidays. I also apologize for not being a better husband and father during this time and for not been able to appreciate you as you deserved. This thesis is truly yours.

A great and special acknowledgement should go to my supervisor Prof. Linden Vincent, although we are a dangerous couple for closing works since both suffer from the same commitment of trying to catch the whole complexity: without her support it would not be possible for me to finish my PhD. Her patience technical guidance, continued encouragement, and her willingness to work to through my manuscript with me to make it a readable book - despite her other busy agenda with IWE issues and PhD students - is highly appreciated.

My dear friend Richard Soppe also deserves a special distinction: without the hospitality of him and his family, I would have not survived the last 4 months in Wageningen far away from my family. The working environment in his flat helped me a lot to keep the focus on my work and reduce my home-sickness during evenings and week-ends.

I want to thank my friends and collaborators at the Natural Resources Research Group of the INTA - Santiago del Estero Experimental Station (Gabriel Angella, Cristina Angueira, María C. Sánchez, José Salvatierra., Mario Valoy, José Rodriguez, Mario Umbide, Juana López, Gabriela Barraza) for their contribution and support; the UER people (Guillermo Angriman, Jorge Ledesma, Mario Juarez, Pedro Leiva, Mr. Tevez, Mr. Kusmus, Mr. Cárdenas and all other interviewed field staff) for sharing their information files and operational experiences. I also highly appreciate the contribution of the large number of farmers that spent hours sharing their experiences - especially to José Ramón Rodriguez, Jorge Lund, Antonio Oliverio and the family of Vicente Salvador for sharing their memories.

I also do not forget the help of Dutch students (Mechteld Andriessen, Jeanet Gupta, Howard van Meer and Etta Meuter) and Argentinean students (Salvador Prieto, Martín Roggero and Martín Harte) with the measurement of discharge, groundwater levels and soil salinity ,and with farmers' interviews and their processing.

Many people in Wageningen should be also thanked, starting with my old friends Francisco (Chiche) and Susana Sassano for opening again their place to my family and me as they have done for most South American students at Wageningen in the last 25 years. I also enjoyed a lot the companionship of Alejandra Moreyra and friendship of Lucas and Adriana Seghezzo.

Most present and former members of IWE (Gerrit van Vuren, Frans Huibers, Flip Wester, Kai Wagerich, Bert Bruins, Margreet Zarteveen, Gerda de Fauw, Bernita Doornbos, Peter Mollinga, Willem Genet) have contributed to my work during the final period of my PhD, with their comments and support. However I would like to give a special acknowledgement to Rutgerd Boelens and his wife Esther, to Gerben Gerbrandy and his wife Irene, and to Maria Pierce for supporting me outside curricular activities and making my stay in Wageningen comfortable and hospitable. Discussions with the now Drs' Eric Chidenga, Jeroen Vos, Puspa Khanal, Vishal Narain and Suman Rimal Gautam and my fellow Conrade Zawe have also been very beneficial and enjoyable.

Chapter 1

Introduction

1.1 Problem Statement

The Rio Dulce Irrigation Project (PRD), with its irrigable area of 120000 hectares, is one of the most important irrigation systems in Argentina. It has contributed more than 40% of the gross agriculture product of Santiago del Estero province for many years and supports the livelihoods of more than 50 % of its population. Irrigation in the area of the Rio Dulce started before 1900, first through the spontaneous action of local settlers developing local canals for irrigation for local markets. However, political changes and new commercial possibilities since the beginning of the twentieth century brought a succession of public and private impulses to enlarge and modernize the irrigation system. The economic and political importance of the PRD made the system an "ongoing" project of interventions by provincial and national politics. However, much actual expansion has been shaped by the two main actors in day-to-day activities, an unmotivated agency (in irrigation terms) and private farmer interests.

The PRD system first evolved in relation to the maximum area cultivable under the unregulated water source of the Rio Dulce (Sweet River). Motivated by continuous conflicts between users and its own interventionist policy, the National Government planned its first structured intervention in irrigation during the 1940's. This presumed the development of physical infrastructure to improve water capture and conveyance, and a reorganization of irrigation operations to achieve the objective of maximizing production per unit of water (protective irrigation). While "modern" physical infrastructure was constructed in some parts of the system, the management of the system was never systematically reorganized. Administration continued under the responsibility of the provincial agency, but the area continued its "wild" evolution and operation.

User and provincial authorities reclaimed Federal Government involvement with construction of a reservoir that started its operation in 1966. Then a second intervention in the area, the Rio Dulce Project (PRD), became planned as a joint effort of the National and Provincial government. Its focus was on new water regulation technologies and a broader rural transformation that implied a complete "modernization package". This package included development of the water storage capacity, reallocation of water, direct involvement of a professional national agency in system administration, strong promotion of "modern" irrigation practices and full government extension support to irrigated agriculture production.

This program was truncated by political forces in 1973 - 1975 in its early stages, leaving - besides the reservoir - only a partially improved infrastructure for conveyance and distribution of water and a National Agency in charge of system operation, maintenance and management. Since then, the evolution of the project has been shaped first by a progressively unmotivated national agency, and then by a provincial agency from 1992, but also by a heterogeneous group of users and general stakeholders and highly unpredictable incentives set by a changed political and economic context. Nevertheless, through political and technical negotiations, project representatives have been able to control different interests and threats that would be a source of conflicts in many other areas. Large and small farmers, farmers with permanent water rights that do not crop and farmers that crop significant areas with only annual water rights have coexisted without serious conflicts during many years.

Overall, irrigation performance of the PRD is well below the expectations of engineers and planners and international norms and its contribution to provincial development has been in the last 30 years far below its potential. However, the system has also shown resilience in its capabilities to survive and continue delivering water without bringing serious environmental degradation or suffering any serious disputes in access to water. Actions by farmers, engineers and politicians have brought adaptations such that the system performs acceptably for most of them and for farmers in particular.

Much contemporary thinking about modernization that improves water delivery and water management assumes homogeneity in operation and management arrangements across an irrigation system, and also homogeneity in farming styles and farmers' capacity for mobilizing resources. It also often assumes that new institutions can be formed and adopted by farmers who will appreciate their benefits in improved local water delivery and reduced transaction costs. However, the PRD has a substantial diversity in it operating conditions across the system. Also, the system of water delivery operates through arrangements of water allocation between large and small farmers that bring high water allowances to all cultivators that might be jeopardized by new 'formalized' management structures unable to represent actual political realities. Finally, many contemporary reform programs anticipate special financial assistance – either national or international - that can focus on system renovation and support new institutions. However, the economic situation in Argentina gives little current scope to new capital assistance programs for irrigation modernization. These challenges to modernization and reform, while at an extreme in Argentina, are also faced in other irrigated areas.

This thesis documents the evolution of this in-system diversity, and the sociotechnical arrangements, contestation and adaptation that enabled water to keep flowing effectively despite a complex and often chaotic history of public intervention and technological changes, and examines the motivations and strategies of farmers and agencies and their 'room for manoevre' to improve irrigation performance of the system.

The hypotheses behind this thesis are that the relatively conflict-free operational environment in PRD has been possible at a cost to provincial development, through an important underutilization of the irrigation scheme that also involves low water productivity, inefficient and ineffective use of suitable land, loss of economic opportunities, and a high dependency of small farmers on populist policies of both National and Provincial Governments. Farmers and agency staff have shown successive adaptations to new technical, managerial and economic conditions that are often highly innovative coping strategies in themselves. However these ongoing interests to minimize conflict and evolve with pragmatic coping mechanisms may actually limit substantively better technical water performance, and ensure water is available to all who want it in the future. To test these hypotheses and related research questions, this study examines the strategies, role and practices of local actors and their effect on the irrigation performance achieved at different levels of the system, to give information that can also reduce speculation and uncertainty over the future development of the area.

However, by also accepting that PRD modernization will continue to be entirely shaped by the force of its social actors, this study can help any future anticipated state intervention with knowledge for advice, based on an understanding of what can actually be done while avoiding application of prescriptive modernization "packages". Such insights may also help future modernization programs elsewhere in Argentina and other countries with large irrigation systems.

1.2 Objectives

The specific objectives of this study were:

- To document the evolution of irrigation practices in the PRD and how different actors (state, agencies, and farmers) have interrelated with other supra-systems shaping the growth of the PRD.
- To establish the factors (ecological, technical and social) determining actual water management practices in particular and performance outcomes of the PRD in general.
- To understand why and how actual irrigation practices differ from technical expectations.
- To develop understanding that can provide advice for contemporary reforms in irrigation distribution practices in the PRD.
- To explore as far as possible the contribution of irrigation to the sustainable development of the area.

1.3 Irrigation in Argentina

Argentina is a federal country: provinces are autonomous, they own their water resources, they have their own water laws, rules and water policies and they are responsible for the development of irrigation facilities and their management. However, despite the autonomy of the provinces and the low relative importance of irrigation in terms of national production, for geopolitical objectives (settlement and development of the arid and semiarid zones of the country) the Federal Government gave importance to investments to boost national irrigated area during the twentieth century, especially from the 1950s to the 1970s. Being directly or indirectly responsible for the international loans that funded most of these developments, the federal government also retained in many cases the management of the systems for many years. However its involvement in irrigation decreased progressively over time. Then, in 1992, as part of deep neo-liberals reforms it deserted irrigation issues and left them completely under the responsibility of Provincial Governments.

The transfer of water administration to the National Government during the earlier period from the 1970's was seen in some cases as a loss of provincial political autonomy. However it should be taken into account that in Argentina, as in many areas around the world, irrigation fees were not usually paid. Thus by taking charge of system operation, the National Government actually subsidized water use in those projects. The large amount of money needed to keep irrigation systems running was the reason why many provincial governments (mainly the poorer ones) accepted involvement of National Government in irrigation administration within their areas, but also the reason why it deserted them in 1992.

Despite the sourcing of funds for irrigation development from international agencies, an important characteristic of irrigation development in Argentina is that involvement of foreign consultants has been rare. Most irrigation projects were designed, constructed and operated by Argentinean engineers and mainly overseen by the irrigation unit of a Federal Agency, the "Agua y Energía" (A&EE), whose irrigation staff had a high level of specialization at that time.

The national irrigated area is nowadays the third largest area in Latin America after Mexico and Brazil (Table 1.1). However it rarely receives too much attention from the international irrigation community perhaps due its low contribution to the national economy or because it represents only 5% of the total national cropped area (column 4 Table 1.1).

Table 1.1 Irrigated area in South America Irrigated area as percentage of the Total Cropped Area (TCA) per Province (%)

SOUTH AMERICA			
Country	Irrigated Land (IL) (ha*1000)	Total Arable Land(TAL) (ha*1000)	IL/TAL (%)
Mexico	6320	24800	25
Brazil	2920	58980	5
Chile	1900	1982	96
Argentina	1561	33700	5
Peru	1195	3700	32
Colombia	900	2293	39
Cuba	870	2668	33
Ecuador	865	1620	53

Source: FAO, 2004

However, irrigation is the main source of agricultural production for a majority of the twenty three Argentinean provinces, as shown in Table 1.2. This table shows that irrigation is important in terms of economic development in most provinces in the arid and semi-arid regions of the country, not only because irrigated areas represent a high proportion of the total cropped areas (IA/TAL) but also because of the high proportion of households in those areas depending on irrigation (Irrigated EAP/Total EAP). Further comparison of Tables 1.2 and 1.1 demonstrates that for the arid and semi-arid regions of Argentina, irrigation is as important as in other Latin American countries highly dependent on irrigated production.

The irrigated area in Argentina grew continuously until the 1980's, after which it reached a plateau. According to the Agriculture National Census of 1988 and 2002 the national irrigated area has remained close to 1.300.000 has in the last 16 years, but this national figure hides important differences in growth and decline between provinces as shown in Table 1.3.

Table 1.3 1998-2002 increment of irrigated area per province and climatic region.

ARID REGION			SEMI-ARID REGION			HUMID REGION		
Province	Ha	%	Province	Ha	%	Province	Ha	%
La Rioja	24.427	140	Córdoba	36.219	63	Bs.Aires	65.229	64
Catamarca	32.325	109	Salta	21.776	22	Santa Fe	24.220	183
San Juan	2.482	3	San Luis	9.153	97	Corrientes	23.344	65
T.del Fuego	-78	-99	Jujuy	8.378	10	Entre Rios	22.441	46
Santa Cruz	-3.355	-47	La Pampa	-214	-4	Tucumán	9.070	16
Chubut	-18.499	-50	S.del E.	-17.219	-24	Chaco	5.474	264
Río Negro	-32.697	-31				Misiones	-1.188	-87
Mendoza	-35.232	-12				Formosa	-2.088	-34
Neuquen	-65.476	-81						
Tot / Mean	**-96.316**	**-7**	**Tot /Mean**	**58.307**	**34**	**Tot/Mean**	**146.502**	**65**

Source: Own calculations based on 1988 and 2002 INDEC census

Table 1.2 Relative importance of irrigation in Argentinean provinces (source INDEC, 2002).

ARGENTINE								
ARID REGION			SEMI-ARID REGION			HUMID REGION		
Province	IA / TCA %	N° Irrig EAP[1.1] / Total N° EAP %	Province	IA / TCA %	N° Irrig EAP / Total N° EAP %	Province	IA / TCA %	N° Irrig EAP / Total N° EAP %
Mendoza	99	79	Jujuy	64	65	Corrientes	13	5
San Juan	99	75	Salta	16	63	Tucumán	10	23
Rio Negro	62	48	Sgo. Del Estero	10	34	Formosa	3	1
Chubut	43	28	San Luis	2	3	Entre Rios	3	2
Santa Cruz	39	8	La Pampa	2	1	Buenos Aries	1	5
Catamarca	34	82	Córdoba	1	7	Santa Fe	1	2
Neuquén	30	85				Chaco	1	1
La Rioja	7	67				Misiones	0,02	1
T. del Fuego	0,2	3						
Mean	41	52	Mean	19	29	Mean	4	5

IA= Irrigated Area; TCA=Total Cropped Area

[1.1] EAPs are Agriculture Production Units. This is one or more farms or plots under the same administration.

The tendencies are clear: in the last sixteen years irrigated area increased mainly where there was either adoption of supplementary irrigation related with high profitability of extensive crops (the first four of the humid areas Buenos Aires, Santa Fe, Corrientes and Entre Ríos, plus Córdoba and San Luis from the semiarid region), or in provinces where there were national fiscal incentives during this period (La Rioja, San Juan and Catamarca in the arid region and San Luis in the semi-arid region). The main characteristic of these developments is that they have been based mainly on exploitation of groundwater, and undertaken almost completely by the private sector in large farms. Salta, the other province with positive figures in this period is a particular and remarkable case since the increment of its irrigated area was caused by the establishment of 3 to 5 very large farms (roughly 10.000 has each) but using surface irrigation (Juramento-Salado River).

Also remarkable is the reduction of irrigated area in most traditional areas[1.2]. Although in some of them like Mendoza, Rio Negro, and Neuquen there has been a concentration of land and a qualitative change from surface to localized irrigation application methods, in 2002 the irrigated area of most of them was far below the area with water rights in 1986 (that could be roughly considered as the maximum irrigable area) as can be seen from Figure 1.1.

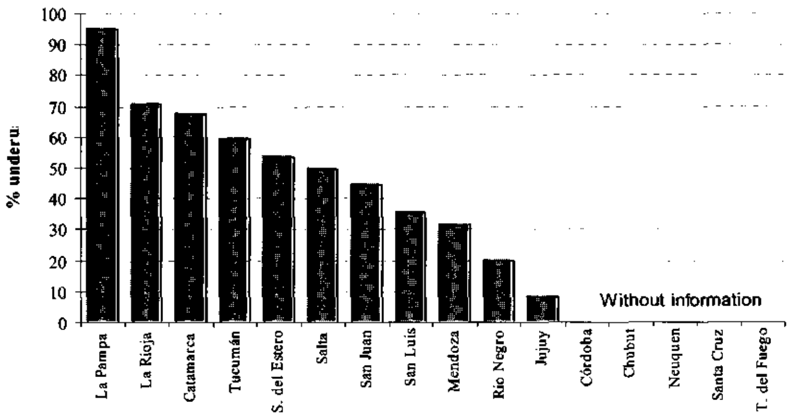

Figure 1.1 Percentage of underutilization of irrigation per province (INTA, 1994)

The above information, plus the fact that only 5 provinces (Mendoza, Tucumán, San Juan, Neuquén and Chubut) have signed an agreement with a National Program for Agriculture Services (PROSAP) for modernization of irrigation infrastructure (and that few others -Formosa, and Rio Negro - implemented small rehabilitation programs with national funds) makes it clear that in the last 16 years there has been an extremely low investment in rehabilitation, modernization or enlargement of irrigation infrastructure.

[1.2] The negative difference for Santiago del Estero does not agree with cropped areas surveyed by the irrigation agency. While figures from both sources are similar for 1988, the agency's reported irrigated area almost doubled in the 2002 Census data. Using agency values, the irrigated area in Santiago del Estero would increase to 29.287 ha (41%) a rather high but more consistent value in my experience.

Regarding irrigation system management, by the 1970s, Operation and Maintenance (O&M) management activities of Argentinean irrigation schemes were centralized by the state, and performed mainly by the afore-mentioned irrigation agency of A&EE or similar provincial agencies. Participation of farmers was at a very low level, except in Mendoza where participation of users has been present since the beginning of irrigation. At the beginning of the 1990's, due to the neo-liberal reforms of the Federal Government, Provincial Governments of those provinces where irrigation was still administered by the National Agency were compelled to re-assume O&M activities. Some did not have the required capacity to be in charge of that heavy task, showing permanent cash deficits and lacking a structure, therefore compulsory "turn-over" O&M activities to users took place.

While the 1990s can be considered the "turn-over and/or participatory irrigation decade" (see section 1.5.2 for further analysis), it will be clear that in Argentina to transfer responsibility to users was not a well-defined or centralized national plan as debated in other well-known irrigation reform programmes in Latin America like in Mexico, Chile and Colombia, or other countries of the world. The process, that could be named a "modernization process" due to some analogies with the above planned process in selected countries, was highly dependent on the political orientation and capacity of each Provincial Government. In most cases it was limited to a reorganization of O&M activities with greater participation of users. For example, in Rio Negro a few WAUs took responsibility over large areas from early in the turnover process. In Salta, O&M activities that were re-assumed by the provincial government before 1992 were transferred later to a Cooperative of former employees of that provincial agency. Other Provinces, like San Juan, Catamarca and Tucumán, continued with centralized O&M systems. Again, only in Mendoza did the "modernization" program include increased farmer's participation at higher levels, and later on improvement (modernization and rehabilitation) of irrigation infrastructure. This was a consequence of a strong and professional agency and pre-existing participation of farmers at lower levels of the irrigation systems (Chambouleyron et al, 1994,, Bustos *et al*, 2001; Morabito et al, 1998). The case of Santiago del Estero will be further described in this thesis.

There is no well-systematized inventory of the performance of Argentinean irrigation systems. Problems have been surveyed in several different studies, but most of these works (INTA, 1986; Chambouleyron et al. 1994; Bertranou and Shulze, 1992; Fiorentino, 1988) are superficial, often strictly "professional"[1.3] in nature and without any systematic methodology. Bertranou and Shulze (1992) identified the main constraints of the Argentinean irrigation sector as: the engineering bias of their irrigation systems; the low profitability of most irrigated production; insufficient O&M activities; the low technical skill of farmers and operational staff and poor water management at system and farm level. There is no analysis by national or provincial irrigation sector done from any interdisciplinary perspective that also includes local user perspectives. However, this section has shown the large climatic, social and even cultural differences in irrigation history between Argentinean provinces, and gives a clear idea of the diversity of situations of irrigation in Argentina and the specificity of study cases.

[1.3] Following Mollinga, 2003, the term professional is used here to include three different disciplinary approaches to irrigation, - engineering, economics and management - that have produced much irrigation literature but which has remained unconnected.

1.4 SANTIAGO DEL ESTERO PROVINCE

The province of Santiago del Estero is located in the northwest of Argentina (see in Figure 1.2) between the south latitudes 30°29' and 25°38' and west longitudes 61°40' and 65°11'. Physically it is almost as far away from the capital Buenos Aires (1000 km) as from Mendoza (800 km), the best-known Argentinean irrigation community. Santiago del Estero is also far away from Buenos Aires and Mendoza in social, political and economical development as shown below.

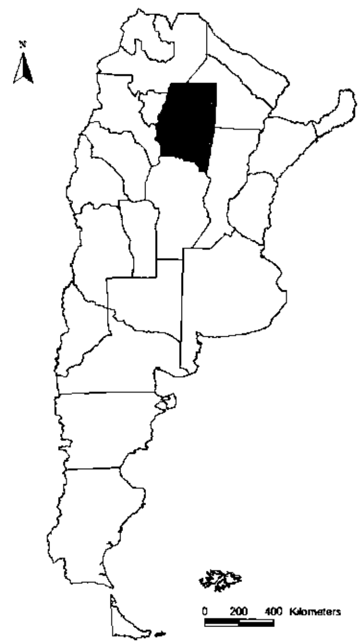

Figure 1.2 Santiago del Estero Province

Argentina is a country with a relatively high Gross Domestic Product (GDP) per capita but distribution of wealth is not uniform. The historical ratio between GDP of the richest (Federal City Buenos Aires) and the poorest provinces (Santiago del Estero and/or Formosa) has ranged from a factor of 12 to 17 times. The GDP for Santiago del Estero is similar to countries like Bhutan and Djibouti and is below Angola, Zimbabwe, Egypt and Congo (Fraga, 2003).

Santiago del Estero covers 136.351 square kilometres, inhabited by 804,457 people (INDEC 2001). It is located in the semiarid portion of the physiographic area "Gran Chaco Americano". The mean annual temperature is 21,5°C with relatively cold winters (absolute minimum – 5°C) and very hot summers (absolute maximum 47°C). Annual precipitation, mainly as seasonal summer rains (November-April), ranges from 500 to 850 mm/year with its maximum value towards the east and northwest borders and its minimum in a south-north central strip in the centre of the province. Since annual reference evapotranspiration ranges from 1300 to 1600 mm/year the annual water balance is negative in all areas of the province. In the central strip where the study area is located even the monthly climatic water balance is negative across all the months (Figure 1.3) and irrigation is vital for agriculture.

Through this dry landscape meander two rivers - the Salado (Salt River) belonging to the Río Paraná basin and the Rio Dulce (Sweet River). The Rio Dulce is the main tributary of the closed basin of Mar Chiquita, a salt-lake located in the Province of Córdoba, close to the south border of Santiago del Estero.

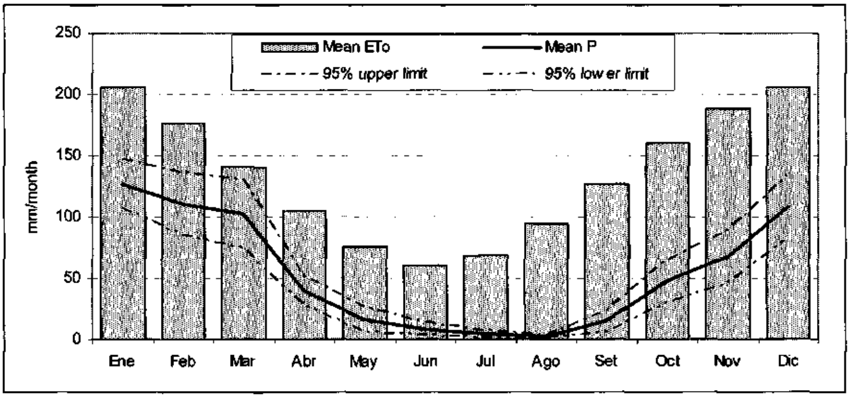

Figure 1.3 Monthly water balances for La Maria climatic station in the core of PRD

1.4.1 *The Río Dulce basin*

The Dulce River basin partially covers 3 provinces: Tucumán, Santiago del Estero and Córdoba. In 1967, these provinces agreed to share the use of mean available water (calculated as 3.600 Hm^3/year) as follows: Tucumán (32%); Santiago del Estero (49%) and Cordoba (14%). In volumetric terms, the percentage for Santiago del Estero is 1.773 x 10^6 m^3. Most of the water of the watershed is collected in the upper part of the Dulce River basin in Tucumán, where slopes are steep and rainfall high. In the middle part, where the PRD is located, slopes are gentle and there is less rain. In the lowest part, where the area is almost flat, lie wetlands surrounding Mar Chiquita. This area has been declared a Ramsar site by UNDP.

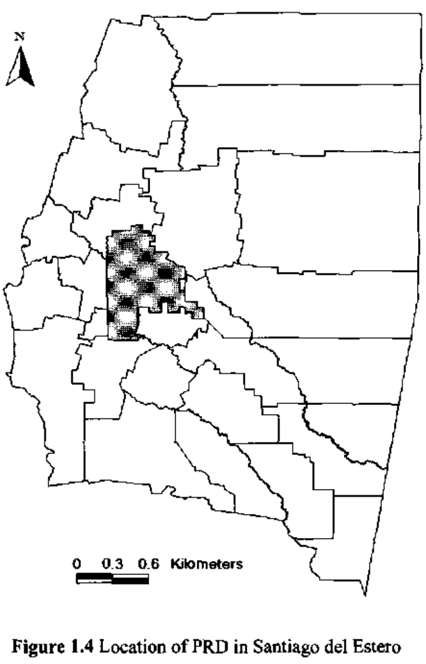

Figure 1.4 Location of PRD in Santiago del Estero

1.4.2 *The Research Area*

The Dulce River Irrigation Project (PRD) (Figure 1.4) is by far the greatest user of Rio Dulce water. It has an immense influence in absolute and relative terms on the water and nature balance of the river basin. While the irrigated area first expanded through independent and privately developed canals (*acequias particulares*), later large-scale public works expanded the irrigated area around these older canals, which became embedded in the system but subject to variable technical modernization.

The maximum irrigable area of the PRD is 122,000 hectares but its gross command area is about 350,000 hectares. It was the water shared by the Province that determined the maximum area of 122000 ha in the PRD, because land was not a constraint. The policy criterion, during the last state intervention (1968-1973) was to cover the full irrigation requirements of selected cropping patterns (with a project efficiency of 40%). However, since the actual cropped area has never reached 122000 hectares, water has never actually been scarce in the PRD from this technocratic point of view.

According to official information from the irrigation agency, in 2004 the number of irrigated holdings with permanent water rights was 6.800 but as one farmer may own more than one plot, the number of farmers or EAP is less. Roughly 65% of these EAPs have less than 10 ha, 34% are between 10 and 100 ha and 1% are greater than 100 ha. This data shows that large and small farmers coexist across the irrigated area, a pattern settled at early stages of irrigation development. Since the increase in water supply available in the reservoir, and extensive area with permanent rights that remains uncropped, 'surplus' water has been allocated out as non-permanent and revocable rights called PRETAS. PRETAs allow the agency to allocate annually water that is unused. The conditions for PRETAs are: payment in advance, enough capacity in water courses to convey this water for use on annual crops only (not to be used for permanent or semi-permanent crops like orchards). The payment in advance is an especially attractive point to the agency as fee collection was traditionally very low.

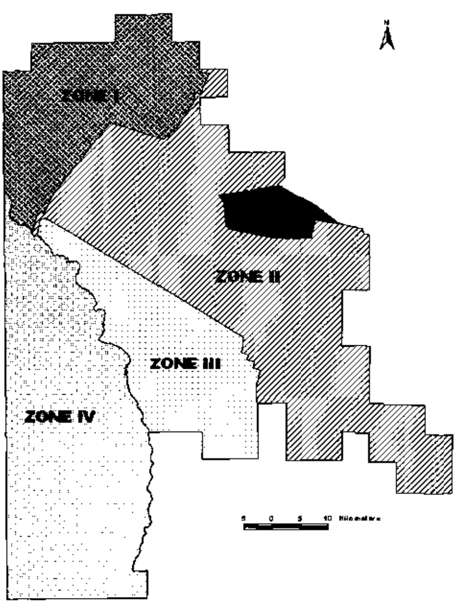

Figure 1.5 Administrative Zones of the PRD

PRD has been a jointly managed system, with users being responsible for water distribution at low levels of the system (the quaternary water course in most cases) since its conformation as an irrigation unit with construction of the main delivery dam, Los Quiroga, in the 1950's. A provincial agency (DPI), a national agency (A&EE) and again a provincial agency (UER) have succeeded each other in the management of the upper part of the system, following changes in the national and provincial socio-political context. Only during a short period (1992-1995) was participation of users promoted as part of decentralization plan of O&M activities at secondary level that should lead to a definitive turn over of the system to users. However this process was truncated by an abrupt change of political orientation of the provincial government in 1995.

The scheme is divided administratively in 5 zones (Figure 1.5). Due to historical reasons and the unfinished last process of 'modernization', these zones have a very uneven development of water control, as follows.

In Zone I (19000 ha) the irrigation network was completely 'modernised'. Canals were lined to quaternary level. A dense network of primary and secondary drains and sluice gates for water offtakes and for water-level control were built. Long-throated flumes were constructed also in the head end of all canals, including the *comuneros*[1.4] (the lowest level water course, administered by farmers).

Zone V (7500 ha) is the other zone with its network of irrigation and drainage canals constructed during PRD implementation. However, canals are not lined in this area. Automatic Neyrpic Avio gates have been located at the head of secondary and tertiary canals. Module-à-masque structures are sited in these canals for water measurement. Constant head orifices were built at the heads of the *communeros*[1.5].

In Zone IV (19000 ha) modernisation reached tertiary irrigation canals and led to construction of a dense network of primary and secondary drains. Offtake and control structures were also incorporated through a combination of automatic Neyrpic Avio gates and sluice-gates. The old *comuneros* are still in use to distribute water to farms.

Modernisation did not reach Zones II (46000 ha) and Zone III (15000 ha). Old earthen canals are still being used. Nevertheless these have received high maintenance in the last years sometimes under the responsibility of large farmers. Measuring devices are only available at the head of secondary canals. Few drains have been built in these zones.

Table 1.4 summarizes the physical characteristics of the main and secondary canals

The working hypothesis at operational level is then that these differences in physical infrastructure have a great influence on access to water, levels of water use, and levels and uniformity of performance across zones. However, they also have an influence on the possibility to increase irrigated area. Farmers from zones with lined canals find it difficult to increase canal capacity because a large investment would be required, while those using old canals can afford to increase capacity themselves or lobby to do it with the PRD budget. (This study will show that the canal capacity has only been enlarged in Zones II and III).

1.5 CONCEPTUAL FRAMEWORK

Irrigation is "human intervention to modify the spatial or temporal distribution of water occurring in natural channels, depression, drainage ways, or aquifers and to

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[1.4] *Comuneros* (also sometimes called *comuneras*) are distribution ditches or the water courses at the lowest level of the system. Officially farmers are responsible for water management at this level. "Modernized comuneros or comuneras" and "old comuneros or comuneras" are used in this thesis to differentiate those that have been re-built during PRD intervention after 1966, from those ditches built before PRD but still in use.

[1.5] All measuring structures and automatic Neyrpic gates were never been used for operational purposes before 1995 and only those at the head of secondary canals have been used since that year. In the particular case of automatic Neyrpic gates at the head of tertiary canals, sluice gates originally located upstream from them for service reasons are normally used for operation.

manipulate all or part of this water to improve crop growth" (Small & Svendsen, 1992). I highlight three aspects of this definition. The first is that irrigation is a human intervention, (a collective human intervention most of the time); the second is that irrigation embraces manipulation of water, a natural resource and the third one is related with the final goal of irrigation - crop production. A collective human intervention implies a social construction, ideas and criteria of people and society on what technologies they choose, and emergence of complex social relations between different types of actors. Manipulation of natural resources links this human intervention with its ecosystem, and possible externalities over other water users and natural resources but also implies use of technology in its broad sense (tools, knowledge and labour power), while the final goal stresses the productive character of irrigation and its direct relationship with economic development.

Table 1.4 Characteristics of the main canals

Canal	Type	Zone	Material	Length (km)	Capacity (m3/s)	Measurement Device[(a)]
Matriz (Main)	Main		Lined	21,7	100	LT - flume
Alto [(b)]	Sec	I	Partially lined			
Norte	Sec	I	Earth	27,0	7	LT - flume
Cuarteada	Sec	I	Partially lined	36,4	8	LT - flume
Sud I	Sec	II	Earth	20,6	10	LT - flume
San Martin	Sec	IV	Partially lined	65	10	LT - flume
Los Romanos	Sec	III	Earth	10	20	LT – flume
Municipal[(b)]	Sec	III	Earth			
Suri Pozo	Sec	II	Earth	20	27	LT – flume
Jume Esquina[(b)]	Div[(c)]		Earth	59,5	20	LT – flume
Sud II	Sec	II	Earth			Emp. Rating
Simbolar	Sec	V	Earth	15,8	15	Neyrpic Mod

a) LT = Long throat flume, Emp. Rating = empirical rating curve to a canal reach, (b)Not included in this study (c) derive water from the Salado River but also conveys water to Sud II, Rodeana and Simbolar Sec.Canals

Irrigation systems are specific realizations of irrigation in concrete socio-environmental situations, where different activities should be done to assure the shared use of water by multiple and many times heterogeneous users.

The above put clear that irrigation systems are sociotechnical system in nature (Uphoff, 1986; Kloezen and Mollinga, 1992; Mollinga, 1998; Vincent, 1997, 2001; Mollinga, 2003) and that their analysis requires an interdisciplinary approach that can address both the technical and social dimension simultaneously.

1.5.1 *The sociotechnical approach.*

The ***sociotechnical approach*** is a jointly developed approach by staff members and students of the Water Engineering Group of the Wageningen University (Vincent, 1997, 2001; Mollinga, 1998, 2003) that has evolved as an alternative to other different ways to study irrigation[1.6].

[1.6] Eggink & Ubels (1984) also differentiated the ***Technocratic approach*** that focused on technical issues of irrigation (infrastructure and their technical performance) and has a strong commitment to positivistic science and western technology and the ***Organizational approach*** that emerged as a reaction to the problems resultant from a narrow technocratic approach and its lack of attention to

Beside the conceptualization of irrigation as a combined sociotechnical phenomenon other central elements of this interdisciplinary approach are: its conceptualization of irrigation systems not only as different level of canals connected to higher and lower levels by hydraulic structures but a number of socio-technical levels with different sociotechnical connections; its conceptualization of irrigation practices embedded in wider structures or social events; and its conceptualization of technology mediating not only people with their biophysical context but also shaping and being shaped by people-people relationships[1.7].

Figure 1.6 (after Mollinga, 2003) sketches the descriptive model of irrigation systems (static component) from the sociotechnical approach.

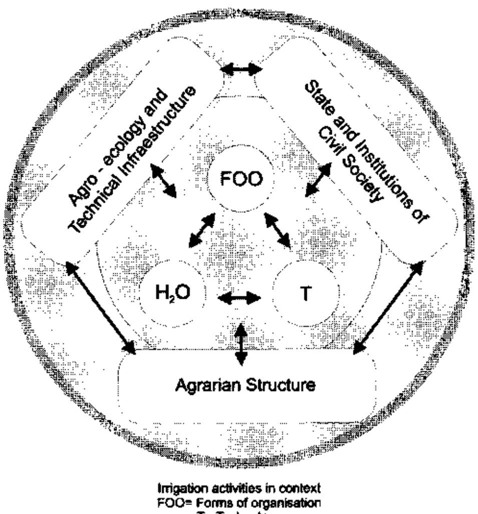

Figure 1.6 Sociotechnical view of irrigation activities and context (redrawn from Mollinga, 2003).

At the outer part of the figure the context or conditions of possibility where irrigation is embedded are presented grouped under *agro-ecological system and technological infrastructure (AE&TI) agrarian structure (AS) and state and institutions of civil society (S&CS)*[1.8]. These conditions of possibilities that enable irrigation to be conducted in a particular way are not static, but are broader systems in continuous and evolutionary transformation whose change produces continuous adaptive change of

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operations, maintenance and management, and drew heavily on management science. Coward (1980) noted how institutional difficulties were considered a more important reason why irrigation performance was below expectation.

[1.7] According to Mollinga, 2003 the social dimension of technology is specified through, the social requirement for its use (social conditions that have to be fulfilled for the technology to work effectively and/or technologies require different enabling conditions), its social construction (technology development is a social process in which different stakeholders interact and shape its technical characteristics) and its social effects (technology affects people's livelihoods from irrigation and their wider environment).

[1.8] In short AE&TI includes climate, vegetation, soils, topography, production technologies excluding irrigation technology; AE incorporates labour markets, credits, social relations including ethnicity, religion, etc under S&CS is found government agencies, NGOs, social movements, education and training institutions.

irrigation systems and are in some circumstance also changed by irrigation. Chapter 2 covers the historical path of this interaction in the PRD area.

At the core of the representation lie the three basic elements of irrigation systems, water (the resource), irrigation technology (tools) and people and forms or organization (social component) form a triangle that summarizes all the activities required within an irrigation system. For operationalization of the descriptive model it is necessary to look in detail at those activities relevant for the study[1.9].

For the socio-technical approach, the dynamic component of irrigation systems has as a main goal water control in its three differentiated dimensions: *technical* control (the physical control of water by means of irrigation technology); *organizational* control (the collective actions needed to manage water distribution process in the irrigation system); and *political* control (involving struggles between social groups with different interests for the use of a natural resource).

For operationalization of this analysis of the dynamic of irrigation, the concept of practices (Van der Zaag, 1992; Mollinga, 1998, 2003) is crucial. Human practices are regularized types of acts that people do in a structured and structuring fashion (Giddens, 1976 cited by Mollinga, 2003) highly determined by the nature of human agency, and social interactions. This means that people are knowledgeable, capable and active in creating in new social and material environments (human agency), that they devise strategies and employ resources to achieve their objectives, but also that practices take place in social, spatial and time areas (arenas) and that they are routines structured by rules (institutionalization).

In other words allocation of water rights, process of water distribution, technology choices, allocation of water priorities under water scarcity situations and state-water user's relations in irrigation systems are areas of contestation (arenas) where people, with particular objectives and strategies and different capacity to mobilize resources, are crucial actors and builders of their network.

Eggink & Ubels (1984) proposed a framework to study communal irrigation systems that focused on the organizational structure of rules, roles and dominant groups participating in management, and system activities of water allocation, system maintenance, conflict management, and construction and rehabilitation. Gutierrez (2005) added a fifth activity, system operation and distribution. She also expanded the framework of organizational structure to differentiate decision-making and task supervision of activities, and formal rules from the local and nature of informal local rules.

Eggink & Ubels, 1984 recognized that large-scale bureaucratic-communal irrigation systems consisted of two different organizational components, and that the interaction between them is relevant for the functioning of the system and that water distribution

[1.9] Uphoff's (1986) activities classes - activities related to control structure, water use activities, organizational activities - that are defined in his now well-known cube will be used in this thesis but emphasis is put on relevant activities.

is by far the most crucial activities in this type of system. They proposed a further analytical framework for these systems based on the three following elements

- the functioning of the central bureaucracy and main system management
- the functioning of the water users' community and tertiary unit management
- the interaction of bureaucracy and users, and the scheme and the local community governance

Issues such as government interest, headend-tailend problems, poor staff performance and corruption, lack of adequate management structures, complicated technology and operational requirements are considered important to study the functioning of the central bureaucracy and main system. The characteristics of water-user groups, their use of indigenous form of organization, and analysis of farmers' participation in local society are included by Eggink & Ubels (1984) as relevant topics for assessment of the functioning of the water users' community and tertiary unit management. Finally conflicting interests between the bureaucratic agency and users' community, the main objectives of the project (e.g. settlements vs. non-settlement), the functioning of the water users community and tertiary unit management, and technology and local power structure are considered determining factors on agency-users-community interaction.

Figure 1.7 presents the analytical framework followed in this thesis to study of the PRD. A third organization component, irrigation management at farm level, has been added to the framework of Eggink & Ubels (1984), since farmers' decisions at this level are certainly highly determined by water management upstream, but under specific circumstances they can also determine and/or put conditions over available alternatives at higher levels. Also, inclusion of this level in the analysis of large scale irrigation systems should be a paramount principle under service oriented irrigation management. The new organizational component brings two new elements to the Eggink & Ubels' analytical framework:

- the functioning of irrigation at farm level
- the interaction of farmers decision and upstream components

The Main System Irrigation Management component has been expanded by including government interest on irrigation issues (a factor already identified by Eggink & Ubels, 1984), agency power, agency identification with government policies and operational appropriateness of available infrastructure.

Irrigation agencies are normally seen as the operational arm of government, not only to operate main systems but to implement official irrigation policies. However this connection is often too weak to empower the agency enough to lead the proposed intervention effectively. In other cases irrigation agencies are so far from political decision-making that they find room to manoevre to 'decode' or adapt such interventions as wanted (by themselves or in agreement with water users).

Available infrastructure and its operational appropriateness refers to the required tuning between infrastructure and water delivery method, and operation and maintenance capability in terms of operators' skills and organizational capability as well as with general irrigation management principles such as equity, transparency, accountability. These topics have been extensively analyzed by different authors

(Horst, 1983, 1998; Lankford and Gowing, 1996; Renault, 1999; Plusquellec, 2002; Chidenga, 2003).

The modified framework propose by Gutierrez (2005) was adopted to study the tertiary units under communal management while irrigation strategies and application practices are considered the main activities that will directly affect water use and water productivity. Irrigation strategies imply decisions about when and how much water to apply, while application practices refers mainly to how water is applied to crops.

For operational reasons emphasis in this thesis is in water allocation and operation and distribution activities at both main systems and tertiary units, while irrigation strategies and application practices effect on water use at farm level are also analyzed.

In parallel with the above analytical framework, the framework proposed by Perry (1995) to study the functionality of the systems is considered useful to research the evolution of PRD. The conceptual model proposed by Perry (1995) considers that functionality of any system depend as much of its basic component as of the inter-linkage between them. In case of irrigation systems the author considered functionality as prerequisite to achieve significant improvements of performance and water rights, infrastructure capable of delivering the service implied in water right, and assigned operational responsibility the three essential elements.

Also helpful is the concept of water as a factor substitute introduced by Levine (1980). This concept reveals the value of "excess" water as a substitute for other resources in more limited supply at different levels of the irrigation and for both the agency and users of irrigation water.

Water allocation and water rights

Uphoff (1986) defined water allocation in a pragmatic way as the process during which it is decided who should receive how much water. In the context of this thesis water allocation is seen as a social process through which some people receive or acquire directly privileges for using a certain amount of water under certain conditions, while others result in being excluded. Water allocation is therefore a political process with a high power for social differentiation and normally subject to continuous negotiations, with different types of claims from stakeholders not in few cases based on different legal sources.

According to Murray-Rust and Snellen (1993), water allocation is normally defined by two sets of rules. The first set defines the principles by which water will be shared between individuals and forms the basis of water rights. The second is the degree of conditionality of the right, normally based on a determination of actual water availability at the head of the system. They differentiated five different ways to share water and three types of conditionality.

BUREAUCRATIC - COMMUNAL IRRIGATION SYSTEMS

Main System Irrigation Management					
	Water Allocation	Operation & Distribution	System Maintenance	Conflict Management	Construction & Rehabilitation
Government interest					
Agency power and Agency identification with government policies					
Operational appropriateness of available infrastructure					
Decisions & Tasks					
Formal Rules					
Participants and roles					
Logic and informal rules					

Tertiary Units - Communal Irrigation Management					
	Water Allocation	Operation & Distribution	System Maintenance	Conflict Management	Construction & Rehabilitation
Decisions & Tasks					
Formal Rules					
Participants and roles					
Logic and informal rules					

Farm Irrigation Management		
	Irrigation Strategies	Application practices
Crop selection		
Production styles & Resources		
Participants		

Figure 1.7 Analytical framework for the study of the PRD

Water rights are the main output of the water allocation process. Boelens and Hoogendam (2002) defined them as 'authorised demands to use (part of) water, including certain privileges, restrictions, obligations and sanctions accompanying this authorisation, among which a key element is the power to take part in collective decision/making about system management and direction'.

Schlager and Ostrom (1992) pointed out that there is a bundle of rights that various users and management entities might have. They proposed the classification presented in Table 1.5 that helps to understand the grade of control actors have over their resources.

Table 1.5 Water rights classification by Schlager and Ostrom (1992)

Use Rights	Access	Access to resource – Normally applies to non-consumptive uses
	Withdrawal	Permit to take out some of the flow
Control Rights	Exclusion	Power to determine who will and who will not have access to the resources
	Management	Power to regulate use patterns. It provides the ability to define access or withdrawal
	Alienation	Rights to sell, lease or bequeath rights

Many authors (Meinzen-Dick and Bakker, 2000; Meinzen-Dick and Bruns, 2000; Benda-Beckmann *et al.*, 1997; Boelens and Hoogendam, 2002; Gerbrandy and Hoogendam, 2002) show the many perspectives from which water rights can be studied and stress the need of go beyond the formal and statutory rights and looks to customary law and even to different bases of claims to water use. These perspectives will be used in this thesis (Chapter 3) to explore how present water rights were constructed, formalized and made effective.

1.5.2 *Modernisation concepts and programmes*

Modernisation has been used as an objective for decades by irrigation engineers from international and national agencies to justify interventions in irrigation systems. It allows a stress on fresh ideas that the "new" and "well" planned interventions in irrigation systems could implement in order to overcome the main constraints preventing achievement of the stated objectives of former planned interventions. Most such interventions, due their high financial requirement, have been state interventions supported by international loans, which implicitly means a dominant participation of the international irrigation community and their approaches.

The word *modern* comes from the Medieval Latin word *modernus* that means "relating to the present time." or "new; that involves the latest ideas or equipment". To *modernise* is to change something by replacing old equipment or methods with new ones", the action of replace giving new shape or new aspect to old things" (Collins English Dictionary, 1995). From the above it is clear that modernisation cannot be defined in terms of a specific set of hardware and software options, because these will not be modern tomorrow.

The character of a continuous process of modernization is clear following the historical change of its scope that included construction of huge irrigation systems, centrally managed by strong agencies with a top-down approach and externally-trained managers in colonial times. A sharp change of the dominant paradigm from protective to productive irrigation including "scientific" design of infrastructure based on a greater understanding of hydraulic principles and soil-crop-atmosphere relationship (see discussion of the CROPWAT approach in Halsema, 2002, p.21) followed in the post-colonial period.

After a new verification that "modern" technically-scientifically designed irrigation systems - like the "old fashioned" ones - did not reach their goals, the focus changed to stress the role of system management, and the needs of changing organisational and institutional aspects, including decentralisation to lower levels and impulses to user participation. Under this new modernization paradigm programmes for Irrigation Management Transfer (IMT) and/or Participatory Irrigation Management (PIM) have been promoted wordwide (Johnson *et al.* 1995; Vermillion, 1995; Johnson, 1997; Mundra and Garg, 1999; Svendsen and Murray-Rust, 2001; Svendsen et al., 1997; Vermillion, 1997; CNES, 2003; Peter, 2004; World Bank, 2005).

More recently, with the increasing competition for water by different use sectors and the societal awareness about environmentally negative effects of irrigation, challenges to increase efficiencies, effectiveness and water productivity have increased. Now modernization prescriptions stress concepts of service orientation, operational decentralisation, demand management, higher water productivity, and water markets with its implication of tradable water rights.

In line with the above thinking, Renault (1999) showed the metamorphosis of modernisation, stating that modernisation has been central to the concerns of the irrigation community, but the concepts behind it have evolved. It is now well understood that modernisation is not limited to the introduction of modern hardware and software techniques, but is rather a fundamental transformation in the management of water resources. This transformation can include changing rules and institutional structures related to water rights, water delivery services, accountability mechanisms and incentives, in addition to the physical structures. Box 1.1 summarises a number of contemporary definitions for modern irrigation and modernisation needs, in which the concept of service provision according to norms is prevalent.

However, my criticism about modernization is not about change in its content and scope since I am strong believer that sustainability of irrigation systems is highly associated with their adaptive capacity to meet changes and/or power transformation of their internal social forces. My criticism of modernization interventions deals with the prescriptive character of its application (Box 1.2 presents one of such prescriptions) by external and international consultancy firms and multinational donor agencies. Also how such prescriptions become a vehicle for dissemination worldwide of a "modern" standard set of hard and soft technologies for water management that invariably would make possible achievement of the highest efficacy, efficiency and water productivity under every context, independent of local experiences and local conceptualization of irrigation systems[1.10].

Box 1.1 Definitions of Modernization

"Irrigation modernization is a process of technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes combined with institutional reforms, with the objective to improve resource utilization (labour, water, economic, environmental) and water delivery service to farms" (FAO, 1997).

"Modernization, which is a more complex intervention (than rehabilitation and process improvement) implying fundamental changes in the rules governing water resource management. It may include interventions in the physical infrastructure as well as in its management" (Renault, 1999).

"Irrigation modernisation is a process of change from supply-oriented to service-oriented irrigation. It involves institutional, organisational, and technological changes. It transforms traditional irrigation schemes from protective to productive irrigation. The modernisation process is now accepted as a strategic option to increase water productivity, total production and increase economic output of large gravity irrigation schemes" (Burt and Styles, 1999)

If we go back through the irrigation path of the PRD in relation to this overview of modernization we could say that it offers an excellent study case since there have been only two modernization interventions. The first one in the 1950's (Los Quiroga intervention) included a basic improvement of infrastructure for physical capture and control of water at head level of the system, along with consolidation of political control of water by the provincial government highly absent in the previous period. The second intervention, after construction of Rio Hondo reservoir, was planned as a strong intervention. It included precise hydraulic design of irrigation canals in accordance with well-calculated peak crop water demands, a large number of diversion structures for close water control, modernization of on-farm water management, and the imposition of powerful agencies for the required centralised system management. After this intervention whose implementation was truncated by a radical change of political orientation of the provincial government, the system continued its evolution under the force of its main actors, the operational agency and water users. The study of the way these actors re-elaborated most of the "modernization" concepts still present in the Rio Dulce Irrigation Project, and the output in terms of water use, were the main driving forces for my research.

1.5.3 *Performance studies and indicators*

Performance assessment of irrigation systems has become a specific focus of the irrigation community alongside modernization, to gain a baseline picture of systems before intervention (and many times to justify it), to highlight aspects not working well and needing corrective action, and to compare irrigation systems with different purposes.

[1.10] Another distinctive feature of the prescriptive management of modernization is the effort made by the international irrigation community in finding a standardised definition of modemisation.

Different definitions of irrigation performance have been proposed (Box 1.3) underpinned by the technocratic-positivist approach that dominate modernization interventions and business management. However, there is an alternative definition from the socio-technical approach that from my point of view would help in the design of advice for future sustainable interventions. This is to see irrigation performance as the art of the possible under given specific conditions of possibilities, in which users and operators may have different criteria in choosing how to distribute and use water and even different from designer criteria

BOX 1.2 "Modern design" or "modern schemes" according to Plusquellec *et al.* (1994)

- consist of ***several levels with clearly defined interfaces***
- Each level is technically able to provide ***reliable, timely and equitable water delivery services*** to the next lower level. That is, each ***has the proper types***, numbers, and configurations of gates, turnouts, measurement devices, communication systems and other means to ***control flow rates and water levels*** as desired.
- An ***enforceable system is in place that defines the mutual obligations*** and creates confidence at each level that the next higher level will provide reliable, equitable and timely water delivery service.
- Modern irrigation schemes are ***responsive to the needs of the end users***. Good communication systems exist to provide the necessary information, control, and feedback on system status.
- The hydraulic design is robust, in the sense that it will function well in spite of changing channel dimension, siltation, and communications breakdowns. Automatic devices are used where appropriate to stabilise water levels in unsteady flow conditions.
- ***Motivated and trained operators*** are present at all levels of the system. Operating rules for individual operators are well understood and easy to implement.
- A maintenance plan is defined during design, adequately funded through water fees, and strictly implemented

There is recognition of the importance and requirements of agricultural irrigation and the existing social conditions. Engineers do not dictate the terms of water delivery, rather agricultural and social requirements are understood and satisfied at all levels and at all stages of the design and operation process within overall resource availability

Independent of the approach assumed I strongly believe that, given the evolutionary character of irrigation systems and their continuous adaptive change to changing conditions of possibilities, assessment of irrigation performance should be an explicit[1.11] routine task of donors, planners, operators and users.

This section first reviews the evolution of the debate on performance assessment and performance indicators as it has evolved alongside debates about of modernisation. It then summarises the choice of indicators and in which way they are used in this study to show actual conditions in the PRD.

[1.11] I stress the need of explicit performance assessment because I am convinced that, given the character of human agency in both operators and water users who implicitly make (conscious or unconscious) assessment of the water allocation and water distribution process, it can help then to define the need to keep or change their strategies.

Box 1.3 ***Irrigation Performance Definitions***

"The performance of a system is represented by its measured levels of achievement in terms of one or several, parameters which are chosen as indicators of the system's goals". (Abernethy, 1989 cited by Murray-Rust and Snellen, 1993)

"Performance assessment in irrigation and drainage can be defined as the systematic observation, documentation and interpretation of activities related to irrigated agriculture with the objective of continuous improvement. (Bos *et al.* 2005)

Constructing a general framework

The dominant path of development of irrigation systems performance criteria has progressed from an initial stage where definition and validation of performance indicators for different levels or domains of an irrigation system were the main objective (Albernethy, 1986, 1990; Bos and Nugteren, 1982; Levine, 1982; Levine and Coward, 1989; Bird and Gillott, 1992), to procedures to fix standards that allow the judgment of the performance level reached by different types of organizations.

Small and Svendsen (1990), with their discussion about the framework for assessing irrigation performance, were among the first to clarify the problem of different perspective and interest from which the assessment can be done, that had put confusion in the initial stage. They discussed performance indicators related to their model of nested levels in a scheme – for irrigated agriculture, for the water delivery system and contribution to the national economy. Small and Svendsen also outlined three types of measures: process measures (that led to outputs); output measures (quality and quantity of outputs as they become inputs elsewhere) and impact measures (relating outputs of the system to the wider environment) - a differentiation that would remain in almost all future contributions.

Murray-Rust and Snellen (1993) from the irrigation agency level complemented this work with a more business and organizational vision. They introduced the concept of a service-oriented approach to irrigation systems that would later predominate in future contributions, due its central role in modernization paradigm. Other important contributions of these authors were: their differentiation of operational and strategic performance[1.12]; the recognition of performance dependency from design-management environments (physical infrastructure, institutional and organizational conditions); their clear differentiation of objectives and targets; and the utility of the two main ways of setting standards for performance judgement (taking them from similar systems elsewhere or comparison of outputs with intended results).

[1.12] This differentiation was based on the adoption of Ansoff's criteria (Ansoff, 1979 cited by Murray-Rust and Snellen, 1993) that effectiveness of any organisation's activities can be measured by two complementary criteria: the degree to which organization's products or services respond to the needs of its customer and the efficiency with which the organisation uses resources in supplying these needs.

Process assessments

Process performance is normally assessed in terms of the following different qualities (sometimes referred to as parameters): adequacy, equity, reliability, predictability, timeliness, efficiency (now re-named outflow-inflow ratios), productivity, etc. (Bos and Nugteren, 1983; Bird and Gillott, 1992, Jurriens, 1996, Renault and Vehmeyer, 1999, Bos et al., 2005)

Bos et al (1994) referring to the nested broad framework of Small and Svendsen (1990) went on to develop a generic set of performance indicators oriented towards irrigation systems managers. Most of the proposed indicators focus on internal process but some of them go further than the irrigation system level as relevant to this wider framework of complex systems. It includes attempts to assess the impact of irrigation on the environment and socioeconomic change, and a first attempt to evaluate the level of services linked to contemporary modernisation proposals.

In the same line of helping operational management of systems to assess water supply variability and efficiency, Jurriens (1996) developed a set of *seasonal performance indicators,* for which the required data could be collected on a routine basis by operational field personnel. For Jurriens, timeliness and reliability are not easily quantifiable qualities, because they are greatly dependent of the subjective judgement of the users. For accountability - a very important parameter for the "modern" service orientation of irrigation systems - the author considers that the irrigation agency could be accountable to its users and its superiors on the basis of how well the targets have been reached. Also the number of farmers' complaints could be another accountability measure, although one should know what these complaints are about.

Another point highlighted by Jurriens was the fact that the irrigation service performance could never be equated simply with the quality of the agency's performance. He argues that a poor delivery performance does not automatically mean that the quality of the operators is poor, because poor delivery can be due external factors beyond the control of managers. On the other hand the quality of service depends largely on customers' satisfaction, from how well service matches the users' requirements in relation to their own business and technological level. If the user's requirements were low, a poor water delivery from the engineer's point of view could still cover all customer expectations and they would judge service performance as good.

More recently Bos et al. (2005) in their guidelines for Irrigation and Drainage Performance Assessment updated the "state of the art" in terms of performance assessment for performance-oriented management agencies. Performance indicators are presented grouped in relation to three main topics relevant from "modern" management point of view: Water Balance; Water Service and Maintenance; Environment and Economics. Emerging indicators based on remote sensing were also presented.

Comparative performance studies

In general terms comparative performance studies among different systems and sub-systems are normally assessed in terms of the following different criteria: Productive efficiencies; Water supply; Financial and Environmental Performance.

Molden et al (1998) worked exclusively with indicators for comparing performance between irrigation systems – between countries, but also between different infrastructure and management types and between different environments: also for assessment over time of the trend in performance of a specific project. For that purpose they differentiate external and internal indicators, a differentiation that would also persist in future contributions.

'Internal' indicators (corresponding to process measures of Small and Svendsen, 1990) are those tailored to meet system-specific needs: they relate performance to management targets, and tend to be data intensive. Their relations with the systems' output are not straightforward and therefore were considered not suitable for comparative studies. External performance indicators measured the performance of the irrigation system in terms of input and outputs in strategic terms. They were designed to show gross relationships and trends and should help to detect where a more detailed study is needed. A minimum set of 9 external indicators where used in the study, covering three broad areas, Irrigated Agriculture Output (4), Water Supply (3) and Financial (2) (See Appendix 1 for details).

Although not a focus in the Molden *et al.* (1998) study, these "external" indicators could be useful to investigate different patterns within large irrigation systems like the PRD in this study. Values of the indicators calculated for different units or subsystems, for instance secondary and tertiary canals, make it possible to compare some aspects of equity in the system.

Burt and Styles (1999) studied 16 different irrigation systems around the world with the main objective to answer the question: Do modern water control and management practices in irrigation make positive differences? They made a combined use of external and internal indicators (see Appendix 1). This work made some important advances from the point of view of internal (operational) indicators, going deep into the survey of turnout structures, and some important recognition of the existence of users' participation and budget quality. Also it was a first attempt to study some correlation between the indicators, since the final capacity of the systems to offer a high level of water delivery service is, in most cases, the output of a combination of many factors rather than one individually.

Malano and Burton (2001) consolidated the concept of "benchmarking" in irrigation and drainage sector, extended from corporate business. Benchmarking is a continuous process whose main aim is to identify and apply the organization-specific best practices. Its final goal is to improve the competitiveness, performance and efficiency of the system being benchmarked. Through benchmarking the organization should be able to assess its internal processes - then to compare them with the best practices of more successful similar businesses in the market, determining any performance gap between current and best practice and selecting those best practices, tailoring them to fit the organization and implementing them. In line with Molden *et al* (1998) and Burt and Styles (1999), they work with a minimum set of simple but effective and universally applicable external performance indicators to be used for benchmarking, and an international on-line data base has been implemented.

Alternative approaches

The work of Hoeberichts (1996) is one of few attempts to search for the water users' perspectives of irrigation performance. Based on the application of a Participatory Rural Appraisal (PRA) seven qualities of the irrigation service were identified as important from the users' point of view. They were: adequacy, timeliness, predictability, equity, tractability, water quality and hassle. In this study, the first four referred to canal water supply, tractability was important for both canal and ground water supply, while the last two, water quality and hassle were only important for groundwater supply assessment. Most of these terms are well known: however their meanings were sometimes different from those in use by engineers, as summarized in Box 1.4.

These types of alternative approaches based on local practices and users' visions that look to learn from interactions of people with their conditions of possibilities, and that survey people-technology and people-people interactions, are certainly powerful tools to identify and promote workable options for transforming practices and water use. However they are necessarily site specific, offer little possibilities of standardization and cross-comparison and require a deep knowledge of local people values, practices and possibilities that restrings possibilities for outsider prescriptions.

Box 1.4 ***Farmer's performance priorities (From Hoeberichts, 1996)***

- **Adequacy** to the users meant the proportion (ratio) of turns received in relation to the number of turns they needed, including sometimes a correction according to the water depth. A key point here was the turns they needed, that were more related with their own irrigation practices defined by their crop, their soils (mainly referring to salinity level) and their own irrigation strategies for those crops and soils.
- **Timeliness** was defined as receiving water at the right time for farming practices. A high level of this quality was relevant to specific periods, related to on-farm water management needs and practices - for example during land preparation and grain-filling periods in the case of rice crops.
- **Predictability** meant knowledge obtained in advance on a certain pattern of water supply. The users' predictions were based on past experience and knowledge about future events. There was a great difference within water users in this last point. The level of knowledge about future events were directly related to the possibilities of the users to contact people who have been upstream and/or their good relation with gate keepers from at least the head of distributaries.
- **Equity** proved to be a complex indicator since it was found that if water was in abundance users would not concern themselves with equity issues. Quantification of this quality was mainly subjective based on observations. However one interesting point was that some users accepted as fair that to a certain extent powerful water users receive more water than less powerful water users due their high capacity to influence management decisions.
- **Tractability** was defined as the ease with which the water user can manage the water from the head of the watercourse off-take to the farm off-take and from here to the field. Tractability was considered highly dependent on the stream size and flow velocity.
- **Water quality** was important in case of groundwater supply. Water quality referred to the presence of mud, sediments, nutrients, minerals or salts. The first four were considered positive water content while salts were considered highly negative.
- **Hassle** included two dimensions: to obtain and use tubewell water and the second one to cost/expenses related to those activities.

A critical vision of performance and performance indicators

The review shows that the current proposed frameworks, methodologies and indicators for irrigation performance assessment have been a collective construction by groups of international irrigation scientists. My criticism of these is basically concerned with its almost systematic application until now to justify "modern" intervention, while my concern is that more has to be done to enrich present proposals for incorporating users' perspectives.

External indicators have proved to be useful for comparative studies, identification of trends and need for more detailed studies. However big problems arise with performance assessment for operational purposes based on internal performance indicators. This study will show some incoherence and weakness even from the technocratic point of view from which they are proposed.

Service oriented management of irrigation systems is one of the principal flags of the modernisation efforts. However there are neither any measures nor specific indicators to assess the system in terms of specific conditions such as service orientation, accountability and customer satisfaction. The "top-down" engineering vision persists to the extent that the "required" volume of water needed to calculate adequacy indicators refers to full crop water requirements, and not to the amount of water required by the water users according to their own practices[1.13], production styles and resource mobilization capacity.

The issue of standards to assess level of performance, a key step for judgement, remains weak for both external and internal indicators. Benchmarking should still be further developed, and targeted to operational management that assumes performance-oriented management and explicit objectives and service level agreement. Further, in times when "industrialized" commercial agriculture moves to precision agriculture based on the acknowledgement of soil differences at plot level, irrigation performance assessment still assumes, in large scale irrigation systems, homogeneity of water users, production and irrigation practices.

Looking at strategic aspects of irrigation, the impact of the irrigation systems on the river basin is highly recommended in terms of the "modern" approach to water resources use, planning and governance, but has also not been evaluated extensively and still needs further development.

Alternative approaches offer a good opportunity to dive deep into actors' preferences which summarize well their real possibilities in terms of resource mobilization and technology choice under specific sets of conditions or possibilities. However since often in practice, water substitutes other production factors and technology limitations (Perry, 1996: Levine, 1982), a strategic vision for a better irrigation water use at higher scale can be missed if preferences and objectives of lower level stakeholders are not included. In this sense these approaches should be seen as "complementary" rather than alternatives to the now dominant perspectives.

[1.13] Its use in external indicators could be justified by the need to unify the approach for national and international comparison but it highly unacceptable in performance assessments to improve the service level of a particular irrigation system, under particular conditions of possibilities.

On the other hand more effort should be made from those who advocate more attention to users' perspective to offer workable alternatives at operational level, especially for large irrigation systems, where attention to in-system diversity is far from being solved in technological, institutional and organizational terms. In my opinion, highly reinforced by this study, the main challenge of "modernization" interventions for the immediate future is the construction of institutional and technical capacity for the adaptive management required to deal with diversity of actors, situations and realities.

1.6 Performance assessment and Indicators Used in this Thesis

In spite of my criticism about bias and the incomplete character of present performance assessment, the usefulness of particular criteria to describe water conditions, make diagnostics and assess impact of actors' practices on process and system performance is beyond discussion (Wahaj, 2001, Vos, 2002, Kloezen, 2002, Chidenga, 2003). With these objectives, external and internal performance indicators have been used in this thesis as shown in Table 1.6. Detailed definitions of these indicators are given in Appendix 1.

Table 1.6 Performance indicators used in this thesis.

	Time Period	System Level	Secondary Canal	Selected Tertiary	Field
External Indicators					
Total irrigation water delivered	Annual Monthly	√ √	√ √	√ √	
Irrigation Water delivery per unit irrigated area	Annual Monthly	√ √	√ √	√ √	
Relative Water Supply	Annual Monthly	√ √	√ √	√ √	
Relative Irrigation Supply	Annual Monthly	√ √	√ √	√ √	
Water Delivery Capacity	Annual Monthly	√ √	√ √		
Internal performance indicators					
N° of turns out, mean canal length, N° of water users, Gross Area and Water Righted Area per *tomero*			√		
Number of days/month canal discharge change	Monthly		√		
Delivery ratio	Annual Monthly		√ √		
Real irrigation order vs Official irrigation order	Irrigation Turns			√	
Frequency Delivery Ratio	Annual			√	√
Time Delivery Ratio	Annual Irrigation Turns			√ √	√ √
Water Delivery Ratio	Annual Irrigation Turns			√ √	√ √

In line with my alternative proposal there has been also a particular effort in this study to assess system performance from the vision of the main actors in day-to-day activities, - not only agency engineers and field workers but also from the users' point of view. This effort covered not only the grade of satisfaction but also research into which parameter (adequacy, equity, reliability, timeliness or predictability) they consider most and why.

Although not in a systematic way at secondary canals or tertiary units, sustainability of irrigated production under PRD conditions and environmental impact has also been researched. This has been done through analysis of differences in numbers of active farmers and land concentration and a rapid appraisal of soil salinization processes, variation of water table levels, and water quality changes downstream of the PRD.

Following the same criteria of performance indicators, Institutional Arrangements and Operation of Water distribution at tertiary units were assessed by comparing user's organization, key institutions and collective actions in the real world against official rules. Rules for constitution of "*Sociedades de Agricultores Regantes* de Canales *Comuneros* (SARCC)" (*Comuneros* Water Users Associations), approved in June 1971 were taken as the intended target for users' organization. These rules defined four positions – *Administrador* (Administrator), Secretary, Treasurer and *Celador* (ditch keeper) as well as participants, the actions allowed to be taken for each type of participant and any other legal requirements to constitute and operate a SARCC. The first three unpaid positions that constitute the Administration Council of the *comunero* are appointed by users vote for a 2 years period but they could be re-elected an unlimited number of times[1.14]. *The Celador* is the field controller of water distribution in the *comunero*: he does not need to be a water user and he is paid by water users in proportion to their irrigated areas.

1.7 Research Question

To reach its objectives the research was designed around the following main question
What are the present water distribution objectives and actual patterns of water use in the PRD and how have these evolved in relation to "modernisation" initiatives to stimulate sustainable development?

1.8 Research methodology

As Vos (2002) observed, case study research is the most common methodological approach used in irrigation management research. According to Yin (1994) case studies are preferred when "how" and/or "why" questions are going to be answered, where the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context. This explains its extended application in irrigation water management research.

When looking at or at least exploring causal effects as in this study, a comparative research design should be used. However "classical" comparative research based on comparison of cases with equality of all parameters is different from the situation

[1.14] The *administrador* is the key position: he is the head of the Administrative Board responsible of the operation of water distribution and maintenance within the *comunero*. Their role will be analyzed in the empirical chapters 6 to 9.

where effects over dependent variables are to be studied. It is very difficult, or even impossible to apply in irrigation research in general and in large scale irrigation systems in particular.

This study makes comparative studies of water use at system and secondary canal levels, and among four sampled (study cases) tertiary units to capture the effect of actors practices given modernization initiatives (that are mainly manifested in different infrastructure).

1.8.1 *Selection of Study Cases*

Selection of tertiary units for in-depth studies was difficult due to the large area of the irrigation scheme, and the heterogeneity of infrastructure, agrarian structure, crop patterns and presence of temporary water rights. The number of areas studied should be great enough to represent this heterogeneity but a compromise was needed in relation to available research resources.

Four rotational units were selected based on the five attributes that could influence their irrigation performance (Table 1.7). The selected number represented a compromise between variability and operational possibilities of the research. It is perhaps statistically not sufficient to be conclusive however based on my experience in the area I will argue that they are good samples of the main representative situations that could be identify in the area at least at the beginning of the research.

The classification of physical infrastructure as "modern" or "old" refers to how far it was modified during the last scheme modernization in the 1968-1973 period. That also means that "modern" relates to 30 years ago in this study. Homogeneity of farm size distribution is self explanatory. "Restricted" and "not restricted" water availability refers to a general appreciation of the local community that should be proved by the research. Relative presence of temporary water rights (PRETA) was also considered a factor that could explain differences behaviour and output. The rotational water delivery schedule officially declared by the agency in most areas was considered rigid, and the arranged rotational water delivery applied in Zone V as flexible. The main characteristics of the four selected units are presented in Table 1.8 while Figure 1.8 presents a schematic picture of the canal network and location of tertiary units.

These areas were visited at least monthly, and other tertiary units were also visited during the research in order to check how representative the findings were in the researched areas. Due to operational reasons (relatively long distances from the office to tertiary units - 25 km to JS and more than 50 km to TTS, RS and SMFN - and the difficulty of knowing the water turn of farms in advance) water delivery to farms were not always monitored at the same farms. Irrigation data was collected at this level in those farms irrigating at time of the monthly visit.

1.8.2 *Data Collection*

To answer the main and specific sub-questions using the interdisciplinary sociotechnical framework it was required to explore technical and social aspects at different level of the system not only at present but also based on historical information that could show the evolution of the system and its main subsystems.

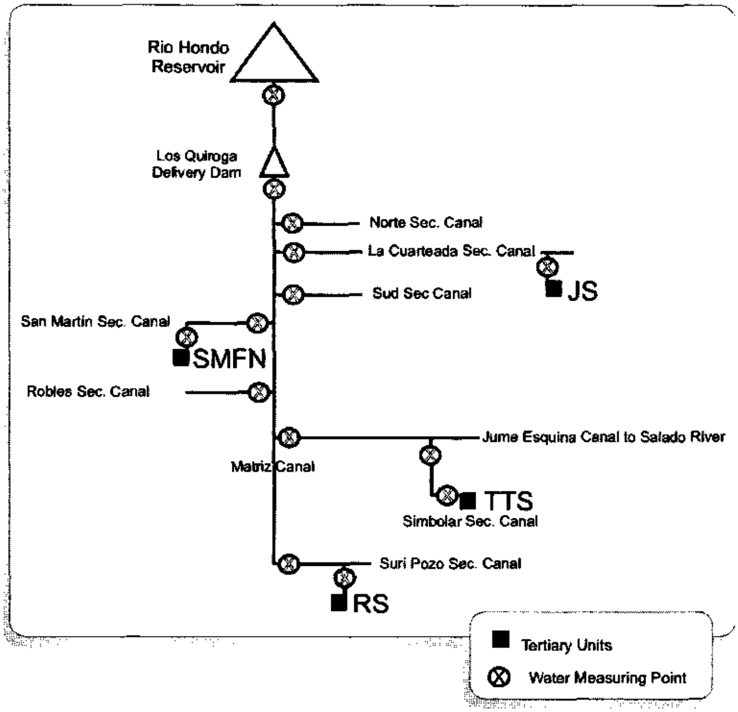

Figure 1.8 Schematic layout of canal network and location of measurement points and sampled tertiary units

As summarized in Table 1.9 technical data collection was focused on infrastructure, water distribution (delivery discharge and duration and operational practices), crop production and controlling institutions at three levels of the irrigation systems: farm, tertiary unit and system.

Table 1.9 Data collected at different systems levels

	System Level		
Basic information	Secondary	Tertiary	Farms
Flume rating curve	√ INTA	√ INTA	√ INTA
Load data base	√ INTA	√ INTA	√ INTA
Infrastructure type	√ INTA	√ INTA	√ INTA
Delivery discharge	√ UER	√ UER	√ INTA
Delivery Duration	√ UER	√ UER	√ UER
Cropping pattern	√ UER	√ UER	√ UER
Operational practices	√ INTA	√ INTA	√ INTA
Production practices	√ INTA	√ INTA	√ INTA
Soil Salinity	√ INTA	√ INTA	√ INTA
Water table depth and quality	√ INTA	√ INTA	√ INTA
River water quality	√ INTA	√ INTA	√ INTA

Table 1.7 Five main attributes considered for selecting study units.

Attribute	Value	Characterization
Infrastructure	Modern	Modernization (infrastructure) reached *comunero* level
	Old	Modernization did not reach or go downstream of secondary canals
Agrarian Structure	homogeneous – Small farmers	More than 90% of farms within the rotational unit smaller than 50 has
	homogeneous – Large farmers	More than 60% of farms greater than 50 ha
	Heterogeneous	
Water Availability	High	Considered high in base to local "view" or "myths"
	Low	Considered low in base to local "view" or "myths".
Probable presence of PRETAs	High	Permanent water righted area lower than 60% or the gross command area
	Low	Permanent water righted area higher than 60% of the gross command area
Water Delivery	Rotational	Stated in official documents or agency discourse
	arranged demand	Stated in official documents or agency discourse

Table 1.8 Characteristic of researched units respect the five attributes considered for its selection.

Rotational Unit	Infrastructure	Agrarian Structure	Water Availability	Presence PRETA	Official Water Delivery	Area (ha)	N° Holdings	Water Righted Area ha (%)
JS	"modern"	Homogeneous –Small	High	Low	Rotational	916	90	711 (79)
RS	"old"	Heterogeneous	High	High	Rotational	785	30	740 (94)
SMFN	"old"	Homogeneous -Large	Low	High	Rotational	1793	113	801(45)
TTS	"modern"	Homogeneous -Media	High	Low	Arranged	2433	18	755(31)

Physical infrastructure

Structures (cross-regulator, off-take, jump, etc) were surveyed in the main and secondary canals in order to check types and operational conditions. A detailed survey of the structures for physical water control was done in the four sampled tertiary units, and also other tertiary units taken at random were visited for surveying the type of structure at that level.

Operational procedures

Operational practices such as decisions on, frequency of, and ways of gate setting were surveyed by unstructured interviews with agency field officials and engineers responsible at the district offices. At *comunero* level that was done by interviewing the *administrado*r or the *celador* distributing water and accompanying them from time to time during their normal work.

Irrigation and agronomic practices at farm level were monitored during monthly visits of two to four hours. During these visits testimonies of farmers and irrigators (employees or family members depending of the size of the farm) were also collected over different topics related to the research.

Flow rates

Data collection at main and secondary canals was planned as a joint task of INTA and the irrigation agency. This was set up as a learning process that implied that initially I would be the organizer and controller of the process for data collection and information processing, then later transfer these tasks gradually to the Agency to be incorporated to its routine. Flow rates entering the system were measured by the agency at the head of Canal Matriz (main canal) and secondary canals. The agency was also responsible for the daily measurement of the water height (two times per day) at the observation wells of the long throated flume at the head of all secondary canals (Figure 1.9). Existing rating curves were confirmed or adjusted using the software Winflume version 1.03 (Whal *et al,* 2000) and checked periodically by direct measurement with a current meter. Water depth data were also checked periodically by direct observation by me or collaborators. Within a certain time delay I had access to all this information.

At tertiary level, JS had a long throated flume and TTS Neyrpic module for discharge measurement. In RS and SMFN, a gauge was installed and a rating curve adjusted by direct measurement. Gate keepers or *tomeros* were responsible for water level measurement. This procedure did not yield good results: gauges were destroyed or removed many times, and data were not collected with continuity. Use of an empirical rule on *tomeros* data was therefore adopted. Gate keepers register discharge using a local unit, the "*caudal*". The rule of thumb used says that one *caudal*" should be 500 l/s at the head of tertiary units and the same *caudal* at the inlet of farms should be 300 l/s. In their daily reports they describe the amount of water using that unit (in some cases multiple and submultiples are used). By direct measurements of the discharge a relationship was established between reported discharge using *caudal* and the discharges in litres per second (l/s). That yielded a discrete series of approximate discharges at tertiary canals.

At farm level water streams at their inlets were measured during the monthly visit but for comparative studies discharge measured at the head of *comuneros* was assumed at farm level.

Figure 1.9 View of long through flumes at the head of Norte, La Cuarteada, Sud and San Martin canals.

Water delivery duration

Official delivery times to main, secondary and tertiary canals were used for calculations. Their management is centralized at local office (La Dársena) close to the offtakes of most secondary canals. Information is transferred daily by radio to the central office in Santiago del Estero and hard copies sent monthly. Delivery times to tertiary canals are registered in the district office (four district offices covered the whole area). They are then transferred together with the daily reports of the *administradores* monthly to the central office but no further analysis is done. After some checking of the information by field observation it was decided to use it.

Delivery times to each farm is managed and registered by farmer organizations (Asociación de Regantes de Canales Comuneros) which are in charge of water distribution within *comuneros*. The *administrador* is responsible for the register (*partes de riego*) and hands it to the *tomero* of his *comunero* at the end of each turn. This official information was checked during the monthly visit and used in further calculations.

Crop areas

Types of crops and cropped areas (*Censos de cultivos*) were collected and compiled at the central office the National Agency (Agua y Energia) from 1968 to 1990. The work was reassumed on a regular basis by the Provincial Agency (UER) in 1998. Information is collected two times in the year (to cover winter and summer crops) by gate keepers and reported to the central office. This information was used for calculation at main and secondary canal level. A precise checking of data was not possible for the whole area, however for the researched tertiary units it was checked by direct interview of all farmers within that unit.

Social and institutional aspects

Collection of social, institutional and organization aspects was done through analysis of official documents, records of institutions, and direct interviews and informal talks at field and public places within the area. Unstructured interviews and informal talks were preferred when possible to explore the personal perception of different actors. From my knowledge of the area this could be done with officers, engineers, field officials, farmer leaders, farmers and even with some local politicians.

In the researched tertiary units an initial structured interview was done at the early stages of the research, with all farmers (using or not using irrigation water) of the tertiary unit. The interview dealt with a great variety of subjects, from land tenure, irrigation practices on different crops, participation in collective actions, level of satisfaction with the irrigation service and reasons for that, to detailed socio-economic aspects to typify the production system. Owners of abandoned farms were also interviewed when they could be identified and located. Interviews were done with the help of trained Argentinean and Dutch students undertaking thesis research[1.15] Unstructured interviews of farmers were incorporated later in order to investigate emergent issues during the research.

1.8.3 *Secondary Data Collection*

Beside the logical local literature and technical reports from the Agencies, the study made use of a wide range of secondary information and/or of information collected before the specific research presented in this thesis. These mainly refer to historical records of main canal discharge and cropping areas.

A review of historical documents and full records of a local newspaper gave relevant information about the evolution of the PRD and its social actors. That was very important to evaluate also how the roles of the different actors change with time.

1.9 THE ORGANIZATIONAL FRAMEWORK OF THE RESEARCH

I joined the National Institute for Agriculture (INTA) at Santiago del Estero Experimental Station (INTA-EEASE) in 1986 as an agrohydrology researcher. INTA is a huge autarkic national institute created in 1956 with the main goal to improve the livelihoods of the rural population through development, adaptation and dissemination of technology. Throughout its history INTA has followed the changing political conditions of the country. However its financial independence from the National Treasury - only removed during the time of the last military government and during the part of the 1990's under the privatization policy implemented by the neo-liberal government - has given INTA a considerable continuity in its work that few other public Argentinean institutions can show. There have been four main INTA goals (sometimes expressed in different ways) since it foundation 50 years ago: production efficiency to increase agriculture production and product quality for the internal and external markets; diversification of production to extend the geographic sources and destination of Argentinean's agricultural products; sustainability to use each ecosystem according with its capabilities and promoting environmentally sound use of rural lands; and equity to ensure that all actors of the Argentinean's agricultural sector receive the benefits of

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[1.15] 3 Argentinean students and 1 Dutch student (Andressen, M) from Wageningen University during her practical period, help me with structured interviews.

technological change and a fair economic distribution through all components of the production-commercial chain.

INTA is basically composed of two main branches, the research and extension branches that operate through 11 Institutes, 48 Experimental Stations and 311 Extension Offices. These give a good but uneven coverage of the national territory that followed in general terms the wealth and population distribution of the country. Despite this uneven distribution, several features allow INTA to be close to particular local needs of its clients. These include the matrix planning of its work based on national and regional strategic plans, and the fairly decentralized organization of its operation from 1987 based on 15 regional centres shaped by regional authorities but also regional boards with representation of main regional stakeholders (farmers' organization and local universities).

Supported by the institutional goal of equity and the fact that peasant production systems have greater relative importance in Santiago del Estero than in other provinces, INTA-EEASE's activities have had a social bias greater than in many other Experimental Stations. This is expressed in the prominence of organization of extension activities and inclusion of development of alternative technologies in the agenda of research teams.

Clearly identified with this profile by my bachelor formation in agronomy during the 1970's and during my MSc at Wageningen in the early 1980's, I have been critical of the traditional technocratic research. I understood that farmers also had other problems and priorities in their agendas than the traditional INTA's research topics (development of best practices for on-farm irrigation, drainage and/or soil salinity management). Therefore I became involved in the implementation of water resources research with a broad scope (irrigation systems and even regional scale rather than irrigated plots) and broad views (interdisciplinary work rather than pure engineering). The reader should have in mind therefore that the research presented in this thesis - its descriptions, findings and conclusion - has not been constructed from an objective vision of a "visitor" but is a deep follow up of continuous work about PRD by an insider highly identified with an organization with deep roots in the area.

Within this organizational framework, I had the logistical help of 2 colleagues and 2 field assistants, but due to the many topics that our research group is involved; their time on this specific study was less than part-time during the three years of field work. Also of great help, beside the students already mentioned for their participation in interviews was the work of other 3 Dutch students (2 from Wageningen and 1 for TU Delft) who helped me during their practical work with topics such as flume calibrations, canal discharge measurement, loading secondary canal discharge in a data base and the initial calculation of performance indicators.

1.10 Outline of the chapters

This introductory chapter has introduced the research topic, analysed the importance of irrigation in national and provincial terms, and introduced roughly the research site. More importantly it has informed the reader about the conceptual vision, the methodology, type of information collected and the organizational framework environment.

Chapter 2 reviews the social construction of irrigation in the area, since beginning of the twentieth century. It roughly describes the main historical changes in socio-political and economic context and its interaction with the changing role and strategic of the main actors, including the provincial and national state governments and irrigation development in the area.

Chapter 3, also makes an historical overview, but in this case specifically over the negotiated process of water allocation. Again the changing role of the state and the adaptive strategies of actors to changing context are presented. Together, Chapter 2 and 3 should provide the reader a complete idea not only of the physical and technical context of PRD in the central period of the research, but also of the social dynamic characterized by a weak role of the state in irrigation activities in particular and development initiatives in general.

Chapter 4 closes the series of descriptive chapters, describing briefly the main production systems present in PRD area, the agrarian structure based on official information, cropping patterns and main agriculture outputs as crop yields and production prices at market places.

Chapter 5 deals specifically with water management practices for operation and water distribution in the main systems (upstream of tertiary units). Outputs (performance) for the whole PRD system and each of its 8 main secondary canals are analyzed as well as its matching or differences with expectation.

Chapter 6 to 9 complete the empirical chapters on the tertiary units studied, with each units reviewed in turn. Each chapter follows a similar format and describes the particular context of the unit in sociotechnical terms and researches actors' behaviour and irrigation practices.

In chapter 6, the JS case shows how modernization (hydraulic control and water delivery method) is decoded and adapted by the traditional irrigation practices of a homogeneous group of small farmers. Chapter 7 analyzes the case of B1-TTS, a tertiary unit with arranged rotational water delivery again with traditional practices at farm level. The RS tertiary unit case presented in chapter 8 is a representative case of modernization of water distribution on an old *acequia*, under control of a heterogeneous group of users. Finally in chapter 9, SMFN is a case of a small group of large, entrepreneurial farmers with diversified production within an unmodernized tertiary unit.

Chapter 10 makes a comparative analysis of the findings on the tertiary units studied and looks for explanatory ideas and causal relations, and presents the views of higher level stakeholders on the management of the PRD.

Chapter 11 explores alternatives approaches to irrigation performance assessment from the agency official and user visions. It also briefly discusses the findings in their environmental context, looking particularly at soil salinity and river water quality.

Chapter 12 closes the thesis with a re-discussion of the relevant ideas developed in the research, with a revisit to the theoretical framework to stress its strength and weakness, with a brief description of the main topics that should be in the agenda for a new cycle of modernization in the PRD and with the main conclusion of the research. The conclusions cover a large number of topics but highlights the pragmatic character of the evolutionary path of PRD; the decodification of modernization interventions by local actors to their real requirements including persistence of traditional practices in modernized areas; the adaptive management of the irrigation agency close to the service approach of the "modernization" package without use of any of the proposed performance indicators proposed by the literature; the usefulness of comparative indicators on monthly base to unmask diversity within large irrigation systems. In more general scale stress the changing role irrigation has had in the area as social force for development and the as cause of social exclusion and social differentiation.

Chapter 2

THE SOCIAL CONSTRUCTION AND ADAPTIVE CHANGES OF THE PRD

This chapter explores the dynamic of irrigation in the Proyecto Rio Dulce (PRD) area with the objective to show how irrigation practices, actors' strategies and their interactions evolved under changing economic-political contexts and other specific conditions of possibility. The chapter focuses on the emergence of formal and informal institutions that have determined the way the system has run during the last 30 years, to help understanding of the following chapters. For the sociotechnical approach, the local political system - with all its implications in terms of policies of natural resource exploitation, implicit or explicit benefit of social groups, and definition of economic frameworks - is a relevant element of this context. The chapter is divided in four sections dealing with different periods in the evolution of irrigation in the Rio Dulce area. These periods were defined by stressing relevant events that in my opinion generated the biggest adaptive changes in the system.

In Argentina, despite its character as a federal country, many provincial issues are highly dependent on national policies. Irrigation development especially in its earlier stages was one of these issues dependent on national government. For this reason, although a precise analysis is beyond the scope of this thesis, Appendix 2 gives a brief summary of wider relevant national events influencing the political context and relevant actors' strategies described in this chapter.

2.1. THE "INITIAL" STAGE FROM 1870 TO 1926

The political, economic and social processes consolidating the Nation State in this period, and its liberal/positivist economic development model (summarised in Appendix 2) had their epicentre in the Humid *Pampa*, and great impact also in provinces with productions not competitive to this Central Area, like Mendoza (grapes) and Tucumán (sugar cane). Santiago del Estero, a pastoral producer province had similar production to those from the Humid *Pampa* but a lower competitive capacity due its semi-arid conditions and the long distance to markets. However, in provincial terms the positivism of the liberal national government during this period would nevertheless produce positive changes in the provincial economy and in the development of irrigation in particular.

According to Vessuri, (1972a) there were three main factors that put Santiago del Estero into the path of National economic growth in those years. The most important was its large areas of hardwood trees in high demand by foreign railroads companies for sleepers, and by landowners from all over the country for the fences needed for animal production and for consolidation of land property. The second factor was the large extent of suitable lands available for colonization plans[2.1] a profitable business that attracted foreign investors[2.2] from outside the area. The third and most important for irrigation development, were the new opportunities for and increased profitability of agriculture, due the huge improvement in

[2.1] State and private colonization plans were common in the Humid Pampa in this period as part of the national plan to populate the country. Large plots of land were divided in small parcels and sold to immigrants. Private entrepreneurs got cheap loans for this business.

[2.2] According to Vesuri (1972a) some of the investors had the speculative objective of getting the land to re-sell it in a short time rather than develop colonization plans.

transport facilities by the newly constructed railroads[2.3] bringing possibilities to reach Tucumán the greatest market of the region, and even Buenos Aires.

Despite the great differences in ecological conditions and suitability of land for agriculture between Santiago del Estero and the Humid *Pampa,* there was another important socio-political feature that provided the basic conditions to reproduce in some ways the development model implemented in the Central Area by the National Government. This was a powerful oligarchic group of landowners involved in political issues, with prestige, power and liberal ideas, and with large extensions of land under low productive ranch production in different areas of the province - including the future irrigated area.

The liberalisation process brought to Santiago del Estero mainly two new economic alternatives: woods exploitation or *obrajes*[2.4], and irrigated agriculture; both were developed by different actors. The local oligarchic group preferred *obrajes* as the best economic option due its low risk, higher profitability than traditional pastoral animal production and because it provided more land, the main source of its power. However, irrigated agriculture, an economic activity with high risk, was initially the main activity of European immigrants that arrived to Santiago del Estero. (Vessuri, 1972a).

The number of European immigrants (most of them Spanish and Italian) that settled in Santiago del Estero - 3,6 % of the population in 1914 - was of course much lower than in the Central Area of the country: it was 40,8 and 34,1 % of the population in Buenos Aires and Santa Fe respectively (Table 2.1). However in my opinion, they were the main actors in the initial development of "modern" irrigation. Despite their low importance in national terms, their absolute number of 6850[2.5] was highly relevant in relation to the 1.934 irrigated farms noted in the public irrigation systems in 1935 (Michaud, 1942) and to the 5.000 farmers estimated in 1926 by the La Banda delegation of the Federación Agraria Argentina (a trade organization of small farmers, see Appendix 2 and Section 2.1.5).

2.1.1 The Irrigated Area

Santiago del Estero, founded in 1553, is the oldest city in Argentina and for that reason is known as *Madre de ciudades* (Mother of towns). There are historical references about cultivation of the Rio Dulce's terraces following their periodic floods by native people (*indios*) before the Spanish colonization. This irrigation practice, at a small scale similar to that practice in the Nile valley in Egypt, was adopted by Spanish settlers. They were later to develop a primitive irrigation area located 40 to 50 km south of the city of Santiago del Estero where the slope of the landscape is very low and the river shows the typical meanders of mature rivers across floodplain areas and changes of its main channel after flood events. Michaud (1942) also states that the ditch constructed by government of the city of Santiago

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[2.3] As a sample of the optimism and expectation on irrigated land is the paragraph of the letter from Alejandro Gancedo to the Director of the National Agriculture Department reproduced by Vessuri (op citt): *"One does not talk about ten or twenty "chirolas" (cents) as it was common the years before, but of hundreds or thousands of patacones (name of current $). This region is completely transformed and we are not wrong when we say that Santiago del Estero is the California of Argentina"*

[2.4] "obraje" was the name given to the exploitation of natural woodland in the Chaco Area of Argentina.

[2.5] This number was calculated based on the 3,6% of foreigners cited for the 380.000 inhabitants of Santiago del Estero in that year (Castor Lopez, 1998). Also assuming that from the total number of foreigners, 9.500 (last column of Table 3.5) 90% were Europeans, and that 80% of them stA&EEd in the irrigated area - based in the statements of Vessuri (1972a) and Tasso (2002) that most of them settled in this area.

del Estero, that had a list of its users in 1756, was the first irrigation ditch built in colonial times in the country. This *acequia*[2.6], known first as *acequia real* and later as *acequia municipal* had its off-take just upstream Santiago del Estero city and served a small irrigation area producing vegetables and fruits for the local market.

Table 2.1 Immigrants as % of the total population in Buenos Aires, Santa Fe and Santiago del Estero provinces from 1869 to 1914.

				Santiago del Estero	
Ethnic group	**Year**	**Buenos Aires**	**Santa Fe**	**%**	**No.**
Native	1869	69,5	84,4	99,0	132.666
Foreign		30,5	15,6	1,0	1.334
Native	1895	60,2	66,4	98,5	159.570
Foreign		39,8	33,9	1,5	2.430
Native	1914	59,2	65,9	96,4	257.388
Foreign		40,8	34,1	3,6	9.612

(Source: Cuadro I of Vessuri, 1972 Originals source National Census)

Despite the above antecedents, in this study the "initial" stage refers to a later period, when simple but effective collective actions to capture and distribute river water for irrigation purposes became evident and irrigation entered in a period of continuous growth.

2.1.2 The Agrarian Structure

With traditional landowners more interested in the very profitable and low risk activity of exploiting forest resources and intermediating in the property market, a small group of capitalized immigrants found room to access lands close to the river and to use its water, a natural resource almost unexplored until that time given the dominant pastoral production.

Definitely the largest initial impulse to the development of commercial irrigated agriculture came from this group of capitalized immigrants[2.7] with initiatives to undertake new production activities for the region like sugar cane, or to increase the scale of traditional production like wheat and alfalfa, fruits and vegetables. Their example would be closely followed by some traditional landowners, and together they constituted the "*water owner*" group that initially appropriated water resources.

Non-capitalised immigrants and local *criollos*[2.8] initially provided the high labour requirements of irrigated agriculture. Because the owners of *obrajes* preferred *criollos* due their higher skills in forest and livestock activities, immigrants became dominant within the irrigation labourer group. Many of them would evolve to become leasers or sharecroppers

[2.6] The local nomenclature for water courses will be used through this thesis. It reserves the term "canals" for the largest water courses (main and secondary and tertiary). Medium to small individual or on-farm water courses are called *acequias,* while those used for water distribution to multiple users and normally under users' administration (tertiary water courses) are referred to as *acequias comuneras* or simply as *comuneros*.

[2.7] To have a better picture of the social context it is necessary to distinguish two groups of immigrants, that of capitalized-immigrants, that established commercial activity based on agriculture and had a rapid access to land and water, and that of poor immigrants with only their labor power as capital.

[2.8] *Criollos* is the name given to the existing population before the massive European immigration began.

and later 'settlers' of both private and public colonization plans when the group of "*water owners*" - reproducing the agricultural model of the Central Area of the country and due their own limitations to crop their entire landholdings- offered land for leasing or sharecropping. Relatively speaking, they found fewer restrictions to land ownership than their colleagues in the Central Area (see Appendix 2) but they would face hard restrictions to access scarce water resources. Struggles for the political control of water would become one of their main activities when the intensity of water use increased.

In this way, an agrarian structure was developed in the area of PRD with large and small farmers coexisting in a symbiotic but asymmetric power relationship. This could be reduced but not totally removed by future government interventions.

2.1.3 The Early Years of Irrigation Infrastructure Development

In 1870 four *acequias* diverted water from the river and served an irrigated area of more than 800 has. The *acequia municipal* was still the most important with 450 has but there was another public *acequia* that diverted water to Loreto city, 40 to 50 km south from Santiago del Estero[2.9], The other two were private *acequias* built by two large land owners: the Vieyra and Cia's *acequia* that served 250 has in the right bank of the river just south of Santiago del Estero city and Luis Frias's *acequia* in the left bank serving 84 has.

The number of private *acequias* increased continuously during this initial period. Table 2.2 shows that in La Banda department[2.10] on the left bank of the river, 21 private *acequias* were constructed between 1873 and 1881. They increased the irrigated and irrigable areas to 1.253 and 5.553 ha respectively.

Two points have to be highlighted for their effect on irrigation practices. The first is the considerable difference between irrigated and irrigable areas of the *acequias* (that expresses the actual capacity of the farmers but also the great availability of suitable lands). Second, the relatively large length of the *acequias* (average 10,5 km) caused by the need to locate the offtake structure far upstream from the irrigated area to take water by gravity, due the very flat landscape (mean slope 0,001).

Not only private actions were taken in this period. In 1878, the provincial government built a large canal (La Cuarteada) upstream of Santiago del Estero to transfer water from the Rio Dulce to the Rio Salado, with the objective of decreasing peak discharges that periodically flooded Santiago del Estero and other cities. However due a mistake in its design or construction, the canal did not work properly and periodically flooded riparian lands that started to be cropped by riparian farmers. Later on non-riparian farmers built and connected their own *acequias* to the main canal, creating in this unplanned way the first public irrigation system. This was known afterwards as the La Cuarteada system and it would be the initial nuclei for the development of public collective irrigation systems in the area.

Government involvement in irrigation issues and public investments in irrigation infrastructure increased in subsequent years. The La Cuarteada system was expanded with the construction of two secondary canals, Canal Norte (north) and Canal Sud (south)[2.11]. A

[2.9] This *comunero* would have a sad fate, when in 1908 due the lack of control structure at its off take the whole river flow through it destroying completely the city of Loreto.
[2.10] The province of Santiago del Estero is politically divided in 27 departments.
[2.11] Because the off-take structure of La Cuarteada canal was periodically destroyed by high river discharges the government made large investments in different attempts to built a permanent off-take structure at the river

provincial agency (Irrigation Department) was created and its main office built (1905) close to the diversion point of the two secondary canals. This office, La Darsena, is still being used today by the Agency.

Table 2.2 Private *acequias* built in La Banda department (period 1873-1811).

Owner	Year of construction	Extension km	Irrigated Area (ha)	Irrigable Area (ha)
Silva Hnos.	1873	14	202	337
MacLean Hnos.	1874	9	135	337
R. Rojas	1878	7	101	211
M. Ruiz	1878	5	168	337
J. Femández	1879	9	84	253
M. Figueroa	1879	7	67	211
D. Herrera	1879	35		253
M. Ibañez	1879	9	42	202
N. Juarez	1879	4	34	211
Marcos Hnos.& Co.	1879	17		304
G. Barrios	1880	5	25	253
P. Gutiérrez & Silva Co.	1880	2	168	304
P.Lucero,G.Martínez & Castellanos	1880	9		337
B. Moreno	1880	9	50	219
J. Cobacho	1881	9	34	211
M. Comer	1881	11		202
D. Herrera y Co.	1881	9		211
J. Iramáin	1881	9		168
A. Montenegro	1881	14		337
T. Rojas	1881	22		202
M. Ruiz Hnos.	1881	9	135	253
Total		224	1245	5353

Source: Gancedo () cited by Vessini (1972)

In 1913 the Provincial Government built the San Martín canal in the right bank with the dual objective of supporting the enlargement of the irrigated area and to convey water to Loreto city destroyed by a Rio Dulce flood in 1908 and re-located west of its former location. The off-take of San Martin canal from the river was upstream of the old *acequia municipal* but downstream of La Cuarteada.

By the end of the initial period the total irrigated area was 24.400 ha, with 9.000 (37%) of it within public systems (La Cuarteada + Municipal + San Martín) and 15.400 ha (63%) being irrigated from 44 private *acequias,* which suggests a great participation of the private sector in the development of irrigation in this period. A particular feature highlighted for its role in later competition for available water, is that state canals were located upstream of private *acequias* on both river banks (La Cuarteada in the left, San Martin and Municipal in the right).

Although it could not be checked from official documents, dimension of canals and *acequias* still in place suggest that they were highly over-dimensioned in relation to irrigated area according to modern design principles. This however appears as a rational approach taking into account the variable discharges expected under unregulated river flow conditions.

bank. The most important was in 1897 when it was completely rebuilt it following a design by Mr. Cassaffoush a well known engineer contracted by the National Government.

As regards control structures, according to testimonies and historical documents, only public systems and the largest private *acequias* had off-take structures (most of them very weak ones) at the river banks. Few were gated (most private *acequias* used on/off gates) and of course there was no permanent control structure in the river channel. Under these conditions, off-take structures were frequently destroyed and/or relatively long initial section of both public canals and private *acequias* became silted up at times of high discharges (Figure 2.1) while temporary water checks were needed in the river channel to get water during low discharge periods.

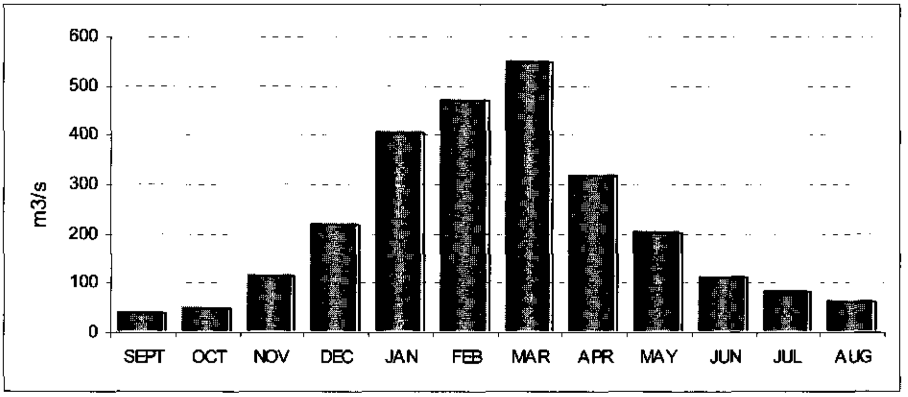

Figure 2.1 Mean annual distribution of Rio Dulce discharge without flow regulation

2.1.4 *Operation of Water Distribution and Institutional Arrangements*

Water distribution

In La Cuarteada system water distribution was under the responsibility of the provincial agency up to the *comuneros* off-take. In theory, water distribution to *comuneros* was proportional to the irrigated area. However due the variable water availability and the poor technology and organization for water control, system management was mainly empirical and highly dependent on operator skills and users' influences.

The number of *comuneros* irrigating simultaneously were defined according to the canal discharge. When canal discharge was enough, water was delivered simultaneously to all or a large number of *comuneros*. However most of the time turns had to be established between them. Within *comuneros* only one farm irrigated at one time. However, due the normal over-dimensioning of the water course, in periods of high discharge more than one farm could irrigate simultaneously

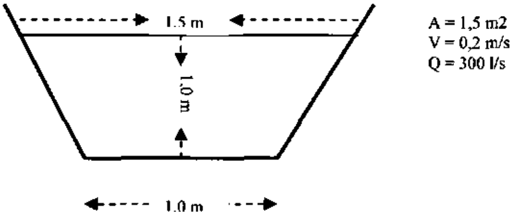

Figure 2.2 Standard dimensions of communeras and approximated discharge capacity.

Water delivery duration was the adjusted factor rather than discharge. Water delivery to farms in well supplied periods lasted according to farmers needs, but it was progressively adjusted to 3hr/ha by the agency. However delivery duration was very variable. With the objective to least save permanent crops or refill water reservoir for people and animals, turns with delivery times of only 10 minutes per hectare were not uncommon in severe dry periods according to testimonies.

There was no mention about differences in delivery discharge in farmers' testimonies collected during 1999 interviews and in official and public information surveyed. Since interviewed farmers agree that most *comuneros* were built using the standard dimensions shown in Figure 2.2[2.12] I surmise that this feature, and farmers' and operators' rules of thumb, controlled delivery discharge within a variation range acceptable for all parties.

In private *acequias,* water was distributed to farms by turns within the *acequias*. Normally one farm irrigated at a time but depending on the capacity of the *acequia* and the river flow two farms could irrigate simultaneously.

According to the information surveyed during the field work, in all cases water distribution rules in use established that water use started at the tail-end farms and moved backward to the head of the *acequia.* This rule was just the obvious result from the fact that the owners of private *acequias* were in most cases the tailenders, therefore in short what the rule said was simple: the owner irrigates first.

This distribution model setting tailenders as the first irrigators was not exclusive to the private *acequias*. It was also adopted by *comuneros* of the public systems built and governed by large farmers and not long after it became the official method for water distribution in the all *comuneros* of public systems.

Delivery duration was also the regulated component of water delivery in private *acequias,* while delivery discharge remained fixed (almost all farms intake had on-off gates). Only the owner of the *acequia* irrigated until his needs were fulfilled, while water was proportionally shared the rest of the time by *clients*.

Institutions

One of the institutions emergent in this period and consolidated for the rest of the PRD history was the practice of starting water distribution at the tail of the water course and moving backwards to the head. This practice, that was established initially in private acequias for logical reasons that their owners were the tailenders, controls one of the main problems in irrigation - the unfair distribution of water along water courses that normally forced tailenders to adopt different practices (such as incorporation of groundwater use and changes to less water consumptive crops) as the most powerful farmers were located at the head of canals.

One of the factors that would have contributed to support this rule could be relatively high water availability. According to Michaud (1942), water availability was high in private *acequias* during this initial period not only because of relatively low competition for river water but also because water management and crop patterns were in balance with the availability and variability of water supply. However in my opinion, more important for the consolidation of the practices was the presence of a strong rule enforcement system highly

[2.12] Applying the average water flow velocity (0,2 m/s) measured during my field work in earth ditches of similar characteristic the standard dimension of *comuneros* would yield a discharge capacity of around 300 l/s, which would be the delivery discharge selected in the later modernization interventions.

based on patronage relationships between the owner of the *acequias* (patron) and users (*clients*) and reinforced by other well known features that enlarge cooperative behaviour of people, such as small group size and face-to-face communication (Ostrom, 2002 Bardhan and Agraval, 2002; Dayton-Johnson, 2002;

The patronage relationship that was common in the rural areas of the irrigated area of Santiago del Estero in relation to land use (Vessuri, 1972), assured clients access to water use through the complacency of the patron. It also forced them to contribute to the maintenance of the water course and accept all rules and norms about water distribution. Patrons got water and acquired social prestige and power by being fair and generous and in cases of traditional land owners the relationship established around water reinforced the patronage relationship between them and their clients in relation to land access. In cases where the owner of the *acequia* was a capitalized-immigrant, the relationship completed the frequent asymmetric commercial relationship established between them (as patron) and the sharecroppers (as clients)[2.13].

Another feature that I think confirms that owning an *acequia* conferred power to its owners is the lack of collaboration between them to solve acquisition of water from the river in a collective way. This is proved by the fact that many *acequias* of neighbouring owners took water from the river almost at the same point and ran parallel for many kilometres not more than few meters from each other (Figure 2.3 from Michaud (1942) shows seven of this groups of *acequias*).

This lack of collaborative behaviour between patrons stressed in most testimonies from this period - that was in contrast with the considerable cooperative behaviour of water users on maintenance and water distribution tasks - can only be explained if the risks from loss of power or prestige and difficulties to get agreements between users to share infrastructure were higher than the benefit of decreasing individual maintenance and improving operational conditions.

Within the *comuneros* of the public system the well-accepted rule of starting water distribution at the tail was applied not only in those controlled by large farmers (where the patronage relationship also worked). It was applied also in public *comuneros* without owners, where a farmer leader assumed the role of the owner and effectively controlled water distribution among asymmetrically empowered farmers. However water distribution in these systems was more complex as water also had to be distributed also among asymmetric powered *comuneros*. Rules for water distribution at this level do not seem to have been so clear since almost no reference was made to this. Also, most interviewees (Mr. RJ, Mr. OJ and Mr. MS) agreed that initially there were conflicts only in periods of low discharges but they became more intensive and frequent with the increase of irrigated area.

Collective Action – Maintenance

Maintenance requirements of both private and public systems were very high in this period. This was due to: the precarious nature or lack of off-take structures; the long length of water courses and the periodic need to reconstruct or excavate silt from the initial sections of both public canals and private *acequias*; and/or control of weed growth in banks that reduced carrying capacity, increased water depth and produced breaks in banks. Construction of

[2.13] Share croppers and leasers were obligated to accept unfair contracts, expensive loans and to sell their production to the capitalized patron.

temporary water checks in the river channel to get water during low discharges periods also frequently required collective action by users.

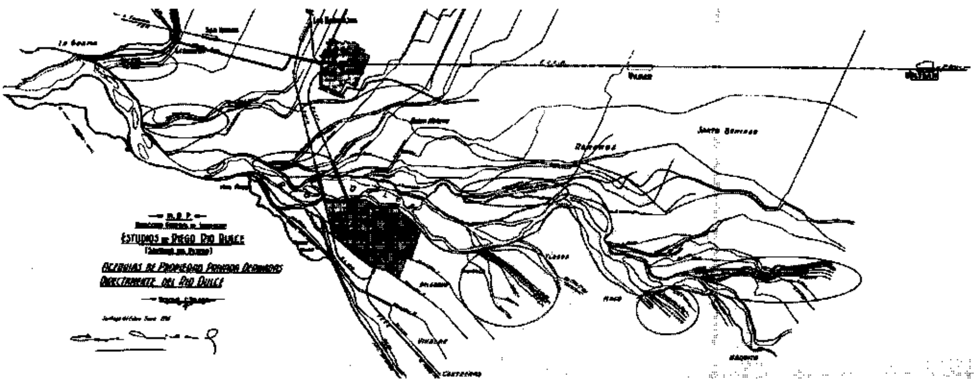

Figure 2.3 Irrigated area with public canals and private *acequias*. (Source C.Michaud (1942)).

Maintenance was highly dependent on user participation, not only for private *acequias* but also for public systems where the annual budget assigned by the government for the maintenance was always very low. Farmers' participation in maintenance of public canals is clear in the following testimony of a user son of La Cuarteada system:

> *"My father used to go with other users when heavy maintenance should be done at the head of the main canal. Being a child I used to go with him in periods of low discharge of the river. Little water entered the canal in those periods because the main channel of the river flowed close to the west side far from the canal entrance. People used to build a sort of control structure in the river bed leading water flow into the canal. It was a temporary check control built with plant brushes and sand filled bags. Our work (referring to children) was to ride donkeys that moved plants brush to the river channel".*

In private *acequias* case it is not too crazy to think that the high maintenance requirements in relation to available resources was one of the reasons why owners of private *acequias* used to offer to barter water with small farmers for maintenance works. Maintenance in these systems was also a collective action as a user of one of these private *acequias* remembered:

> *"Three to four times per year users of the acequias should go to its head to repair and sometimes almost reconstruct its first 100 to 150 meters, destroyed and more frequently silted by river floods. We used to be around 20 users plus a variable number of labourers from the owner's farm - that depended on the magnitude of the task to be done and the intensity of labour required in his own farm. Normally it took us 2 to 3 days to complete the work. The owner of the acequia fixed the day, organized the tasks and most of the times joined us during those days. Beside that episodic work I had the permanent task of keeping free of weeds 2000 m of acequia's banks close to my farm."*

Definitely maintenance requirements were high and critical for water capture in both types of irrigation systems in this period and cooperative participation of users was essential. Most interviewees highlighted the high participation of all types of farmers - large, medium and small - in collective maintenance activities in this and the following stage of system development. They mention that many times farmers automatically convened for these activities.

2.1.5 Users' Contribution to 'Social Construction' of the System

The management of public irrigation systems just described worked during the initial periods; however with the continued increment of the irrigated area the availability of water per unit of land decreased and more precise water control was needed. Whatever the changes in manager's skills, improvement of water control was not possible, due the poor and unstable infrastructure and lack of clarity on rules for water distribution among *comuneros*. Thus differentiation between users and potential for conflicts between them, and between them and the agency, sharply increased.

Most testimonies tell that conflicts between strong and weak *acequias* were easily resolved in favour of the first. Resolution of conflicts between *acequias* with similar or more powerful farmers could not be resolved by poorly empowered field officials or even at irrigation agency level and higher official or political authorities had to intervene directly in many cases. It was this tension within the public irrigation systems, highly aggravated by the heterogeneous social structure that would produce a first deep crisis of the system and the beginning of a re-organization process.

Conflicts in public systems increased their intensity when the less political powerful sharecroppers and leasers converted to being settlers of public and private colonization plans, and managed to organize collective action to fight for a more fair access to water. The process was led by foreign settlers socially less restricted by patronage relationships than local small farmers. The struggle ended, following the example of their colleges from Humid *Pampa* (Appendix 2) with foundation of FAA-La Banda (Figure 2.4)[2.14] a branch of the Federación Agraria Argentina.

The first action of the new farmers' organization (mainly constituted by settlers irrigating from public systems) was in 1924, a dry year. They sent a letter to the governor, in which they asked for improvement of irrigation canal conditions, and demanding a better water distribution. When the next year, also a dry year, passed without any positive reaction from the local political authorities to the previous demand, the intensity of actions increased. A letter was sent to the governor and to the president and a public meeting was organized in La Banda city. In 1926 they organized a one day strike and a demonstration in the main square of Santiago del Estero city just in front of the Governor's House. According to the local newspapers (El Liberal, La Tierra, 1926) 2000 farmers with their families were present in what would be one of the greatest farmers' demonstrations in the history of the Province.

[2.14] The constitution of FAA-La Banda, was a unique case of small farmers organization in the north of the country, one of the few outside the central provinces of Buenos Aires, Córdoba and Santa Fe, and a clear demonstration of the importance of the irrigated area and of the relevance of European immigrants within the small farmers group in this period.

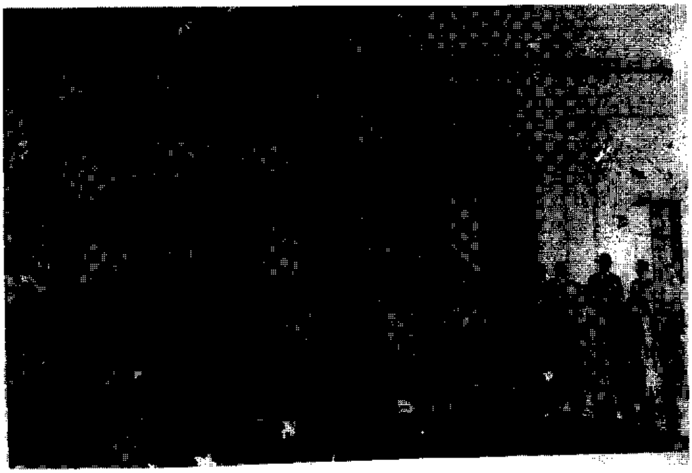

Figure 2.4 Constitution meeting of the FAA-La Banda (kindly given by V. Salvador family).

The first action of the new farmers' organization (mainly constituted by settlers irrigating from public systems) was in 1924, a dry year. They sent a letter to the governor, in which they asked for improvement of irrigation canal conditions, and demanding a better water distribution. When the next year, also a dry year, passed without any positive reaction from the local political authorities to the previous demand, the intensity of actions increased. A letter was sent to the governor and to the president and a public meeting was organized in La Banda city. In 1926 they organized a one day strike and a demonstration in the main square of Santiago del Estero city just in front of the Governor's House. According to the local newspapers (El Liberal, La Tierra, 1926) 2000 farmers with their families were present in what would be one of the greatest farmers' demonstrations in the history of the Province.

The official document handed to the governor by farmers' leaders (3 of them were Spanish) stated: the farmers' rejection of an official project to increase the irrigated area of La Cuarteada system by connecting a large private *acequia (acequia Fernández)* located downstream to the canal network; their demand for consideration of the need to improve the infrastructure for water control including construction of a permanent La Cuarteada off-take structure in the river bank; the need for maintenance or rehabilitation of works (specific works required in each canal were described); their favourable position to provincial adherence to the National law No. 6458; and finally the need to improve general infrastructure in the area such as roads and bridges, etc.

According to Tasso (2002), at local level the meeting demonstrated, from the social and political standpoint demonstrated: the consolidation of small farmers as a social group within the irrigated area; their organizational capacity and conviction to question public issues and social hierarchies; but also their economic relevance in the local context as shown by the accompanying mobilization by local merchants who closed their shops that day.

At the same time the irritation of the governor - who considered the protest as arrogant and qualified it as an anarchist movement - showed the concerns of the oligarchic class at the organization and mobilization of small farmers and indirectly how much they saw threats to their water use privileges.

From the sociotechnical perspective on irrigation, the farmers' mobilization of March 1926 also raised an interesting point. The settlers and small farmers directly questioned the quality of the physical and organizational water control that gave a low adequacy, equity and reliability of water distribution - three key components of a good irrigation systems performance.

The low adequacy and reliability of the irrigation water supply were the main reasons for farmers to demand a permanent structure to capture river water and improvement of maintenance of canals, but also one of the main reasons for farmer's opposition to the extension of the command area. There was no direct mention in the official document to the unfair distribution of water in public irrigation systems operated by the provincial agency. However it was one of the main points of farmers' mobilization, as was clear in the invitation for the meeting published in the local paper. In the speech of Mr. VS one of the speakers at the meeting - and in the following article from La Tierra (the official newspaper of the FAA) reproduced by Tasso (2002) - the distrust of the settlers with the provincial government is evident too.

> *"The public agency ignores water turns and gives water to the acequias of the privileged farmers. We believe that this type of abuse is allowed by the provincial authorities since nothing has been done against the responsible despite of the many complaints of those farmers adversely affected."*

Farmers also advocated for a change in the political control of water through the involvement of the National Government in the management of the irrigation systems. They saw this as guaranteeing a more fair access to water and the best possibility for modernization and/or rehabilitation of irrigation infrastructure. This was the reason to ask for provincial adherence to the National Law N° 6458 -- this allowed acquisition of funds from the National Government for modernization of irrigation infrastructure but demanded the transfer of system administration to the National Government. It was that requirement that made the National Law N° 6458 unacceptable to the oligarchic dominant class and its political expression, the provincial government, who argued that it would be a loss of provincial autonomy.

Surprisingly, despite this achievement of change in the political control of water and the Spanish origin of most settlers' leaders, there was no mention in this protest or in future farmers' actions for the constitution of a Water User Association (*Junta de Regantes*). This was an institution with a recognized role in the management of irrigation in the south of Spain, which would have allowed farmers a direct involvement in the key process of water allocation and water distribution.

Ansaldi, cited in Tasso (2000) argues that there was a lack of revolutionary characteristic in the 1924-1926 farmers' mobilization organized by the FAA–La Banda, unlike the contemporary mobilization of settlers and sharecroppers in the Humid Pampa. However, it is clear break point in the adaptive cycle of PRD, promoting a process of reorganization and national resource mobilization that would end with the first structured state intervention in irrigation issues in the PRD area.

2.2 THE 25 YEARS INCUBATION PERIOD OF THE FIRST MODERNIZATION INTERVENTION

2.2.1 Irrigation Infrastructure

In terms of irrigation infrastructure, it was not the Provincial Government but the National or Federal Government that reacted to the 1924-1926 demonstrations of the smallholders and water users in state managed irrigation systems, as stated in official documents (Introduction of the National Law N° 12.259 and the Final Report of the Professional team of the National Irrigation Department, Michaud, 1942).

In March 1925 the National Irrigation Department was authorized to start "the required studies to solve the water problem in the area" and a professional team from that Department was assigned to Santiago del Estero to make basic studies (they worked for almost 10 years) and prepare a Master Irrigation Plan for the province.

In 1933, as a first step of that Master Water Plan, the Federal Government submitted a draft law to the National Parliament proposing the construction of: a delivery dam at the Rio Dulce 30 km upstream of Santiago del Estero city (Los Quiroga); a main canal to connect it with existing secondary canals; and any other complementary works to assure irrigation in the right and left bank of the river (La Cuarteada and San Martin old systems). The Federal Law N° 12259 was approved on September 30th 1935, establishing a command area of 130.000 has. It made explicit the political objective of the government to extend irrigation benefits to many people by recognizing formally documented water rights up to a maximum area of 400 has, and limiting new water rights to a maximum area of 50 has. It assigned system management to the provincial government and left the main operational parameters such as frequency, discharge and duration of water delivery to be defined in a specific regulation[2.15].

Construction of Los Quiroga delivery dam lasted 12 years (from 1938 to 1950). In this sub-period not other change in irrigation infrastructure or water distribution criteria happened and there was not improvement in the operation of the system took place.

However, it would be a period of deep qualitative changes in terms of water allocation (to be analysed in chapter 3). There was consolidation of state control over irrigation, and definition of the agrarian structure in the command area. This change was highly encouraged by a number of combined influences: a change in national and local political context; loss of political power by large farmers; speculative behaviour by most users based on the optimistic

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[2.15] In spite of its apparent inactivity, the Provincial Government would had been an active and apparently successfully negotiator with the National Government as can be concluded from analyzing differences between the draft law submitted by the Federal Government and the final text of the approved law 12259.

	Proposed Law	Approved law (N° 12259)
Command Area (ha)	60.000	130.000
Location of irrigated area	East river bank	East and west river bank
System Management	National Government	Provincial Government
New water rights	Not allowed	Not mentioned
Promotion of land subdivision in small plots to assure its intensive use and development included as specific objective of the project	Explicitly included	Not included

predictions of future irrigated area under the Quiroga dam,-; the continued mobilization of users; and a long period of low river discharge that aggravated conflicts and threatened continuity for many users.

2.2.2 Change of Context and Adaptive Users' Behaviour

The change of political context

The main political success of this period was the emergence and empowerment at National and Provincial level of the populist *peronista* movement that reinforced the interventionist profile of the state (that followed the failure of the liberal economic development model started at the beginning of the century). The populist political orientation of the National and Provincial Government in this period effectively empowered small farmers and seriously weakened the dominant patronage relation between them and land and water owners.

Examples of the new balance of the social forces came in January, 1948. In a meeting with the provincial minister of Public Works a group of small farmers from Maco (right bank) requested expropriation of the Contrera Lopez private *acequia.* They received the answer that the funds required were already included in the proposal of the provincial budget for the following year and that the communist governor candidate Dante Cesca in the 1948 election proposed nationalization of all private *acequias.*

The more capitalist relationships established in this period between large and small farmers are also clear in a letter sent by a group of small farmers without public water rights to the Provincial Minister of Public Works. Asking for the extension of a public canal to their lands they said:

> *"... Not having public water rights to cultivate our lands, and agriculture being our unique source of income, we have to implore owners of private acequias every year to sell us some water hours most of the time with negative results....." ("El Liberal"February 6th, 1948).*

Low Water availability

Another main feature of this long second period was the low river discharge (as can be seen in Figure 2.5, 1944-1954 was the decade of lowest mean river discharges in the last 80 years). This brought serious water supply problems to users of public systems, aggravated in the case of small farmers by the permanent unfair water distribution.

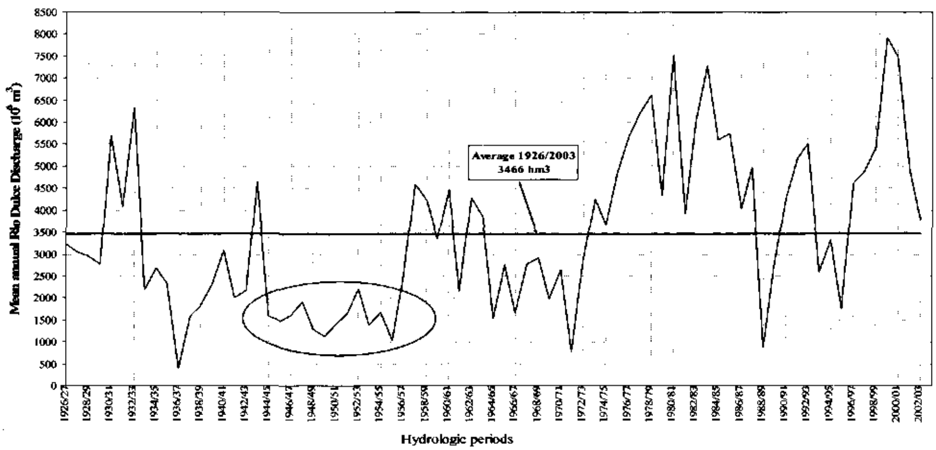

Figure 2.5 Historical annual discharge of the Dulce River upstream Los Quiroga (source A&EE and UER)

Water supply problems were even worse for private *acequias,* all located downstream OF public systems. This is clear from the extreme situation reported by the local newspaper in January of 1948 for the private *acequias* located in front of Santiago del Estero city that would have been even worse for other private *acequias* located downstream.

> *"After a long dry period water could seen flowing in the river bed yesterday. The low discharge was taken by a few of the private acequias from the left bank that irrigated land in the Banda department. On the few times the river flowed this year in front of our city, most of its discharge was taken by la Cuarteada and San Martin canals" (El Liberal, January, 11th, 1948).*

The report also pointed out the competition for river water, and the predominance of public systems taking water upstream over private *acequias* Also in this period of low discharges came the first symptoms of problems between the two public systems, expressed by frequent demand for water from users of the Canal San Martin located downstream of the La Cuarteada system.

It can be noted also that an increase in water use upstream in Tucumán province was seen as a complementary reason for low Rio Dulce discharges. This also drove new political discourses on promoting nationalization of rivers shared by different provinces, and the need to agree shared rules for exploitation by a range of other social actors, including small farmers and their organization, the FAA.

In summary, a relatively long period of low water availability revealed the contested character of water use. Under these conditions, competition between provinces sharing the Rio Dulce watershed and between users within Santiago del Estero province was evident beside that between individual users within public systems.

Adaptation of users' behaviour to contextual changes

Both users and agency were confronted in this period with a contradictory situation. There were high expectations of improved water supply and increased irrigated area with the construction of Los Quiroga and the main canal of La Cuarteada system, but also the need to manage support a long period of very low river discharge that considerably reduced production possibilities and increased conflicts.

The engineering approach of improving the infrastructure almost closed off (because all efforts were on the construction of Los Quiroga and the main canal of the La Cuarteada system), while possibilities to improve the organizational control in public irrigation systems were also very limited. Thus the most common adaptive strategies adopted by users were to reduce their cropped area, and a massive effort to join public systems by the users of private *acequias*, without distinction among farmer type. As a result of these contradictory strategies, the irrigated area decreased to a minimal area of 30.000 ha and the "water righted" area within public irrigation systems sharply increased (see Chapter 3).

Although incorporation of new users increased water distribution problems within the public systems, there was no real resistance from farmers' organizations, which also changed in this period (see below). Nevertheless the subject was discussed publicly and some people argued a predominant fiscal objective and/or an irresponsible or (corrupt) behaviour of the provincial government in the acceptance of new users, as clear from this fragment of a local newspaper editorial from June, 1948.

> *"………We know that despite the fact that the present area with water rights exceeds the canal capacity, and the specific instructions of the provincial government to limit and even decrease the area with water rights, it is being apparently allowed to increase. In many cases there are lands that have their concession to take water directly from the river as is the case of some owners from the south of Capital department, with or without official documentation.*
>
> *We understand that a fiscal interest is the main reason. However the fantasy of some farmers to extend their irrigated land can not be encouraged …."*

The editorial mention of some owners from the south (downstream) made me think that the reason to accept new areas within the public systems was not purely fiscal but to a certain extent a yielding by the provincial government to the wishes of powerful farmers, mainly former owners of private *acequias*[2.16], highly affected by water supply problems in this period.

This gradual integration of large farmers within public irrigation systems implied also their incorporation into users' organizations. In concordance with this enlargement of their social base there was a change in the objectives and discourses of these organisations in relation to the previous period. The old dispute over access to water between social groups of settlers - (poor immigrants against "water owners" i.e. capitalized immigrants + the traditional

[2.16] The strategies of this group of large farmers included to maintain their concession for taking water directly from the river, in addition to their integration into the public systems. With the two sources of water, the probability of having irrigation water during dry periods was higher. However also important, was that through this they overcame the restrictions of a maximum of 400 ha imposed on individual water rights in the public systems by the provincial government.

oligarchic group) changed to objectives related with the need to improve infrastructure to increase water availability, and hydraulic control and reinforcement of operational rules for water distribution.

Another important characteristic of this period that merits emphasis in the context of this thesis is the high capacity for integration of farmers. Many local farmers organizations[2.17] and a federation of them (Federación Agrícola Ganadera y Cooperativa) emerged in this period, and crowded meetings of most of them (many times more than 100 members) were frequently mentioned in the local newspaper and in the testimonies collected during the field work. Thus the capacity of farmers' mobilizations around irrigation issues shown in the previous periods remained present - in my opinion due the continuity of many leaders of the former FAA[2.18] as leaders of the new organizations. Meetings of users with high level government officials were frequent, as well as public users' claim (through the newspaper) about system operation and/or long term planning for irrigation. Another demonstration of this great farmers' mobilization capacity and their confidence was shown in November of 1948 when almost 200 farmers from the PRD irrigated area and a small group from the irrigated area of Colonia Dora from the Salado River went to Buenos Aires meet the National Minister of Internal affairs.

The objectives of the group - that also succeeded in meeting the President Perón (Figure 2.6) - were to promote water infrastructure for the development of the province. In particular these included: the rapid finalization of Los Quiroga delivery dam; the construction of the complementary canal network including a connection to San Martín Canal in the right bank of the river; the sanction of a national law for the regulation of water use from inter provincial rivers; and a long term vision on the need to construct reservoirs and other infrastructure to divert water from the Bermejo River to irrigate the east part of the province.

2.3 MODERNIZATION IS HERE (1950 – 1968).

2.3.1 The Irrigation Infrastructure

In November 1950 the delivery dam Los Quiroga, and a main lined canal on the left river bank that connected it with La Cuarteada system was concluded. They were the first and basic step to implement the first planned intervention designed by the expert team from the National Government. The main objective was "modernizing" the almost wild and inefficient development of irrigation in the area, that in words of the head of the team (Michaud, 1942) "had avoided permanent investment by farmers always threatened by the uncertainty of water supplies".

The expectations of the most stakeholders around Los Quiroga were very high. Based on the official plan, politicians and government officials expected the irrigated area to increase to almost 870.000 ha. Sixty five percent (570.000) could receive "permanent" water rights and their main use would be agricultural crops. The other 300.000 ha would have cattle rising as the main production and only temporary water rights to receive irrigation water only during the high river discharges - but expected benefits were also high.

[2.17] Sociedad de Agricultores Unidos de Clodomira, Sociedad Agrícola de Beltrán, Sociedad Agrícola de Fernández, Sociedad Agrícola Santiagueña de Huaicuru (Banda), Sociedad Agrícola de Villa Robles, Sociedad Agrícola de Silipica, sociedad Agrícola Ganadera de la Capital, Sociedad Agrícola de Villa San Martín.

[2.18] VS, one of the speakers of the 1926 meeting representing the FAA, was elected president of the Federation of local organizations and would remain very active until his death in 1958.

Figure 2.6 Farmers delegation of Santiago del Estero with Peron in November, 1948 (Picture kindly release by VS's family).

According to the memories of water users already cultivating at that time their expectations were lower and more realistic - for more water, less uncertainty and lower transaction costs to get water especially during periods of low river discharges.

Reality was different from expectations. The new infrastructure clearly benefited the users of La Cuarteada system on the left bank. It adversely affected downstream water exploitation including the San Martín system and private *acequias* still in use, differentiating users' claims from both side of the river.

Farmers from the left bank (La Cuarteada system) demanded improvements to the canal network - mainly enlargement of existing canals and/or replacement of old canals by new ones with higher capacity. Farmers from the right bank, divided in two groups, still needed to solve their access to water. The group already within the San Martin system demanded a quick connection of San Martin and those still taking water directly from the river. Both groups of farmers from the public systems would have a positive answer from the National Government during the 1950s. Between 1952 and 1954 the promised siphon ($Q = 8$ m^3/s) to connect San Martin canal to the Quiroga network was built. The rehabilitation and enlargement of Beltran canal was done between 1954 and 1957. In 1956 the construction of the Suri Pozo canal started (20 km length, $Q = 27$ m^3/s, for 54.000 ha). In 1957 also the Principal a Fernandez canal (20 m^3/s, for 40.000 ha) and the left branch of the Beltran canal (12,9 km, 3,5 m3/s, 3.400 for 7.000 ha) went under construction. In 1958, Siete Arboles (present Sud I) started with 15 m^3/s at the head. In 1954, (a year with very low spring river discharge) the group of farmers irrigating from two irrigation sub-systems[2.19] that had been progressively developed in the east part of the right bank had the first positive answer to their constant petitioning to join the San Martín network. The Provincial Agency accepted to open a temporary connection from the San Martín. A definitive solution for them became effective early in 1957.

[2.19] They were based on two former private *acequias* - the Contrera Lopez and the Maco (later Maco-Manogasta) *acequias*

In spite of the "modernization" of infrastructure, especially during the first part of the 1950's, low rivers discharges and their seasonality made it clear that development of a complete "modernization" of irrigation would require regulation of river flows by construction of a an additional reservoir. The idea was mentioned in the report of the expert team led by C Michaud (1942) as a necessary second step after construction of the delivery dam. However, the first public reference was in May 1955, when the Economic Federation of Santiago del Estero, a second-tier organization integrating farmers' organizations and other economic sectors, demanded the construction of a reservoir. Progressively it would become the main topic of farmers' demands in the second half of the period and as partial modernization of canal networks was achieved.

The year 1956 was a very active year in relation to the Rio Hondo reservoir. In March the military intervention of Santiago del Estero, after the overthrow of Peron in 1955, not only promised the construction of the Rio Hondo reservoir in the Rio Dulce but also other small reservoirs in the Horcones and Albigasta rivers. In April, the farmers' organization sent a letter to the president demanding its construction. In May, the National Government approved the required funds for complementing the studies already initiated by A&EE for preparation of the final project of the dam, and in November, those studies started. One year later, in December, 1957, construction of the dam was contracted with an Argentinean-Italian company. Construction would start in July 1958 and was finished in September 1966.

2.3.2 *Operation of Water Distribution and Institutional Arrangements*

The greater physical control than previous periods, the populist political frame imposed by peronism at the beginning of the 50's, and the authoritarian political context in the late 60's empowered the provincial agency again in comparison to the former

Management demands grew substantially in this period due to the unification of almost all the irrigated area (former public systems and private *acequias*) in a unique irrigation system, Los Quiroga. However organization and operation of water distribution remained almost unchanged during the whole period, with the delivery dam, main and secondary canals under agency control. *Comuneros* were under farmer control, keeping the last users as the first irrigator of each turn.

The empowered provincial agency took a key decision during this period that would have great influence in irrigation development in the area. First it defined a maximum area to have water rights per farm[2.20], and second it restricted duration of water delivery from 3 hr/ha to 1 hr/ha[2.21]

A specific feature of this period was a short lapse with water users officially and directly involved in the operation of the irrigation system. That happened during the second *peronis* provincial government when a new provincial water law included the creation of a Water Board with participation of users. The new Water Board was implemented in 1953-1954 with

[2.20] It is not known if the selected maximum was 400 ha as stated in the National Law 12259 that allowed the National Government to build Los Quiroga, since there are not concrete references. However, direct testimonies of old farmers or their relatives mentioned the existence of a maximum, and the agrarian structure of the irrigated area in the following period also confirms this. In general it is accepted that big farmers adopted two main strategies at that time to keep their privilege, to leave working their facilities to take water from the river as long as they could, and to use "front men" as water rights holders.

[2.21] There was a short period in which the agency proposed to reduce it to ½ hr/ha, which was strongly resisted by the farmers.

participation of farmers' leaders in it but also a farmer was appointed at the head position of the provincial agency in charge of La Cuarteada system. The process was however aborted by the 1955 military coup.

Farmer organizations

As noted, farmers' organizations were gradually incorporating all water users including large farmers initially in contestation with small farmers (leasers and share croppers). At the same time farmer's organizations discourse was changing to becoming less they were also losing some of their power.

Farmers recognized that the daily decisions of the Agency in relation to water distribution were many times influenced by local politicians, and that bribes of field officials were not uncommon. However, such things were seen as context-specific situations and not to permanent practices, or as practice that could not be solved under provincial management. For these and other reasons water distribution issues became less present in their agendas than in the past. It has not been possible to identify all possible reasons for this gradual change of farmers' discourses and the lack of complaints about unfair water distribution. Leaving out a possible political identification of farmers' leaders with the government, I speculate the following reasons why conflicts were low or at least less evident in this period. Water rights of all users had been recognized; users' organizations exerted a certain control over water distribution decreasing room for unclear procedures; water availability increased and in those periods when it was not enough, farmers opinions were clearly influenced by the engineers' vision, and considered the low river discharge as the actual and/or the accepted reason.

In this period the farmers' unions profile predominated in farmers' organization over water users' organizations. They joined the second-tier Economic Federation of Santiago del Estero and adopted the generalized technocratic discourse of demanding new structures of water control. In spite of this, in this period the farmers made, in my opinion, the last demonstration of their mobilization capacity on water issues (Figure, 2.7). On October 23rd, 1958 they called another daily strike (as in 1926) and a farmers' meeting in front of the governor's house. The reason was the increase in water fees from $ 9 to $ 30 ordered by the government.

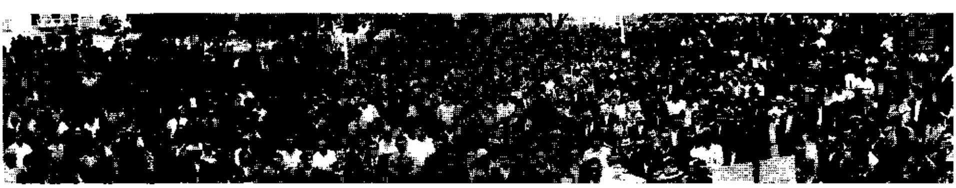

Figure 2.7 General view of the farmers' meeting on October 23rd, 1958.

According to the local newspaper, 3000 farmers were present in the greatest farmers meeting in the history of Santiago del Estero. Four different, historically important speakers, representing different farmer organizations, took part in this meeting that closed dramatically when VS, one of these historical leaders died during his speech. In December a reduction of water fees to former prices was announced as part of the agreement with farmers.

A particular remark from this period

To close the analysis of this period rich in physical realizations, it worth highlighting that there was no further planned intervention in the irrigated area when the decision to construct the big reservoir (1700 hm^3, a dam 5 km long and 27 m high) was taken.

The task to analyse and plan the re-organization of the irrigation area went a private consultant company Fuldner-Hansen was contracted by the military government. National and international experts were part of the staff. With the advance of their work a highly technocratic approach was evident. The main point of their proposal was development of a unique provincial institution for managing both reservoir and O&M activities. For irrigation they proposed use of prefabricated canals and ditches, use of automatic gates at diversion points and sprinkler irrigation at farmer level. To support the big change from basin to sprinkler irrigation, the consultants stressed the need of organizing training programs for farmers.

Although the reasons remain unknown, both the decision of contract a foreign consulting company and its propositions were resisted by the local political and irrigation community. The contract with the consulting company was cancelled and a new strategy for design of "modernization" of the irrigated area more linked with development objectives were adopted under the democratic government established in 1962.

2.4 The Almost Definitive Jump to "Modern" Irrigation (1968 – 1973)

Under the democratic government with a clear developmental approach, modernization of the irrigation area was viewed as a component of a large rural development project for the area. Modernization of irrigation practices were one important component of the main project that also included; a restructuring of land parcels to avoid small holdings and plot concentration by a few owners; a settlement plan; government support for the commercialization of products; constitution of cooperatives; promotion of factories for agriculture processing; and even social support for rural families in the area the second intervention in the PRD area would be.

It was with the implementation of this joint project by Provincial and National governments funded by the Inter-American Development Bank (BID) that the name Proyecto del Rio Dulce finally started to be used and was under this project that the second and last modernization intervention in irrigation issues would take place.

2.4.1 Irrigation Infrastructure

In its 5 to 6 active years the modernization program of infrastructure in the PRD included mainly lining of canals (La Cuarteada and San Martin secondary canals, tertiary canals of La Cuarteada Norte and San Martin canals, *comuneros* of La Cuarteada and Norte) and modernization of many delivery structures in the main, secondary and tertiary canals including water measuring devices (see Chapter 5).

2.4.2 Operation of Water Distribution and Institutional Arrangements

In the general agreement signed on September 24th, 1966 by the provincial government and the specialized national agency (Agua y Energia) that was already in charge of the design and construction of the hardware, the Province transferred to A&EE the operation of the irrigation system and the political control over water allocation. The province explicitly agreed not to extend any other water rights that could affect the availability of the Rio Dulce water in the area of the PRD. Instead, the province gave A&EE the power to extend or remove new irrigation water rights. The agreement also included a curious article stating that the future regulation to be dictated by A&EE should continue even if the province took back water administration.

In accordance with these stipulations in the general agreement, in September 1970 the A&EE published the ***Rules for Water exploitation from Rio Dulce River in the zone of the PRD*** *(Reglamento para el aprovechamiento de las aguas del Rio Dulce en la Zona del Proyecto Rio Dulce).*The relevant aspects are presented in Box 2.1.

Box 2.1 Relevant aspects of the Reglamento para el aprovechamiento de las agues del Río Dulce en la Zona del Proyecto Río Dulce.

Water allocation

- *Water rights were related to the land; they could not be transferred or sold independently.*
- *A water right conceded before the PRD would be recognized up to a maximum area that could be proved had been irrigated continuously or alternately during the last three years before August, 31, 1968 and if their soils are suitable for agriculture.*
- *New water rights would be conceded by A&EE with the consent of Corporación del Río Dulce (CDR) the Provincial Office dealing with the social aspect of the PRD and irrigation at farm level. They would be based on water availability, and good land quality and they could not exceed 50 has per parcel, defining a parcel as a piece of land composed of one or more contiguous units of the same owner. The last restriction was not applicable to those former water rights recognized.*
- Fifty hectares was established as the maximum area of the new water rights.

Water distribution

- *A&EE would be responsible for water distribution upstream of the comunero, and users downstream.*
- *Water distribution would be by turns.*
- *The last users will irrigate first and the irrigation will move upstream.*
- *The irrigation time of each comunero would be calculated in function of the water rights and the time required by water to reach the last users.*
- *If a user cannot take the water in the assigned time, change in irrigation order could be arranged with the administrador of his comunero but the total delivery time assigned to the comunero could not be extended in any case.*

2.4.3 Farmers Organizations and Farmers Participation

Regards modernization of infrastructure and organization of water distribution, the strong technical vision of A&EE engineers dominated the official and even the farmers' organization discourse As result of this technocratic positivist vision expectations about future water availability of most stakeholders were very high.

Under the poorly participative, top-down operation of the system implemented by A&EE, but also due the high water availability under the new scenario of regulated river flow, farmers associations abruptly lost their role of control over the water distribution process and their role as catalyst of demands of new processes. Farmers' formal participation was reduced to representation in a consultant board, in a typical form of "manipulative participation" in the typology of Feitsma, (1996). Farmers would not recover any active role in water management in the following 30 years.

2.5 After the Artificial Resilience (1973 – 1992)

In 1973 the new *peronis* provincial government decided to stop the project rejecting the BID loan, arguing that it would continue with the provincial budget. That never happened. Therefore that political decision left infrastructure, farmers support programs and social plans unfinished and what is more important the Provincial Government would never again have a development plan for the irrigated area or give the irrigated agriculture any role in the development of the province. This left the agency without any political support and contributed to a loss of motivation of both Agency and Farmers' organization.

2.6 Discussion and Conclusions

In general terms it is clear than development of irrigation in the area of the Rio Dulce in Santiago del Estero, did not respond to a structured intervention from the National or Provincial Government nor a self-organized system by it users. Elements of both types of systems are present during the almost 100 years of evolution.

At the same time it is certainly a clear demonstration how social actors and political and economic context and natural environment shape evolution of designed physical systems.

The short revisit of the irrigation development has shown that many features and institutions present in PRD recognized its roots in early stages and primitive irrigation practices. In the initial period the social structure conformed by large and small farmers characteristic of PRD was defined, many people was definitively excluded from the benefit of irrigation and the roots of a future mosaic pattern of water righted and not water righted area were established. The important institution within the PRD, the rule that in *comuneros, tailenders irrigate first* was also created, enforced and definitely incorporated in the local irrigation practices.

The revision of irrigation development shown also that participation, mobilization and commitment of users with water issues decreased in time from self-mobilization at the beginning to passive participation by the end of the 1990s (Feitsma,1996) in parallel with the improvement of water control by physical infrastructure and organization of water distribution and the increment of water availability. The last great mobilization of farmer in relation to irrigation issues (water fees price in this case) was almost 50 years ago

The discourses of farmers' organization also changed over time from the initial discourse based on equity principles and recognition of water rights of small farmers, to a more technocratic discourse demanding better infrastructure and involvement of Federal Government. That was a logical consequences of the gradually larger spectrum of farmers after the initial organizations of small farmers progressively incorporated larger farmers to represent lost the heterogeneous social structure of the system.

The provincial government had a very low participation in the development of irrigation in the area. Their role was restricted to administration (with great difficulties) of the system during periods of great conflict and as negotiator with the National Government. National Government was the main actor responsible for construction of physical facilities.

Chapter 3

FOLLOWING THE CHANGING PATTERNS OF WATER ALLOCATION

Chapter 2 followed the evolution of the mode of appropriation of Rio Dulce's water, the role plA&EEd by different actors and their changing behaviour with the increasing competition for water. It discussed how the state took control of irrigation without a strong designed intervention, until there was complete unification of all private *acequias* systems in a huge public irrigation scheme that we now identify as the PRD. This chapter examines the evolution of the water allocation practices in the scheme - the involvement of the different stakeholders, their changing of strategies, the negotiated character of the process and the current processes that condition the scheme performance, its future development, and its impact at basin level. Across the chapter, five sections examine the predominant types of water rights and why they emerged or evolved in different historical periods. Periods are not necessary coincident with those of Chapter 2 since adopting the same criteria periods were defined to highlight key success for the future development of the PRD.

3.1 The Initial Stage of Water Right Construction

As shown in Chapter 2 the first stage of irrigation development in the area was by local people constructing modest structures to withdrawal water directly from the river. In this case a group of people organized by and around large farmers were empowered either by their situation as large land holders or by their capital and capacity to undertake modern agriculture activities (as capitalized immigrants). Simultaneously there was a parallel unplanned development of a large public irrigation system in the left bank (La Cuarteada system) where other powerful farmers with high privileges shared water with "settlers" from public and private colonization plans.

3.1.1 Acquisition of Water Rights

The ownership of the state over water resources, in the sense defined by Schlager and Ostrom 1992, was formally established already in the Provincial Water law of 1887 and formally acknowledged by all stakeholders from that time. This meant that it had the right over withdrawal of water from the river (use right) and the power to exclude people and dictate management rules for water resources use (control right).

All users of public systems and owners of private *acequias* received official water rights. However not all large farmers that opened their own acequias registered to take water from the river. Their clients (leasers, sharecroppers or just *agregados*) were allowed to share water from these *acequias* and also never registered at all in this period, got effective and permanent rights over water based on their investment and/or labour and prior appropriation - which is a common way for claims for water rights in farmer managed irrigation systems (Meinzen-Dick and Bruns, 2000, Pradhan and Pradhan, 2000, Sutawan, 2000).

Following the differentiation of water rights proposed by Schlager and Ostrom, 1992 owners of the *acequias* acquired more than a simple right for withdrawal water from the river. Within their own acequias they actually had control rights (political control in terms of Mollinga, 2003) when they decided who could take water from their *acequias* (exclusion right), how much and when (management rights) or when they sold water to permanent users-clients of their *acequias* or even to non-permanent users. This was clear from the argument used by the Manogasta small farmers to demand the government to extend a canal to their fields (see section 2.2.1).

This role of the powerful group of owners of private *acequias* during this initial period, who shared and sometimes almost replaced the state, was confirmed by a contemporary analyst of irrigation as proved by the following paragraph:

> "..*The owners of private acequias have assumed the public power, becoming the real owners of water...selling it to other stakeholders by cash or for a share of their harvest. They have monopolized in a few hands all the available water from the Rio Dulce*" (Soldano, 1919 cited by Tasso, 2000).

Unfortunately, there are no concrete references to criteria used by *acequia* owners at this time to exclude or include people, perhaps due the social and technical importance that such exclusion would have in the PRD. I speculate, based on a few testimonies, that patrons gave preference to those who were already linked with them in land patronage or political terms. However they also had to take operational needs into account such as the capacity of a client to contribute to the maintenance of the watercourse and/or the location of the *clients* along the *acequia* due their needs of having "controllers" to enforce water distribution norms.

The location of the irrigated lands of both owners and clients were also key conditions as it is clear from following testimony of a former user of a private *acequia* that also confirms that a client could establish land and water patronage relationship with different patrons.

> *"I got this piece of land from Mr. A, he was a good patron. All I had to do was to look after their animals in this part of his land that was far from his house but close to my land. To crop my land I used to take water from Mr. T's acequia who was also a good patron. His acequia passed just in the border of my land and he offered to me to take water and assigned me 200 m in the bank that I should keep clean of weeds. Mr. A also had his own acequias but their irrigated land was far to "naciente" (to the east, sun rise) around his house".*

Users of public irrigation systems were in a third tier, after the state and owners of private *acequia, s* in the hierarchy of water rights. Both large and small farmers hold formally similar ***use rights.*** However as analysed in Chapter 2, there was a big difference between them in terms of their capacity to make them effective during the process of water distribution.

Users or clients of private *acequias* were in the fourth and last level of water rights hierarchy. Like their colleagues in the public systems they held only rights to use water, but their rights were just pure customary rights since their existence was formally unknown to the government, that only registered owners - and not necessary all of them according to the following paragraph taken from Soldano, 1919 cited by Tasso, 2000).

> "..*for regularizing the payment of water fees by users of private acequias it would be necessary to make first, independent of its cost, a survey of land actually being irrigated and them increase water fees*".

3.1.2 Water Sharing Principles Applied

Independent of being formal or customary, water rights establish the process of water allocation and determine how much and under which conditions users share water. Murray-Rust and Snellen, 1993 distinguished five type of water sharing: Share per unit area; fixed discharge per unit area; fixed volume; instantaneous demand and informal or undefined rights[3.2]

Due the unregulated conditions of river discharge and their large irrigated area in relation to canal capacities, water was shared per unit area in public systems. In private *acequias*, a fixed discharge per unit irrigated area was the sharing criterion confirming the testimonies that in this initial period water supply was high in most of them.

The volumetric way of sharing water in private *acequias* were seen from the technocratic vision of the engineering team of the National Irrigation Department as the main reason for the low number of conflicts in private *acequias*. For this reason in their final report they advised to implement it in public systems:

> *" ....One powerful reason to adopt the charge of water per volume is that this system is practiced by all private acequias at present. With this system there are never disagreements and the system is well accepted by local users. Because the system also is favourable for water exploitation it is advisable to adopt it definitely in public systems. ...." (Michaud (1942)).*

3.1.3 Conditionality of Water Rights

Analysis of water rights in terms of their conditionality, or mechanisms established to modify or suspend access to water on a seasonal or annual basis where or when there is insufficient water to meet all demands, completes the picture of the relationship between people and water and of course people and people in this period. Murray-Rust and Snellen, 1993 mentioned three main types of conditionality: suspension of rights in established circumstances; priority access to some specific areas or users; and temporary rotational irrigation.

There were differences between public and private *acequias* as regards conditionality but also in the observation of the norms. In public systems there was no formal established conditionality in agreement with the established proportional share of the water supply. However as many cases showed, under water supply restrictions powerful farmers had priority access to water over "settlers", and the frequent non-observation of the rules was the base of their claims in 1924 to 1926.

Things appeared clearer in private acequias where a priority access in favour of the *acequias*' owners in time of low water supply was implicit in the social relation of patron and clients

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[3.2] *Share per unit area.* In this case a discharge is not guarantee. It is divided according to share fractions related with the unit area and independent of total water availability. *Fixed discharge per unit area.* In this second case, water is delivered volumetrically in proportion to the irrigable area. There are different possibilities to regulate volume using discharge and delivery durations. *Fixed volume:* the water user is entitled to a maximum volume of water during an irrigation season, timing is normally based on an indent or request system. *Instantaneous demand:* There are not restrictions imposed and an individual water user can take as much or as little water as they wish at any given moment in time. *Informal or undefined rights*: Access to water varies in time depending on the local power structures, in some cases it may be anarchic, in others it may rely on a process of frequent negotiations that re-establishes or reaffirms traditional rights.

and was well accepted by all users. Nevertheless, although it was this conditionality that in theory made the access to water of clients of private *acequias* more precarious that for small farmers in public systems, actually the high water availability of their watercourses before the late 1940's, that made their access to water more sure than the hidden conditionality of "settlers" water rights in public systems.

3.2 THE LONG PROCESS OF UNIFICATION AND MODERNIZATION OF WATER RIGHTS (1926-1968)

In the discussion of the 1933 Federal law for the construction of Los Quiroga and "modernization" of the irrigated area (Section 2.2.1) I stressed that the provincial government was successful in removing from the law most aspects that local society was sensitive to except the imposition of the Federal Government to assume administration of the irrigation system. However during the 10 years that it took to construct Los Quiroga, changes in the political orientation of the Federal Government and possibly other political negotiations kept the irrigation system and water allocation under the control of Provincial Government.

3.2.1 Water Allocation and Water Rights

Simultaneously with the physical unification of irrigation under state control with incorporation of users of private *acequias* into public systems, there was a necessary process of unification and democratization of water rights.

This process benefited former clients of private *acequias*, affected adversely owners of them and was neutral for pre-existing irrigators in public systems. The main benefit for clients of private *acequias* was that their water rights were formally recognized at the same level of their patrons and former users of public systems.

On the other side, the owners of private *acequias* changed from having control over a great share of the river's water with control rights to decide over management and power to exclude or include users, to become simple holders of water use rights, with maximum area restricted and possibilities of make "water business" highly reduced to a minimum. Many of them adopted alternative strategies - such as to use "front men" for part of their lands or kept their private acequias open while trying to make a joint use of canal and river water. However, they were progressively restricted to their own lands and maximum allowed area (this I supposed was restricted to 400 has as the 1935 Federal law specified) by the increased political control of the government and the frequent lack of available water for their *acequias*.

Groups of small farmers from outside of the former command area, most of them very active, were another group of farmers that benefited greatly in this period (as it was the case of small farmers from Manogasta in the south east of the right bank and other similar marginal areas). Although quantitative information could not be found, personal communication and local newspaper articles suggest that many of them were incorporated into public irrigation systems enlarging the gross command area and required extension of existing canals. Strangely the same criteria was not applied for many small farmers within the existing command area, formalizing in this way an exclusion done in the previous period by owners of private *acequias*.

This political decision to allocate water to disperse groups of organized small farmers and ignore existing ones within the command area of the former private *acequias* made a great contribution to the definition of a mosaic pattern of irrigated and non-irrigated lands within the command area. This became a characteristic pattern that would be even reinforced by the principle of acknowledging or restricting maximum water righted areas in later state interventions.

3.2.2 Water Sharing Principles and Water Distribution Process.

In public irrigation systems during this period, there was a definitive change in share principles from proportional sharing based on the irrigated area to a fixed discharge per area (volumetric). Most of the testimonies agree that delivery discharges in this period were similar than in the previous period and to those used at present (that it is suppose discharges round 250 to 300 l/s at farm level) and that they were normally considered homogeneous in time and space within the system. Based in this implicit agreement of discharge homogeneity, water rights were defined in terms of proportional times with respect to irrigated area. The time fixed initially was 3 hours per ha (which would be equivalent to a 270-340 mm mean irrigation depth) and latter reduced to 1 hr/ha (90 to 110 mm of irrigation depth).

The progressive reduction of delivery duration from unlimited time (deliveries duration "until finished") to 3 hrs/ha and then to 1 hr/ha (leaving out ½ hr/ha used only in short periods) would have been dictated trying to avoid conflicts due the increased competition for irrigation water with the increment of the irrigated area and not for any technical reason. Independent of the reason for the reduction of the water delivery duration it would have unexpected consequences for the future development of irrigation in the area as will be analyzed later in this chapter.

In times of low water availability the principle of proportional sharing of available discharge was applied. In this situation delivery duration was the adjusted variable. Delivery duration of half hour per hectare in some turns were relatively common as the following extract for the 1947 annual report of the Provincial Agency for La Cuarteada system proves. It also suggests a maximum discharge per *comunero* of around 400 to 440 l/s that confirms the delivery discharges estimated above.

> *" .... The maximum discharge derived by the main canal, calculated in base of direct measurements done in their derived canals would be 35 m^3/s while the capacity of the canal network were maintained to server simultaneously 80 comuneros.*
>
> *The capacity of the canals in the network in relation to their serviced area have allowed to provide between 4 and 6 turns of 1hr/ha. The turns during the periods of low discharge (this year from May 15Th) have been divided in half turns of ½ hr/ha plus so-called "base" of 1hr per users. The last has been adopted to favour small farmers who are the users that obtain more benefit from extra hour... (a detailed table with turns delivered to each secondary canal follows)... "*

Conditionality

Another interesting feature of this period is the emergence of explicit conditionality in water rights. Three classes of water rights permanent, eventual and precarious were defined expressing an increasing scale of conditionality. Permanent water rights received water in every turn, sharing the available water in time of severe low river discharge. Eventual water rights did not received water when due a severe low river discharge available water should be shared among holders of permanent water rights. Holders of precarious rights received water only after the requirements of the other two categories were satisfied. In practice that happened only in periods of high river discharge and therefore this type of water rights were used to irrigate natural pasture or even wild areas increasing the offer of forage for animal production.

The emergence of these three types of water rights reflects the adoption by local irrigation authorities of the protective irrigation approach advised by the National Irrigation Department group. The proposal, with the objective of maximizing water productivity, differentiated agricultural land to be served by permanent water rights, while rangelands would by irrigated lands covered by eventual water rights, and peripheral areas would receive water surplus in periods of high river discharges that could be used only for pasture irrigation.

3.3 WATER RIGHTS AS A TOOL TO GET WATER.

In the last section I intentionally made only a short reference to the change of water share principles and to the progressive introduction of restrictions in the volume per area attached to water rights. In this section I discuss this point in detail in order to analyze its consequences for the behaviour and strategies adopted by different actors.

One would expect a negative reaction from users to the progressive reduction of the delivery duration, in particular from the former users of public irrigation systems used to receive water "until finish". However there are no references to any public reaction from farmers and none of the old farmers interviewed made references by themselves to that problem.

Only during the 1958 farmer protest against the provincial law that increased water fees from $9 to $31 and reduced delivery duration from 1 hr/ha to ½ hr/ha (that reduced volume delivered to a half and increased the cost per unit volume almost 7 times) did farmers mention the progressive reduction of the delivery duration from 3 to 1 hour first and them to ½ hr/ha.

The topic was also stressed in the call for the meeting and for one of the speakers (Mr. EP) that stated that 2 hr/ha were required by farmers[3.3] making clear that not only ½ hr/ha was not enough water for "normal" irrigation but also that 1hr/ha (the official duration at that time) was only a half of the delivery duration required by farmers.

A deeper research of this topic showed that the actual strategy adopted by farmers in this case was not a public demand and confrontation with the agency or provincial government. Like other farmers around the world that try different strategies for getting water, farmers in the PRD adopted in this case the strategy of getting water rights for more area than they actually used to crop. That was confirmed in a second round of interviews. Mr. JR said in this respect.

> "The *craftiness of our parents was to get water rights for more area than they cropped or they registered their land as different plots. In the last case because each plot had two extra hours, a 'base" hour plus the time required by the water to reach the cropped area within the plot, in this way they also got extra time"* (JR's interview, August, 2002).

The strategies adopted by all types of farmers large and small, powerful or weak, explains the high increment of irrigated area during the 50's as it is shown in Figure 3.1

[3.3] 2hr/ha was also mentioned as the required in the official document published by farmers few days after the meeting.

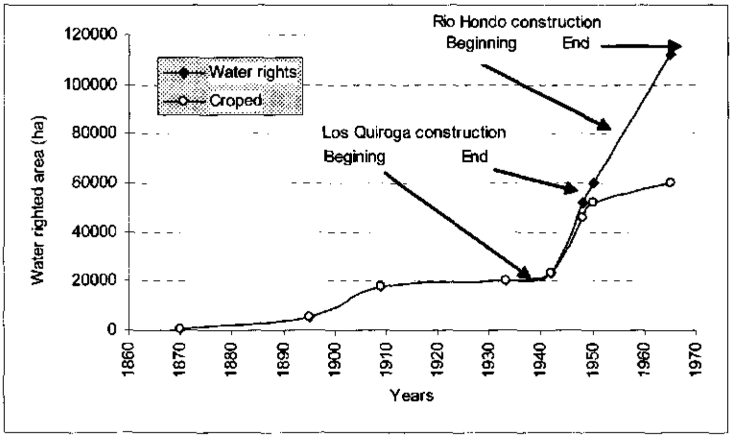

Figure 3.1 Evolution of area with water rights and area cropped in public irrigation systems

Wahaj, 2001 described that to increase the command area was one of the strategies adopted by farmers in some watercourses in the Fordwah Irrigation System in Pakistan for getting more water. In that case the increased discharge delivered to the water course made field irrigation practices easier, but because the time to complete the roster was fixed to one week the delivered duration per area decreased, keeping the volume share per unit area unchanged.

In the case of the PRD there was no increment in the volume of water shared per declared unit of area. However because actual cropped area was smaller than the "water righted area" they got an effective increment of the volume per unit of cropped area.

If according to their own discourse, the time needed by farmers to irrigate one hectare was 2 times the official delivery duration, the declared area needed to be double the actual cropped area. According to Figure 3.1 that was not the case at the beginning of the 1950's, but the ratio was close to 2 in 1965 and was confirmed by a large farmer.

> *"When we bought the farm there was a "funny" thing in this and all farms. Because users received hours/ha and those hours, due the precariousness of the works and management, were not enough to irrigate, this farm and almost all farms had water rights for twice the area that the former owner actually irrigated. Our farms had water rights for 240 has but there was only about 100 to 120 has cleaned and ready to be cropped"* (JO's interview, Sep, 2002).

One point that should also be stressed in relation to the strategies adopted by farmers is that it needed a complacent irrigation agency. One can only guess at the reason why the agency allowed such strategies to continue. It is possible to think that there was a political decision influenced by powerful farmers not to control cropped areas. However, in that case one should ask why politicians did not stop the technical norm of reduced delivery duration before it was realised. It also possible to assume that the Agency took that decision only for technical reasons, but it did not have directly the capacity to control cropped areas.

It looks more reasonable however to think that farmers not only chose the strategy of claiming water rights for more area than cropped for the afore mentioned practical reason that they could not irrigate as they wanted. In addition, at the same time they were encouraged by the high expectations created by the official discourse that construction of Los Quiroga first and Rio Hondo reservoir latter would allow a great increment of irrigated area. These expectations that were also shared by politicians and agency engineers explain the political and technical complacency of the agency towards the large area registered by farmers.

3.4 A NEW ATTEMPT TO RE-ALLOCATE WATER WITHIN THE PRD DEVELOPMENT ORIENTATED PROJECT.

The Provincial Government assumed the responsibility of planning and implementing the reorganization of the irrigated area almost at the end of the construction of Rio Hondo reservoir. There had been a previous unfinished process originally entrusted to a private consultant company, from which only the organizational concept was that an autarkic organization was needed to control and manage water use in the Rio Dulce.

Irrigation was conceived in this second intervention as an important component of a broader development project, the Rio Dulce Project (PRD) and its modernization also included modernization of on farm irrigation practices. It would be implemented by a joint effort of the specialized agency (A&EE) of the Federal Government and a provincial autarkic agency, (Corporación del Río Dulce or CRD) specifically created for that purpose.

With regards to water allocation, this time there was a declared specific objective of re-allocating water to support the main objectives of the project and a formal regulation about water allocation procedure, and many organizational and operation rules for the system were dictated. (*Reglamento para el aprovechamiento de las aguas del Rio Dulce en la Zona del Proyecto Río Dulce, A&EE, 1970).* See Box 2.1 on page 58 for relevant aspects.

Other objectives of the project related with water allocation were: to control small holdings, promote intensive agriculture; and control land concentration. For the first of these objectives an important component of the project dealing with reconsolidation of land was designed and partially implemented, with prohibition to divide land in holdings smaller than the economic unit of 25has that resulted from economical calculations established by provincial law (still valid). With regard to promotion of intensive agriculture and control of land concentration, 50 ha was established as the maximum area for new water rights making effective a political principle for which farmers of other areas are still struggling (Boelens and Hoogendam, 2002).

Expectations of the responsible of implementing the project of having the opportunity of re-allocate water were very high. There was a good understanding that continuation of the pre-existing situation, with water righted area per holding greater than cropped area, could be serious constraint to achieve the objective. The specific definition of "parcels" and the rule limiting acknowledgement of former rights to the maximum area effectively cropped in the last three years previous to the regulation had the implicit objective of counteract the former strategies of farmers of declaring more area.

But the real world demonstrated the powerful negotiation capacity of stakeholders. Soon it was established that the maximum water righted area of 50 ha per holding did not apply for existing water rights, and because the roll of former water rights were almost inexistent or had disappeared it was decided that acknowledgement of water right should be negotiated process[3.4]. The agency tried to base that acknowledgement on a detailed aerial survey of the

[3.4] Art 32 of the Regulation is a proof of the negotiation around the maximum limit of 50 hectares. This article appeared in the original document, in its place as "to be added". A disposition of the joint committee A&EE-

area complemented by a field survey, but this only helped to identify cleared areas that were finally accepted as cropped areas to validate former water rights.

In practice, most users were able to keep their water right unchanged and many with available lands and high expectations of increasing cropped area were disappointed due the small amount of water that actually could be re-allocated. Both issues are clear in the following testimony or a large land holder.

> *"A&EE surveyed the area actually cropped, I believe in 1969 or 1968. The maximum area with water rights was adjusted to the base of that survey. They did not give the option to those who were irrigating less area than the water righted are to keep the water rights, but also they did not give opportunity to those with capacity to enlarge their areas to do it. I did not understand that, because they always said that with Rio Hondo the total area with water rights could be irrigated. We were lucky because at this moment all the area we had with water rights was already cleared and most already cropped."* (Interview with JO, July 2003).

Definitely as one of the engineers accepted during an interview: "*not too much could be done in terms of water re-allocation*" (Interview with EG, Sept, 1999).

It is clear from Figure 3.2 (that complements Figure 3.1) that the maximum area of permanent water rights was reached before the PRD and not during it. There is no official information about the internal re-allocation of water rights during the implementation of PRD. However, taking into consideration that the whole of Zone V (7.500 has permanent water rights) was developed after 1968 it is possible to estimate that water re-allocation could reach a maximum between 10.000 to 15.000 ha, that means 10 to 12% of the existing area with water previous to the PRD.

Again the government did not have too much possibility to re-allocate water even with the knowledge that water was "kidnapped" for the practice of having water rights for more than the cropped area. Again application of the prior appropriation principle kept the exclusion practiced by owners of private *acequias* almost untouched and the "mosaic" pattern of irrigated areas within a larger not irrigated area definitely consolidated.

Water sharing principles and water distribution process.

The approved regulation officially established application of the shearing principle of fixed volume per unit area, and determined that it would change to proportional division of the discharge in case of low availability, but left most of the other main topics of water distribution undefined. That was a logical consequence of the disconnected development of the reservoir and the "modernization" of the irrigation system. Rio Hondo reservoir was functioning in the 1968/69 cropping seasons and operation of the irrigated area already transferred to the national agency. However, the irrigation scheme design was still in its initial stage of collecting existing information and required field data at that time.

CRD approved in July 1970 specifically stated that amore "technical" (quoted mine) base was required to its definition. When, almost one year and a half later, the Art 32 was finally included it stipulated that holdings smaller than 50 ha, with water rights for less area than its gross area, could enlarge them to a maximum of 50 ha - while holdings with a gross area greater than 50 has could increase their water rights by 25%.

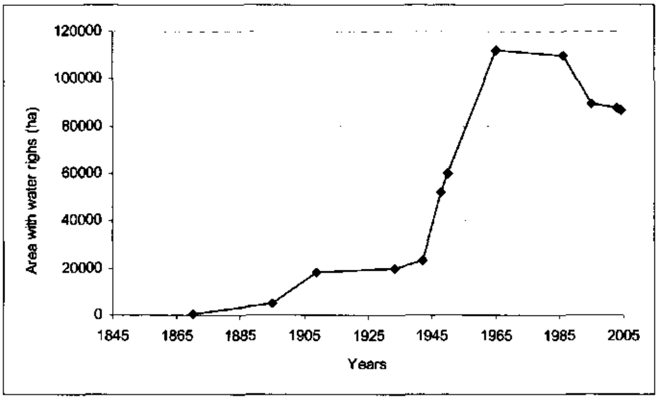

Figure 3.2 Evolution of water righted area in the PRD (source A&EE and UER).

Art 24 only said that permanent water rights would receive the amount of water required to assure a satisfactory production of their crops, Art 39 was more explicit about the undefined topics expressing that amount, delivery discharges and periodicity would be determined by the agency based on technical studies and the land colonization plans.

During his two year work from 1969 to 1971 the irrigation consultant, Mr. C. Romanella from the National University of Cuyo, Mendoza defined 122.000 has as the maximum irrigable area in the PRD and advised for the initial stage of the scheme a turn-based water delivery with a fix duration of 1,22 hrs/ha, a variable volume per ha according to crop requirements and a fixed frequency of 28 days. The study advised a range of practical discharge rate from a maximum of 300 to a minimum of 120 l/s.

The official water distribution finally adopted and still formally in use was close to Romanella's advices but gave priority to operational and administrative aspects. It included a fixed delivery volume of 900 m^3/ha every 28 days, using a fixed discharge rate of 300 l/s and fixed duration of 50 min/ha. Considering the system is closed for maintenance during one month (February in the first years, May at present), 11 turns per year are practically possible, resulting in a share per user of 9.900 to 10.000 m^3/ha.year.

Technical analysis of the above issues is done in the next chapter, but here it is important to stress the important change of the approach of PRD's designers from customary practices and the approach sustained by Michaud and his collaborators.

From the "protective" approach and "deficit" irrigation proposed by Michaud (1942) and actually practiced in the area, the new proposal was constructed with a "productive" irrigation approach based on full crop irrigation. These different approaches explain the great difference between the optimistic estimation of 800.000 ha of irrigable area by Michaud, 1942 and the 122.000 ha estimated by Romanella, (1971).

I will show in this thesis that both irrigation visions are still present in the area and are to some extent a cause of misunderstanding between irrigation practices at different levels of the systems. The testimony of a farmer, in charge of the provincial agency in the period just before its transfer to A&EE, presented in Box 3.1, is an example of that.

Box 3.1. Fragment of the interview with SM former chief of the Provincial Agency.

"In a meeting with the chief of La Banda District office in 1992 I told him: "The A&EE engineers should be in the jail, their engineer degree should be removed and they should pay back all the salaries they received during the period A&EE was in charge of the system management.

Hey! Why do you say that? You are exaggerating the chief told me.

Probable I was exaggerating but you must consider that we served 123 to 127000 ha without the reservoir. They did not anything about system management; the only thing that was important in their time was to build new irrigation canals and drainage canals. With the drainage canals they crossed many irrigation ditches. If farmer received water did not matter, if farmer irrigate or if farmers made profits from their crop did not matter. What only mattered was to build drainage canals.

To talk with the boss, the intendente (the head of the Agency) was impossible. To get a meeting with him was more difficult than with Mr. Bush the present president of U.S.A. It was impossible to talk with him.

The started to reduce the water, the farmers felt bud, disabled. It was impossible to demand water, the management was very bureaucratic. It was a dictatorship. When they were to leave, they were irrigating only 60.000 o 47.000.

I have a report prepared Mr. Cacaos. He made a study in the area around 1932 or 1935. Many hectares could be irrigated with the reservoir!! According with his calculation the irrigated area would increase to 300.000 ha and considering the eventual and precarious water right to 1.000.000 ha. Also Michaud talk about that area.

How would be possible? Michaud used to say to farmers "ok you have 5.000 ha. You will have cows. I will give permanent water right for 10% of that area. In this area you will crop alfalfa. You will have water to crop it the whole year and you will have 1 cow/ha."

The testimony is clear about the different visions that former officials and farmers had over irrigation. It also gives an idea of the high resistance of the former agents of the provincial agency to transfer PRD's administration to A&EE. After thirty years Mr. SM continued arguing against A&EE engineers from Michaud's perspectives.

A final remark should be made with respect to the adopted water delivery method. The proposed annual share per user was significantly greater than what users were used to receive, by increasing the number of irrigation turns from 4 or 5 to 11. However delivery duration did not change (50 min/ha vs. 1hr/ha) forcing farmers to look for alternative strategies to accommodate the system to their irrigation practices. As in many positivist designs for irrigation systems, a change of farmers' production and irrigation practices was expected by the designers based on the new water delivery schemes and the strong socio-technical "support" program to be implemented. It is not difficult to imagine that the contradictions provoked a new round of adaptive changes that will be researched and analyzed in the following sections and chapter of this thesis.

3.5 Implementation of Informal Water Rights (PRETAs). A Way for Releasing "Kidnapped" Water or a State Implementation of a "Grey" Water Market?

After implementation of the project was truncated by political reasons in 1973, the Federal Agency, A&EE had to continue operating PRD irrigation system without any provincial political framework favourable to irrigation development. It was to do this with its provincial partner (CRD) (that should extend "modern" techniques at farm level) being almost inactive, and with in operative terms only part of the infrastructure modernized. Also with water remaining "kidnapped", since the unchanged parameters of water distribution (discharge, frequency and especially delivered duration) made former water rights holders maintain their strategy of using water rights as the key tool to get the delivery time (and volume) they needed to irrigate their plots.

Due the "kidnapped water", the lack of state support and unfavourable economic conditions actual cropped areas has been always been below the maximum water righted area, as is shown in Figure 3.3 (based on a field system for collecting information about actual cropped area implemented by A&EE and re-assumed after some years by new provincial Agency (Unidad Ejectora de Riego (UER)).

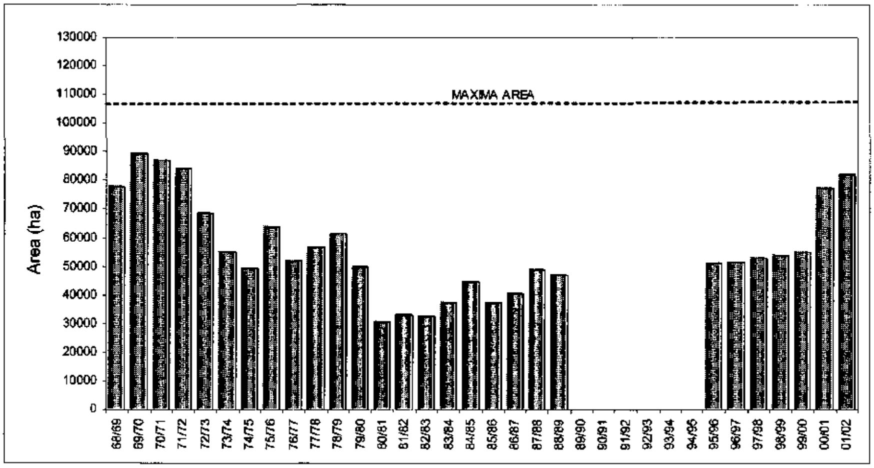

Figure 3.3 Evolution of the cropped are in the PRD under A&EE administration

After 1973, there was: water demand lower than the expected due the unchanged irrigation practices of the users respect to irrigation in early periods of the year(see chapter 6 to 9); a continuous reduction of the cropped area for economic reasons; and a simultaneous period of high river's discharge (Figure 3.4). As a result there was an important amount of water stored in the Rio Hondo reservoir that could be allowed to flow downstream to the PRD every year without any productive use.

In another round of the adaptive practices that characterize PRD′ actors, it did not take to long for a proposition to be made for using that water. Highly supported by the Agency and large farmers as will be discussed below, a new category of water rights, the eventual temporary annual water rights, PRETA (PRETA from its Spanish name "Permiso de Riego Eventual Temporario Annual") was implemented.

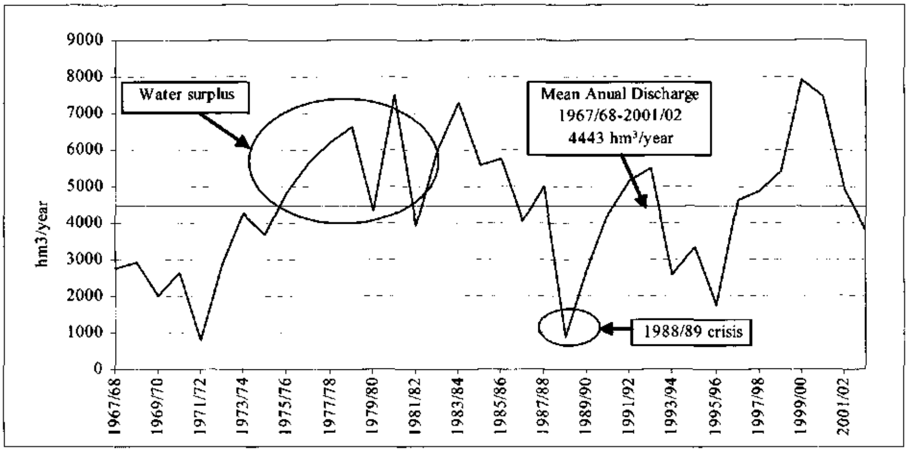

Figure 3.4 Historical Rio Dulce annual discharges (1967/68- 2001/02).

The provincial law N° 4513 from 1977 that create PRETAs argue as its reason the need to give opportunities to use water surplus in years of high river discharges, the same argument used to create, in the 1950s the "eventual" water rights. However, the real purpose underpinned in PRETAs was opportunistic, and considerably different: to allocate annually the unused water surplus available as a result of the low cropped area and/or the known "kidnapping" of water by formal water rights independent of river discharges.

There were other big differences between both types of eventual water rights. PRETAs despite their annual duration gave their holders more secure water supply than traditional "eventual" water rights. While with simple eventual water rights holders received water only during events of high water supply and always only after permanent water rights holders have satisfied their demands, PRETA's holders had, during one year, almost the same rights that those having permanent water rights. They had rights to receive water in all irrigation turns, they were included in the irrigation order of *comuneros* and only in case of water scarcity did the rule determined that permanent water rights would have priority access to water.

There was so high a coincidence of interest between the irrigation agency and large farmers that both strong groups of stakeholders attribute to themselves the idea, as is clear in the testimonies of a former agency's engineer and a of large farmer who participated in the Users Boards in those days. However their conception was slightly different: farmers argued more in the sense of former eventual water rights. Engineers supported the final adopted conception of PRETAs.

> *"Because people irrigated less area than they were allowed by water rights and the humid cycle with high river's discharges pushed the irrigation technical group of the Agency to proposed creation of PRETAs. It was not easy to convince our boss who was very conservative but finally it was accepted"* (Interview with SL, former agency's engineer, October, 2002).

> " *..always we fought to irrigate more area. But we could not, even if you wanted to pay more until I proposed to create a permission that should be temporary and differentiated from the other water rights. From February to July a lot of water flowed downstream without a productive use. I thought we should look for a way to sell it with*

a differential price from permanent water rights. At the beginning they (referring to agency's officials) said no, they always said no, but finally PRETAs were accepted" (Interview with JO November, 2002,).

The Agency discourse repeated the technical argument of using available free water surplus but there was another important practical reason that made PRETAs very attractive for the Agency: they should be paid in advance. This condition (actually imposed by the agency) and its results highly determined the Agency support for PRETAs, when the funds coming from the National Government sharply decreased and collection of water fees from permanent water rights were no more that 5%.

On the other hand, for farmers (large and small) PRETAs appeared in the 1970's as the great possibility to increase their cropped areas otherwise highly limited by the structured permanent water rights. PRETAs were safe since their main conditions, water availability and canal convey capacity were highly assured Also, when this was not the case, as in 1988/89 season when water availability was very low (see again Figure 3.4) they had enough power to make the required political lobby to enact the provincial law N°5740 that removed for that year the conditionality of PRETAs. In other words they succeeded in raising PRETAs to the category of permanent water rights and put their holders in similar conditions with holders of permanent water rights to compete for a water share.

Figure 3.5 shows the evolution of the area under PRETAs. As can be seen it was relatively stable (around 5.000 ha) during the 1970's and 1980's but increased sharply in the1990's and especially in the last 5 years to 2003.

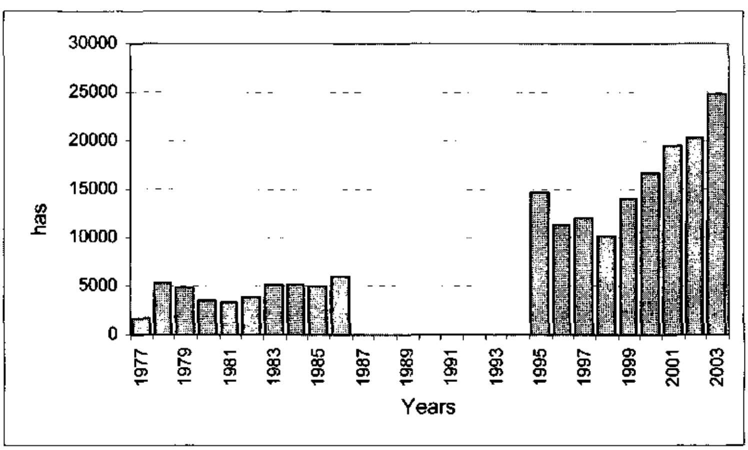

Figure 3.5 Evolution of area under PRETAs in the PRD (Source A&EE and UER).

It is obvious that the reason why PRETAs continued in time and increases their relative share (Figure 3.6) is that they have been functional for most stakeholders. But it is important to understand what have been the reasons that made this sort of "water bank" system functional in an irrigation scheme that had formal rules to withdraw water rights from those holders not using them for 3 consecutive years and where the main users of PRETAs have had sufficient power to force a permanent re-allocation of water.

The lack of political decisions for a permanent re-allocation of water that would have been the correct legal solution to the problem, can be understood from the point of view of local politicians as due its high negative political cost since permanent water rights (in use or not) are always capitalized on land values. However considering that political decisions are also consequences of social pressure especially from powerful stakeholders it is not clear why powerful stakeholders with available land did not create sufficient pressure to achieve a permanent re-allocation of water[3.5].

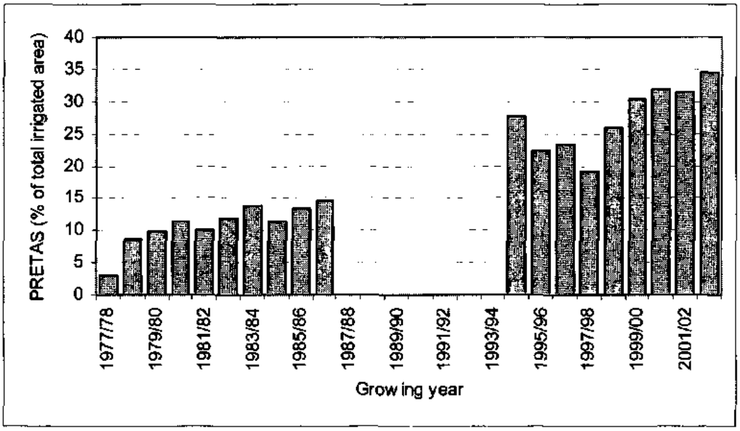

Figure 3.6 Evolution of PRETAs as % of the irrigated area in PRD (Source A&EE and UER).

Leaving aside possibilities of corruption and bribery around PRETAs (that I will not say do not exist,) the Agency's strategy in favour of PRETAs and against re-allocation of water rights looks simple and base on two main points.

- Promotion of a permanent re-allocation of water would signify first to change from "paid in advance" rights (PRETAS) for "almost never paid" Permanent Water Rights, affecting significantly cash flow for O&M. This has been a very important point with the permanent reduction of Federal State support before the 1990's and with the state withdrawal from irrigation issues after implementation of neo-liberal policies in the 1990's.

- Secondly PRETAs have not caused any conflict with holders of permanent water rights - a point to which agency official would be very sensitive- since they affected

[3.5] Actually re-allocation of permanent water rights was in the agenda of the process initiated in 1994/95 to transfer O&M activities to user organizations at secondary canal level that should have concluded with the whole privatization of irrigation management. However the process was stopped in 1998 by the same political fraction that truncated PRD project in 1968.

Nevertheless some steps were taken to release 'kidnapped' water by own holders based on contested technical arguments. A provincial law allowed holders to release their permanent water rights if they could prove that their lands were affected by salinity. In this way the Agency and powerful farmers achieved the objective to release permanent water rights without any political cost by pushing holders to give up their water rights.

Actually the real objective to achieve re-allocation of water was hidden behind a technical discourse that was possibly based on the generalized local belief that reclamation of saline soils is complicated and uneconomic, and by putting pressure over collection of water fees. That explains the reduction of permanent water rights in the last years shown in Figure 4.2 that have remained unexplained.

only temporary "kidnapped" water and/or water from permanent water right holders that have left definitely the agriculture activities for different reasons.

Although I think it is an unexpected consequence, it is also true in a fine point that while PRETAs are a very profitable they are almost "illegal" state business since water with PRETAs is charged twice. A PRETA holder pays for a water share, and permanent water rights holders accumulate debts simultaneously, from the same water share. Of course this has not had any practical relevance in the past since debts of permanent rights holders have been written off many times for political reasons during the history of the PRD. However formally former debts should be paid before a permanent water rights holder can re-assume its use, and it is in this case that the second charge of already used water by PRETAs' holders is made effective.

The above actually happened during recent years, with the high expansion of the irrigated area that can be deduced from the joint analysis of Figures, 3.3, 3.5 and 3.6. In the last 5 years there was an important increment of the irrigated area (Figure 3.3) and of the area under PRETAs (Figure 3.5) but the ratio of area under PRETAs and total cropped area (Figure 3.6) remained constant during the last two seasons. This indicates an increment of the area cropped under permanent water rights, and that these users had to pay old debts.

From the farmers' side, leaving out possibilities of illegally irrigating more area than that the PRETAs offers (and that I will not say it does not happen), PRETAs increase their capacity to respond to market incentives (which is mainly true for large farmers). For instance Figure 3.5 clear demonstrates the high expectation of high prices of cotton and wheat in 1995 (the area under PRETAs increased to almost 15.000 ha), and the economic crisis of the end of the 1990's (they decreased to almost 5.000 ha) and about the high increment of profitability of agriculture after the 2001 devaluation (the area under PRETAs increased again and reached almost 25.000 ha).

In a system with a command area almost 100% suitable for irrigated agriculture and more than 3 times greater than the maximum irrigable, PRETAs have also been functional for the traditional practice of large farmers to move to new lands after some years, to overcome the decreasing yields of the low inputs agriculture practiced by most farmers. Of course there could be more discussion of the reasons for this periodic change of location of large farmers, but what is important here is to stress that PRETAs make it possible to solve the problem of non transferability of Permanent Water Rights.

Existence of PRETAs also gave opportunities in the last years for settlement in the area of new large users coming from other areas. They, together with the local large farmers, are now cropping outlying lands around the traditional command area and putting differential pressure over secondary and tertiary canals. As it shown in Figure 3.7 and 3.8 PRETAs are concentrated in 3 secondary canals, Suri Pozo, Romanos and Simbolar and in no more than 2 tertiary canals of them, Del Este and Principal a Fernández, Pinto, T6 and T7.

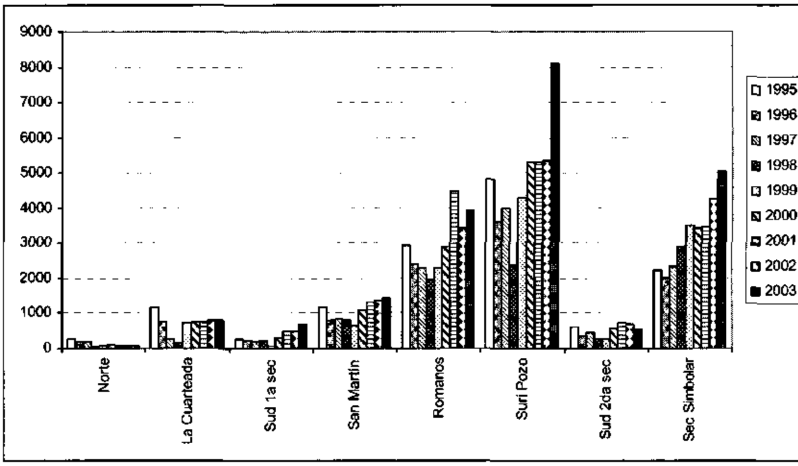

Figure 3.7 Evolution of the area with PRETAs per secondary canals.

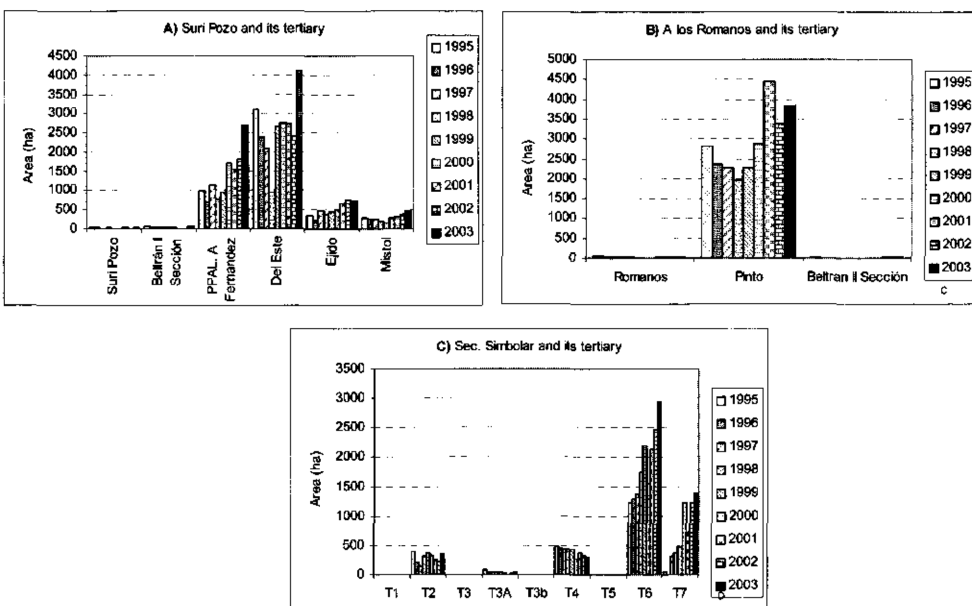

Figure 3.8 Evolution of area with PRETA in the tertiary canals from selected secondary canals. A=Suri Pozo; B=Romanos; C=Simbolar (Source UER).

Tertiary canals with high participation of PRETAs have been highlighted (white canals) in Figure 3.9 to show how PRETAs have allowed the enlargement of the command area, contribute to dispersion of the irrigated area and complicate the operation and performance of the irrigation systems.

Supporters of the treatment of water as a private good propose implementation of tradable water rights and put all their confidence that water markets will allocate water to those more 'economic' efficient use and users[3.6]. PRETAs are not orthodox tradable water rights and the system is certainly not a free water market since the state retains the control over water allocation. However through PRETAs there has been a re-allocation of water to users practicing more profitable irrigated agriculture and to some extend a more profitable use of water. What is not clear yet if these users have made a more efficient use of water?

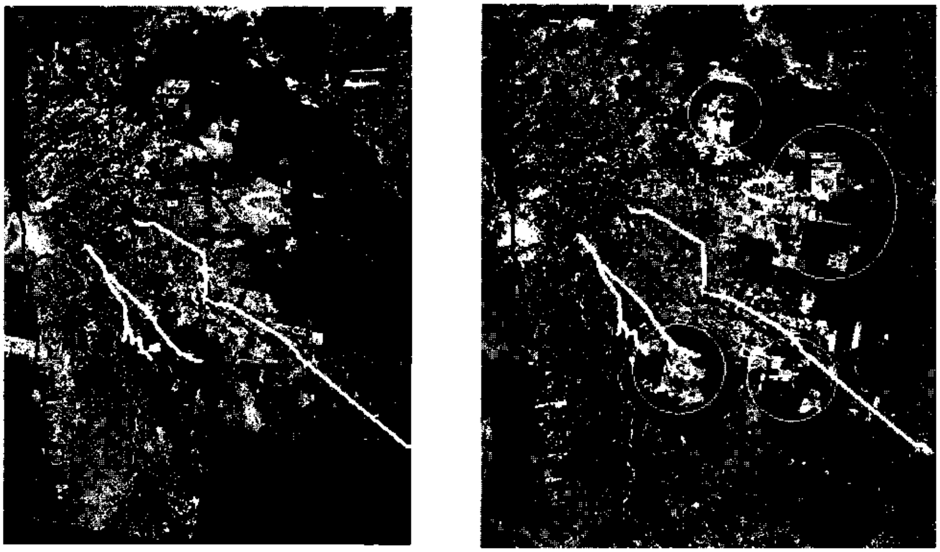

Figure 3.9 Comparison of the extension of the command area from 1984 (right side picture) to 2004 (left side picture). (Source INTA-Santiago del Estero -Remote Sensing Lab).

3.6 Conclusions

Water allocation is a political decision reflecting broader social, economic and environmental objectives of the society and of a government (Frederik, 1992). Like the infrastructure, water allocation has evolved within PRD without a planned project of the Federal or Provincial Governments.

Late involvement of the provincial government in irrigation issues left a large room of manoeuvre in the initial stage of irrigation development in the area. However allocation of water continued to be a contested process in later periods demonstrating that it is a negotiated social process subject to political decisions but shaped by social actors.

In the initial stage the Provincial Government in La Cuarteada state irrigation system and the owners of private *acequias* exercised the control over water allocation. Both dictated water management rules and selected or excluded users. However with the increment of water exploitation there was a progressive involvement of the government in the process of water allocation and a unification of water rights.

[3.6] That of course is clear in the last year under neo-liberal policies but also in the initial period of its application in the 1970's as can be proved by the fact that during the deep crisis of the end of the 1970's and beginning of the 1980s, the total cropped area decreased drastically but the area under PRETAs remain almost constant.

Independent of their political orientation, the strategies of the provincial governments before the PRD intervention had common features: acknowledgement of existing water rights until a certain maximum area (around 400 ha) and a maximum limit of new rights to area of around 50 ha.

The state was effective in the long run to apply its political orientation in the water allocation process. Controlling the accumulation of irrigated area before the 1990's and leaving the systems open after those years. However the simultaneous application of these criteria further validated the initial exclusion of people mainly done by owners of private *acequias*. Most of the time developments incorporated only partially the land of new users, leading to a mosaic pattern of righted and not righted lands that would have other unexpected results on system performance and its environmental impact.

Formal water sharing principles, conditionality of water rights and amounts of water entitlements evolved with development of infrastructure and increment of water availability. Water was shared initially in public systems using the principle of proportional sharing of discharge per unit area, and moved to a fix volume per unit area that was the principle applied in private *acequias* from the beginning. Conditionality also changed with time from temporary rotational irrigation to proportional sharing of discharge.

The amount of water entitled by water rights evolved from being unknown (few times unlimited times during periods of high discharges) to 9900 m^3/ha per year with the implementation of the PRD. However delivery duration has not changed too much along the history of irrigation in the area but delivery duration was the adjusted parameter, from unlimited to 1 hr/ha.

Despite these changing formal rules, during the contested process there was a continuous shaping of actors' strategies to get a maximum water share in relation to changing political and economic contexts and the actions of other actors.

For instance the positivist technical decisions to reduce the volume shared per unit of land during the first important intervention of the state during the 1950's and maintained after the truncated 1968 development project provoked a generalized adoption by the users of an strategy of get water rights for more area than cropped by "kidnapping" water that could not be permanently released until present times.

However it was together with an increment of water, plus during production conditions from the 1970s that were the main reasons for the emergence of PRETA's as a sort of "water banking" system managed by the agency to allocate annually any surplus of water. The system has been highly functional for both the agency and large farmers and for that reason it has persisted in time becoming almost a permanent institution for water allocation in the area and only resisted by holders of permanent water rights in time of water scarcity. On the other hand, as they are used mainly by large farmers to increase their cropped area or settled within the command area, PRETAs has been one of the effective tools to re-concentrate irrigated land after the implementation of liberal policies from the 1990s.

Chapter 4

THE AGRARIAN STRUCTURE AND CROPPING PATTERN

This short chapter includes the characterization of production systems and agrarian structure to complete the description of elements that influence and are influenced by the irrigation system. Not less important in the socio- technical approach is the description of the production system and cropping pattern to make clear the heterogeneous type of users in PRD and their different capacities to mobilize resources, to access to information and definitely to struggle in different arenas. Often this is assumed erroneously as homogeneous in the analysis of large irrigation systems.

4.1 PRODUCTION SYSTEMS

Radrizzani (2000) identified 8 types of production systems in the PRD (Table 4.1) using the RIMSIP methodology base on 9 variables[4.1]. For their general use in this thesis and taking into account the number of holdings and total area of each type (Table 4.2) it seems enough to distinguish two main groups, the M-F production systems (grouping together all types of small holders and family-based production styles) and the ED-E type grouping together the entrepreneur types. The first group includes 65 % of the farm holdings with 30% of the irrigated land while the second group only includes 19% of the farmers but holds 59% of the irrigated land.

Table 4.2 Distribution of the 8 main production systems within the PRD (Radrizzani, 2000).

Production	Farmers		Gross Area		Water righted Area	
Type	N°	% over Total	ha	% over Total	Ha	% over Total
MS	369	10	2819	1	765	1
MC	154	4	1078	1	446	1
MAA	1051	27	10325	5	5338	7
MAAM	342	9	6700	3	4636	6
FAAM	310	8	5520	3	2851	4
FAV	273	7	20838	10	8161	11
ED	580	15	70048	35	32582	44
EE	154	4	44197	22	10878	15
NT	635	16	38255	19	7888	11
Total	3868	100	199780	100	73545	100

NT: Not typified due lack of information.

There exist few economic studies of the production systems of the area, Carrizo and Rodriguez (1999) cited by Radrizzani, (2000) based on sampled MSS and MAA cases concluded that only 47% of the income of these production systems came from the farm. Coronel de Renolfi, (2002) in a study of the "Enterprise" production system types identified 4 sub-types and concluded that the sub-type characterized by the smallest mean cropped area (55has), low mechanization, with long experience in agriculture production (and cropping water melon, pumpkin, maize and alfalfa) still need income from other sources than their farms to cover their basic needs.

[4.1] 1) Farmer size;2) mechanization level; 3) type of manpower; 4) irrigation use index; principal production activity 5) agriculture-alfalfa; 6) agriculture pure; 7) agriculture-vegetables; 8) agriculture-livestock and 9) goat production (meat and/or milk).

Table 4.1 Main types of production systems in the PRD (Radrizzani, 2000)

Production system	Size	Irrig Index	Products	Production destination	Main source of power	Main source of labour	Main source of income
Smallholder subsistence (MS)	Small	0,45	Alfalfa, Maize	Auto	Animals	Family	Outside
Smallholder –goat (MC)	Small / Medium	0,85	Milk and goat lamb	Market	Animal	Family + seasonal labourers	Farm
Smallholder Agriculture-Alfalfa (MAA)	Small	0,85	Alfalfa + Annual crops (1)	Market	Animals	Family	Farm
Mechanized Smallholder Agriculture-Alfalfa (MAAM)	Small / Medium	0,80	Alfalfa + Annual crops (1)	Market	Tractor + Animal	Family + Seasonal labourers	Farm
Mechanized-Familiar Agriculture-Alfalfa (FAAM)	Medium/ Small	0,95	Alfalfa + Annual Crops (1)	Market	Tractor	Family	Farm
Familiar agriculture-vegetable (FAV)	Medium / Small	0,85	Vegetables	Market	Tractor	Family + permanent labourers	Farm
Entrepreneur diversified (ED)	Medium/ Large	0,90	Annual crops (2) + Livestock	Market	Tractor (> 1)	Contracted	Farm
Entrepreneur in expansion (EE)	Medium / Large	4,05	Annual crops(2) + Livestock	Market	Tractor (>1)	Contracted	Farm

Irrigation Index = Irrigated area/water righted area, (1) cotton, maize, pumpkin, water melon (2) Extensive crops (cotton, soybean, wheat, maize

The above is in agreement with the fact that most M production systems depended before 1992 on government support and social laws as the National Law for promotion of Cotton Production[4.2]. Also on National Government Programs such as the "Program Social Agropecuario (PSA)" that subsidises technical assistance and grants cheap loans to organized groups of small farmers or on periodically implemented provincial programs based on distribution of cotton and alfalfa seeds, reduction of irrigation water fees and/or provincial services for mechanized land preparation after the deep neo-liberal reforms of 1992 abolished most social laws and pushed them to compete in open markets without any state protection.

Despite the above official support, the deterioration of income from M and small E production systems under the free-market policies implemented in the last decade is evident. Migration from rural areas to the cities has increased sharply all around the country and the PRD area is no exception. There is a clear process of land concentration (see Section 4.2.3 and chapters 6 to 9) and economic differences among farmers have increased (Figure 4.1 shows houses of both types of farmers as an example of their livelihood differences).

Figure 4.1 Typical houses of M and E farmers in the PRD.

4.2 THE AGRARIAN STRUCTURE

4.2.1 Holding Size Distribution

Table 4.3 for the whole PRD and Table 4.4 for studied secondary canals give a first rough initial idea about the agrarian conditions and the production systems based [4.3] on their size as the main variable of analysis. According to this 1998 official information, 96% of the holdings in the PRD are less than 50 ha and hold 82% of the water righted area, while holdings of more than 50 has are only 4 % of the total but have 18% of the water righted area. There would be no differences[4.4] on the agrarian structure in secondary canals where the number of holdings smaller than 50 has served ranged from 92 (A los Romanos) to 98 % (Simbolar) of the total and hold from 51% (A los Romanos) to 99% (Sud 2nd section) of the water righted area.

[4.2] The National Law for promotion of cotton production established a state control over cotton production to fund a social program that paid a minimum salary and health insurance to small cotton producers with 3 has and 2.400 kg of cotton seed production.

[4.3] Due to the fact that many people own and/or work more than one holding, the number of farmers presented in Table 4.1 is less than the number of holdings presented in Tables 4.3 and 4.4.

[4.4] The conditional expression refers to the fact that, as can be show in Chapters 6 to 9, actual agrarian structure differs from the official information available as a consequences of unregistered changes.

Based on the percentage of righted area of the holdings smaller than 50 ha, three groups of canals can be differentiated. La Cuarteada, Sud 1st section, Sud 2nd section and San Martín irrigating mainly the historical area made up a first group with 72 to 86% of the righted area owned by holdings smaller than 50 ha. Norte, Suri Pozo and A los Romanos canals feeding traditional and new open lands are in the second group, where the percentage of water righted area are belonging to holdings smaller than 50 ha decreases in this group to a range from 51 to 60%. The special case of Simbolar is in the third group, with the water righted area in holdings smaller than 50 ha increasing to a high 94% of the water rights, as a consequence of the homogeneous planned lay out of 25 ha holdings within its command area that developed during PRD implementation (see Chapter 7).

Table 4.3 Holding size distribution in PRD (Source INTA-UER, 1998)

	Holdings		Gross Area		Water Rights		WR	
	N°	%	ha	%	Ha	%	Gross (%)	Mean irrigated area /plot (ha)
0-5	2648	39	13573	7	7012	8	52	3
5-10	1741	26	21483	11	11417	13	53	7
10-25	1621	24	37818	19	24795	28	66	15
25-50	510	7	30397	15	16204	18	53	32
50-100	196	3	33320	17	12869	14	39	66
100-500	92	1	52750	27	15523	17	29	169
500-1000	2	0	8985	5	1305	1	15	653
Total/Mean	**6810**	100	**198326**	100	**89124**	**100**	45	**20 (13)**

4.2.2. Land Tenure in the PRD

Land tenure is another individual variable used frequently to characterize the agrarian structure of an area. In this sense the data in Table 4.5, based only on permanent water righted holdings, shows that the PRD intervention efficiently regularized land tenure in the irrigated area[4.5], since use of land by leasers and squatters is very low and most of cropped plots are been working by their owners or heirs.

Table 4.5 Different land tenure of the holdings with permanent water rights actually in production in the PRD in 1998 (source INTA-UER 1998 database).

	Leasers		Heirs		Squatters		Owners		Total in use	
	N°	Ha	N°	Ha	N°	Ha	N°	ha	N°	Ha
PRD	233	4148	851	9618	248	2431	2633	34096	3965	50293
Secondary canals										
Norte	35	501	97	1546	1	7	184	2925	317	4978
La Cuarteada	28	489	159	1766	65	690	397	4353	649	7298
Sud 1ª	73	1127	136	1727	18	153	664	6955	891	9963
San Martín	47	736	324	2950	104	535	662	7266	1137	11487
A Los Romanos	5	66	18	129	5	37	49	1292	77	1523
Suri Pozo	9	192	17	237	30	791	112	1933	168	3153
Sud 2da	11	356	84	879	22	153	294	3046	411	4434
Simbolar	25	680	16	384	1	20	244	6194	286	7277

[4.5] This contrasts strongly with the situation in the rainfed area of Santiago del Estero where there is a great number of conflicts over land tenure.

Table 4.4 Holding size distribution in secondary canals

Size Classes	Plots N°	Plots %	Gross Area ha	Gross Area %	Water Rights Ha	Water Rights %	WR Gross (%)	Mean area /plot (ha)
Norte Secondary Canal								
0-5	99	25	553	5	306	5	55	3
5-10	141	36	1459	13	907	14	62	6
10-25	87	22	1839	16	1137	17	62	13
25-50	36	9	1802	15	1184	18	66	33
50-100	21	5	2197	19	1396	21	64	66
100-500	9	2	3801	33	1676	25	44	186
Total/Mean	**393**	**100**	**11652**	**100**	**6605**	**100**	**59**	**51**
La Cuarteada Secondary Canal								
0-5	282	34	1722	7	772	8	45	3
5-10	247	30	2868	11	1620	16	56	7
10-25	220	27	4840	19	3186	32	66	14
25-50	49	6	3441	13	1588	16	46	32
50-100	18	2	7076	27	1218	12	17	68
100-500	10	1	6093	23	1655	16	27	165
Total/Mean	**826**	**100**	**26040**	**100**	**10038**	**100**	**43**	**48**
Sud 1st Section Secondary Canal								
0-5	533	41	2694	10	1402	10	52	3
5-10	373	28	3564	13	2517	18	71	7
10-25	302	23	6585	24	4273	31	65	14
25-50	70	5	5553	20	2312	17	42	33
50-100	27	2	6324	23	1791	13	28	66
100-500	8	1	2886	10	1326	10	46	166
Total/Mean	**1313**	**100**	**27605**	**100**	**13621**	**100**	**44**	**48**
San Martin Secondary Canal								
0-5	887	58	3863	8	2215	14	57	2
5-10	307	20	4202	9	1990	13	47	6
10-25	222	15	5668	12	3215	21	57	14
25-50	52	3	3991	8	1724	11	43	33
50-100	31	2	4288	9	2061	13	48	66
100-500	17	1	19112	39	3285	21	17	193
500-1000	1	0	7450	15	795	5	0	0
Total/Mean	**1517**	**100**	**48573**	**100**	**15284**	**100**	**39**	**53**
A los Romanos Secondary Canal								
0-5	194	41	1312	8	511	7	39	3
5-10	113	24	1576	10	705	9	45	6
10-25	94	20	2492	16	1281	17	51	14
25-50	39	8	2283	15	1284	17	56	33
50-100	23	5	2836	18	1526	20	54	66
100-500	13	3	5216	33	2140	29	41	165
Total/Mean	**476**	**100**	**15715**	**100**	**7447**	**100**	**42**	**48**
Suri Pozo Secondary Canal								
0-5	405	31	2020	4	1073	5	53	3
5-10	329	25	5412	11	2122	10	39	6
10-25	338	26	7795	17	4861	23	62	14
25-50	135	10	9204	20	4527	21	49	34
50-100	58	4	8356	18	3708	17	44	64
100-500	27	2	12810	27	4476	21	35	166
500-1000	1	0	1536	3	510	2	0	0
Total/Mean	**1313**	**100**	**11653**	**100**	10000	100	59	17
Sud 2nd Section Secondary Canal								
0-5	206	34	1186	12	643	11	54	3
5-10	212	35	2175	22	1446	25	66	7
10-25	143	24	3248	33	1974	33	61	14
25-50	30	5	1432	14	1010	17	71	34
50-100	9	1	790	8	556	9	0	0
100-500	2	0	1122	11	272	5	0	0
Total/Mean	**602**	**100**	**9953**	**100**	**5900**	**100**	**52**	**14**
Simbolar Secondary Canal								
0-5	0	0	0	0	0	0	0	0
5-10	0	0	0	0	0	0	0	0
10-25	193	66	4592	57	4553	61	99	24
25-50	94	32	2451	30	2404	32	98	26
50-100	5	2	799	10	398	5	50	80
100-500	1	0	199	2	100	1	50	100
Total/Mean	**293**	**100**	**8041**	**100**	**7454**	**100**	**65**	**57**

4.2.3 Number of Active Holdings

The drop in active holdings linked in most of the cases to M production systems is due to the reduction of agricultural profitability in the last 20 years and lack of government protection, was an evident process not quantified in the 1990s in the PRD. Radrizzani (2000), based on the INTA-UER (1998) survey, determined that 42% of the holdings (2828) with permanent water rights were abandoned (definitely or temporarily not cropped), ranging across the different size classes from 39 to 47%.

Comparing 1998 and 2003 official registers of active users (Table 4.6) it can be concluded that the process has continued: during the 5 year period since then 1228 holdings representing 31% of the active 1998 holdings were abandoned. It is also clear that the process is affecting mainly the smallest holdings given that 58% and 25% of the 1998 active holdings in the 0-5 ha and 5-10 has classes were abandoned, while 38% of the 1998 holdings in the range 100-500 has reassumed agriculture activity in the same period. Data prove that there is a land concentration process going on in the PRD as there is in many other rural areas of the country.

Table 4.6 Percentage of cropped and not cropped holdings in 1998 and 2003 in the PRD and abandoned holdings in the period respect 1998 cropped holdings

	1998				2003				Δ 98-03Not cropped 98 active holdings	
	Cropped Holdings		Not Cropped Holdings		Cropped Holdings		Not Cropped Holdings			
	% N°	% ha	% N°	% ha	% N°	% ha	% N°	% ha	%	%
0-5	57	58	43	42	38	40	62	60	- 58	- 74
5-10	59	59	41	41	41	42	59	58	- 25	- 46
10-25	61	64	39	36	40	41	60	59	- 8	- 22
25-50	57	55	43	45	45	45	55	55	- 12	- 17
50-100	55	55	45	45	49	50	51	50	+ 2	- 6
100-500	53	52	47	48	65	67	35	33	+38	+ 6
Total	58	57	42	43	40	48	60	52	**- 31**	**- 22**

4.3 THE CROPPING PATTERN AND CROPPING INTENSITY

4.3.1 System Level

The cropping pattern of PRD in 5 seasons is presented in Table 4.7 (data has been sorted by cropped area in the season 2000-01). Although there are over 20 crops grown in the area, the cropping pattern is highly dominated by 4 extensive crops (cotton, wheat, maize and soybean) 8 vegetables crops (onions, carrots, water melon, small pumpkin, sweet potato, tomato and lettuce, with onions and carrots clearly the most important) and 2 forage crops (alfalfa and annual pastures).

According to this official information cropped area recovered, with the large improvement of agriculture profitability after the devaluation of Argentinean peso in late 2001[4.6]. The recovery has been based mainly on an increase in areas of traditional crops (vegetables, cotton, maize and alfalfa), and wheat (an historical crop in the area that has highly recovered) but soybean and pastures have also contributed recently.

[4.6] Official information for seasons 2000-2001 and 2001-2002 appeared too high. For that reason there has been adjustment based on a qualified informant. I still have doubts about figures from 2001-2002 season: for that reason they have been left out of further analysis.

The increments in wheat and soybean areas are linked, since wheat-soybean has been the dominant crop sequence in the last 4 years in Argentinean rainfed agriculture, due its very high profitability after the 2001 A$ devaluation .The growth of irrigated pastures gives an indication of the augmentation of livestock production within the PRD command area. The first process is a clear example of the responsive behaviour of Argentinean farmers to market incentives, many of them in this case coming from provinces of the humid region of the country. The increment of livestock production in the area is also a consequence of the same process since the important increase in agricultural areas in the central areas of the country after 2002 displaced livestock production to marginal areas in the semi-arid region. Both production trends are associated with large farmers (E production systems) and explain the increased number of holdings larger than 100 has that have became active recently in the PRD as commented on the previous section.

The increment of alfalfa and cotton irrigated areas not only involves large farmers but has an important contribution for small farmers benefited by new official programs as well.

Table 4.7 Cropped area per crop (% of the total cropped area) in the PRD (Source, UER).

CROPS	GROWING SEASONS									
	95-96		96-97		99-00		00-01		01-02	
	10^3ha	%	10^3ha	%	10^3ha	%	10^3ha	%	10^3ha	%
Vegetables	6,5	13	8,2	16	13,4	24	17,3	22	16,4	20
Cotton	35,1	69	21,0	41	10,3	19	13,1	17	15,0	18
Wheat	0,2	0	4,2	8	6,2	11	10,4	13	10,8	13
Maize	2,2	4	6,3	12	7,4	13	10,0	13	11,1	13
Pasture	1,5	3	3,9	8	6,3	11	9,8	13	9,5	12
Alfalfa	4,4	9	5,6	11	6,4	12	9,8	13	9,8	12
Soybean	0,1	0	0,2	0	2,9	5	3,9	5	5,5	7
Citrus	0,4	1	0,9	2	0,7	1	1,1	1	1,30	2
Others	0,7	1	0,9	2	1,6	3	2,1	3	2,9	4
Total	**51,1**	**100**	**51,1**	**100**	**54,9**	**100**	**77,3**	**100**	**82,3**	**100**
Vegetables	**95-96**		**96-97**		**99-00**		**00-01**		**01-02**	
Onion	1,6	25	1,8	22	3,8	29	5,	30	5,2	32
Carrot	1,6	25	1,7	21	3,1	23	3,	21	3,	19
Water, melon	0,8	13	0,9	12	1,6	12	1,	10	1,5	9
Small Pumpkin	0,7	11	0,6	8	0,9	7	1,5	9	1,3	8
Sweet Potato	0,4	6	0,7	9	1,0	8	4	8	1,6	10
Melon	0,1	2	0,6	8	1,1	8	1,3	7	1,0	6
Tomato	0,6	9	1,2	15	0,8	6	1,0	6	1,0	6
Lettuce	0,4	7	0,4	4	0,4	3	0,6	3	0,6	4
Others	0,3	4	0,3	4	0,6	5	1,	6	1,	7
Total	**6,5**	**100**	**8,2**	**100**	**13,4**	**100**	17,	**100**	16,4	**100**

An important point for the objective of this thesis is to recognise that there has not been important change in the type of crops not only in the study period, but from historical references since the cropping pattern reported by Michaud, (1942). The crops he reported for public irrigation systems in 1942 included: alfalfa (2.700 ha), vegetables (1.000 ha), fruits (1.300 ha), maize (10.000 ha), cotton (9.000 ha), wheat (2.000 ha), oats (12.000 ha) and potato and sweet potato (1.000 ha) while Romanella, (1971) enumerated just before the PRD the crops as alfalfa (32.800 ha), cotton (32.800 ha), maize (8.200 ha), sorghum (4.100 ha), wheat (4.100 ha), sweet potato (4.900 ha), onion (2.500 ha), pumpkin (2.500 ha), melon (2.500 ha), water melon (1,600 ha), tomato (1.600 ha) and citrus (2.100 ha).

Although it will be analyzed in more detail later for its effect on water use, it should be noted that most of the extensive annual crops (with the exception of wheat) and the permanent crops alfalfa and citrus and some vegetables (onion, carrot, lettuce) are spring-summer crops grown in the rainy season (November-March) and mostly require only supplementary irrigation.

4.3.2 Secondary Canals Level

Table 4.8 summarizes the cropping pattern of the secondary canals studied, in order to identify differences in the secondary subsystem that help with interpretations of possible irrigation performance at this level.

Most cropping pattern are similar, however it is possible to do the following differentiation: The cropping pattern of Norte, La Cuarteada, Sud 1st and Sud 2nd section canals are more traditional (cotton, alfalfa, maize and water melon and pumpkin among vegetables) with pastures related with livestock production increasing sharply in the last years. Extensive production of maize, soybean and wheat are more present in A Los Romanos and Suri Pozo and San Martín (that also includes pasture), that is highly linked with the strong presences of large E farmers in these canals. Simbolar Secondary canal concentrates on the intensive production of vegetables and in particular the most intensive ones such as onions, carrots, lettuce.

4.3.3 *Cropping Intensity*

Determining cropping intensity is not easy since cropped area is surveyed by the agency's field agents without a precise register of the actual location of the crops within the farm. To have some idea about cropping intensity, total cropped was compared with Total Water Righted Area (permanent + PRETAs) of active parcels (TWRA in Chapter 6 to 9). Results are shown in Table 4.9.

Table 4.9 Cropping intensity in PRD (%)

	GROWING SEASONS				
	1995-1996	1996-1997	1999-2000	2000-2001	2001-2002
PRD	49	51	54	74	77
Secondary Canals					
Norte	44	25	32	55	58
La Cuarteada	37	21	14	25	31
Sud 1st section	38	41	18	42	45
San Martín	36	35	35	52	59
A los Romanos	51	75	87	107	109
Suri Pozo	45	56	65	80	82
Sud 2nd section	47	47	54	62	66
Simbolar	95	100	97	136	126

Without any other climatic restrictions other than water for crop growth, cropping intensities close to 200% could be expected in PRD: however cropping intensity has been historically low - close to 50%. However, data shows a sharp increment in the last two seasons with cropping intensity still below 100% in canals where traditional crops predominate and intensity above 100% only in those with great participation in the wheat-soybean and vegetables crop sequences.

Table 4.8 Cropped areas (ha) in the 8 main secondary canals of the PRD.

	GROWING SEASONS				
	1995-1996	1996-1997	1999-2000	2000-2001	2001-2002
Norte Secondary Canal					
Pasture	0	20	514	2333	3273
Cotton	2584	1285	847	1456	2481
Wheat	1	0	398	654	851
Alfalfa	185	174	188	426	652
Maize	66	101	63	166	225
Vegetables	119	40	83	143	192
Others	62	60	21	58	124
Total	**3017**	**1680**	**2114**	**5235**	**7797**
La Cuarteada Secondary Canal					
Alfalfa	407	324	284	1126	1694
Cotton	3523	1565	538	1000	2206
Wheat	107	138	258	725	797
Maize	83	143	200	424	964
Vegetables	10	27	24	129	416
Others	1	27	147,5	430	686
Total	**4131**	**2224**	**1450**	**3833**	**6762**
Sud I Secondary Canal					
Cotton	4068	3548	935	2539	4615
Vegetables	572	949	742	2387	2963
Maize	90	119	209	950	1280
Citrus	204	377	238	813	1373
Wheat	0	100	35	679	679
Alfalfa	272	321	177	656	1012
Others	64	295	171	999	1829
Total	**5270**	**5609**	**2472**	**8342**	**12770**
San Martin Secondary Canal					
Alfalfa	1088	1549	2108	3951	5519
Pasture	561	1124	827	2485	3667
Maize	294	1120	891	1744	3086
Vegetables	467	607	834	1683	2395
Wheat	2	260	309	931	2105
Soybean	0	0	258	791	1875
Cotton	3312	914	23	30	367
Others	272	88	324	457	738
Total	**5994**	**5661**	**5573**	**12071**	**19751**
A los Romanos Secondary Canal					
Maize	972	1383	2332	3686	6283
Vegetables	246	738	1948	3512	4716
Soybean	0	151	1120	2610	4767
Wheat	20	800	880	2130	3533
Pasture	432	1109	1027	1396	1650
Alfalfa	249	396	382	912	1273
Cotton	3267	2303	212	902	2102
Others	64	493	530	644	1681
Total	**5250**	**7373**	**8430**	**15791**	**26002**
Suri Pozo Secondary Canal					
Wheat	0	1842	2220	5753	7893
Vegetables	640	1111	3085	5359	7620
Pasture	412	1250	2166	4962	6357
Alfalfa	1092	1973	2239	4350	6095
Cotton	8951	5968	2517	3427	4760
Maize	375	1541	2156	3208	4548
Soybean	0	0	1452	1655	3277
Others	199	309	752	1526	2888
Total	**11668**	**13993**	**16585**	**30240**	**43437**
Sud II Secondary Canal					
Alfalfa	593	591	724	1667	2376
Pasture	0	57	637	1234	1919
Wheat	0	320	597	1013	1809
Vegetables	274	445	569	841	1292
Cotton	2124	1031	579	683	972
Maize	48	318	227	267	384
Others	0	145	4	4	6
Total	**3039**	**2907**	**3337**	**5709**	**8758**
Simbolar Secondary Canal					
Vegetables	3511	3816	5277	9336	11183
Cotton	5192	3521	2269	4425	6456
Maize	185	1354	1031	3319	4598
Wheat	37	681	1058	2063	2544
Others	257	116	1019	1961	2603
Total	**9182**	**9488**	**10654**	**21103**	**27383**

4.4 CROP YIELDS

There has no systematic survey of crop yield in the command areas of the different secondary canals by either the irrigation agency or any other official organization. Yields presented in Table 4.10 were surveyed for this study through interviews with qualified informants and by structured interviews with users in the 4 study cases presented in chapter 6 to 9.

Table 4.10 presents mean, improved and maximum yields for the relevant crops in PRD[4.9]. Due the high diversity of production systems, and the big differences in their technology and other resources, and the complex relationship between yields, inputs and crop management, the mean yield presented in the table gives only a weak picture about the diversity of situation within the PRD.

Table 4.10 Mean, Improved and Maximum yield of relevant crops in PRD (source own interviews to qualify informant)

Crops	Mean Yields metric ton/ha	Improved Yield metric ton/ha	Maximum Yields metric Ton/ha
Cotton	1,5	2,25	3,25
Wheat	2,0	2,75	5,25
Maize	4,0	7,0	8,75
Soybean	1,85	2,5	3,25
Alfalfa	10,0	15,5	21,0
Onion	17,5	40	45
Carrot	24	36	39
Water, melon	24	32	40
Small Pumpkin	10	12	16
Sweet Potato	15	20	25
Melon	12	20	30
Tomato	18	30	45
Lettuce	16	18	20

4.5 PRODUCTION PRICES

Information about prices obtained by PRD's farmers is highly variable depending on type of farmers, marketing strategies and possibilities, product, etc. To avoid this problem for further use in this thesis, prices at Santiago del Estero have been calculated subtracting transportation costs from prices at the main national market (Rosario or Buenos Aires). Calculated 2005 prices are presented in Table 4.11

4.6 CONCLUSIONS

Different production systems have coexisted in the area for many years but for the purpose of this thesis they are regrouped in two main groups (M and E), with similar cropping patterns but clearly differentiated by their production scale, mechanization and economic performance.

There has been a process of land concentration in PRD as in many other areas of the country. The neo-liberal reforms of the 1990's worsened the economic crisis of small

[4.9] *Improved yield* refers to that expected with basic improvement on crop management while to *maximum yield* imply use the highest technology available.

farmers (M production system) whose settlement was largely promoted by both Los Quiroga and PRD interventions and many of them left agriculture. This process is still active despite the sharp increase in profitability of agriculture commodities after the A$ devaluation that followed the deep 2001 national crisis, and the new policies adopted by the National and Provincial government recently. Around 1200 holdings were abandoned in the period 1998-2003, most of them holdings of less than 10 ha.

Table 4.11 Prices of the relevant PRD productions (2005)

Crops	U$S/metric ton
Cotton (fibre)	974
Wheat	133
Maize	100
Soybean	215
Alfalfa	67
Onion	260
Carrot	79
Water, melon	110
Small Pumpkin	153
Sweet Potato	147
Melon	553
Tomato	107
Lettuce	125

Although the number of crops is relatively large, 10 crops are dominant. With the exception of soybean within the extensive crops, and carrots and lettuce within vegetable cropping, the type of crops has not changed so much along the years. However cropped areas change in response to change to a better economic environment, market opportunities, and/or official programs implemented in favour of small farmers.

Cropping intensity in PRD has been historically low, around 50-55% in relation to total water righted area. The fact that many areas are not being cropped and those used only cropped in one season as in historical times (despite water being available all year around after construction of the Rio Hondo reservoir) explains the low intensity use of irrigation facilities.

Mean crop yields are low in relation to what are considered potential yields for the area due the low use of inputs and the mismanagement of irrigation as will be show in following chapters. It is estimated that yields could be increased by 20 to 30% by low cost crop management practices.

Chapter 5

MAIN SYSTEM DESIGN, MANAGEMENT AND PERFORMANCE

As is clear from the historical analysis of Chapter 2, the present layout of physical infrastructure for conveyance and distribution of water did not result from any well-planned intervention. It has been a continuous process of partial and successive "rehabilitation" and/or "modernization" interventions of different intensity that added, improved or rehabilitated elements of the network. These differed over time in their approaches to irrigation, but all had in common the objective of removing those elements considered at that time as the bottleneck in constraining the functioning of the system from the expected way. This chapter reviews the water control of the main systems and its secondary canals their performance, to portray the water supply performance conditions upstream of the diverse tertiary units studied in chapter 6-9.

5.1 THE LAY OUT OF THE MAIN SYSTEM.

For study purposes, three main stages have been defined in development of the PRD network. The first was an initial unplanned intervention that set up the old *La Cuarteada* system with a short main canal that took water from the river and conveyed it to three main secondary canals Norte, La Cuarteada and Sud. A second intervention (referred to as the "Los Quiroga" modernization so far) incorporated the Los Quirogas delivery dam, but also a lined main canal that connected it with a network of existing secondary canals (Norte, La Cuarteada and Sud). This intervention also connected the Los Quirogas delivery dam with three new important secondary canals - Suri Pozo, A los Romano and San Martín - that integrated to the system areas formally watered by private *acequias* such as Fernandez, Pinto, Villa Robles, and Contrera López. Almost at the end of this long period taken up by the Los Quiroga modernization, the Jume Esquina canal was planned with the objective to transfer water from Rio Dulce to Rio Salado.

The third and last, the PRD "modernization", was the unfinished intervention initiated in 1968. In its 5 very active years, modernization reached 42% of the actual infrastructure. Works done included; redesign and reconstruction of La Cuarteada and San Martin secondary canals and their tertiary canals (AT2, MT4, CT1,CT2 and CT3 in La Cuarteada and Contreras Lopez, Maco-Manogasta, SMT5, SMT7 and SMT9 in the San Martin); redesign and construction of tertiary canals from Norte canal (NT4, NT6), other smaller secondary (El Alto) or tertiary canals (MT4); and the complete construction of the earth canal network of Zone V (Simbolar Secondary canal and T1 to T7 tertiary canals) that was part of the colonization component of the project[5.1].

These successive actions yielded a heterogeneous canal network in terms of construction material, discharge capacities and type of control, off-take and water measuring structures. Table 5.1 presents information about canal length and construction materials (capacity and structures will be treated later in this chapter). *Matriz* (the main canal of the system), La Cuarteada and San Martín secondary canals, their tertiary canals and those from Norte are

[5.1] A complete network of main and submain drainage canals were also built in Zone I, IV and V.

concrete lined. *Comuneros* in La Cuarteada and Norte network are soil-cement lined. The rest, totalling almost 350 km, are still earthen water courses.

Table 5.1 Main Characteristics of the PRD canals network (Source UER, 2002).

Canal Hierarchy		Length per Canal Material (km)			Total
Main	**Secondary**	**Concrete**	**Soil-cement**	**Earth**	
Matriz		21,722			
	Norte	0,50	0	26,50	27,00
	La Cuarteada	20,03	0	16,31	36,31
	Sud 1ra Sección	1	0	24,45	25,45
	San Martín	38,87	0	26,13	65,00
	A los Romanos	0	0	10,00	10,00
	Municipal	0	0	9,07	9,07
	Jume Esquina	0	0	21,44	21,44
	Suri Pozo	0	0	20,00	20,00
	Sud 2da. Sección	0	0	9,20	9,20
	Simbolar	0	0	16,30	16,30
TOTAL SECONDARY		60,4	0	169,40	229,80
TERTIARY NETWORK		64,31	34,86	175,16	274,33
TOTAL		146,43	34,86	344,56	525,85

5.1.1. The Capacity of the Main and Secondary Canals.

The projected and actual official capacities of the main, secondary canals and specific tertiary are shown in Table 5.2. Data show that the capacity of some tertiary canals was increased to cope with the important growth in area served, discussed in Chapter 3. However, the capacity of the old secondary canals serving them was sufficient and remained unchanged.

Absolute values of canals capacity do not say too much about the actual capacity of the system to cope with irrigation demands. With this objective the initial Water Delivery Capacity (WDC) was calculated (Figure 5.1)[5.1].

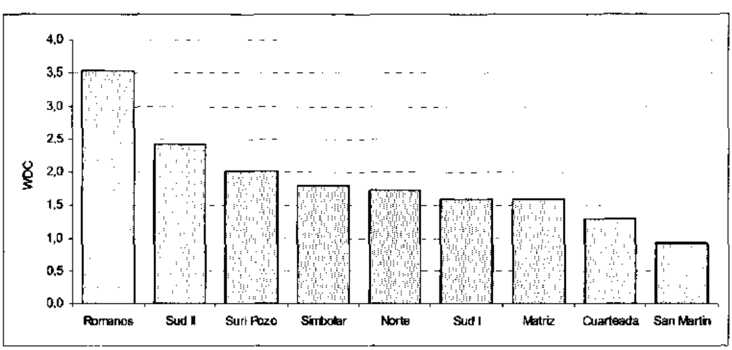

Figure 5.1 Water Delivery Capacity of the Matriz and secondary canals based on planned irrigated and cropping pattern.

[5.1] For the calculation of the initial WDC (the relationship between the capacity at the head of canals and the theoretical maximum discharge capacity based on peak irrigation requirements) gross irrigation requirements were calculated for the cropping pattern and the maximum irrigated area assigned to each canal by the irrigation consultant at the time of PRD design and considering, as he did, a rainfall with 80% probability of occurrence, and 49% Project efficiency (Romanella, 1973).

Three of the four canals re-designed at the time of the PRD "modernization" intervention - Matriz and La Cuarteada and San Martin - have lower water delivery capacities while the fourth, Simbolar, appears with a rather high WDC as a consequence of the fact that a 2[nd] phase of a colonization plan that would increase its irrigated area was considered possible at that time.

Table 5.2 Official capacity of the main secondary canals of PRD (Source, UER, 2002).

Canal Hierarchy			Discharge (m^3/s)	
Main	**Secondary**	**Tertiary** [(1)]	**PROJECTED**	**ACTUAL**
Matriz (Main Canal)			**100**	**100**
	Alto C [(2)]		0,5	0,5
	Norte		7	7
	La Cuarteada		8	8
	Sud 1ra Sección		11,5	11,5
	San Martín		10	10
	A los Romanos		20	20
	Municipal [(2)]		2,0	2,0
		Pinto	4	5
	Suri Pozo		27	27
		Ppal. A Fernández	10	11
		Del Este	3	5
		Ejido	1	1,5
		Mistol	2	2,5
	Jume Esquina [(3)]		20	21
	Sud 2da. Sección		4,5	4,5
	Simbolar		15	10
TOTAL SECONDARY			**125**	**121**

(1) Only tertiary canals that have increased their capacity have been included.
(2) Left out of future analysis because their small command area or low irrigated area during the studied period.
(3) Left out of future analysis because its main purpose is to transfer water from Rio Dulce to Rio Salado.

At the design stage canal capacities are highly defined by the way water is planned to be delivered to tertiary units (Horst, 1998). However, in reverse, during operations it is the capacity of the network which determines how flexible the water delivery schedule can be. In this sense the over capacity of most canals, represents a storage capacity on line useful for increasing flexibility of the water delivery schedule (Renault, 2001)

The explanation of the over capacity of most canals can be found in the changed design paradigm from Los Quiroga to the PRD intervention. Most of the earthen secondary canals still working were designed during the Los Quiroga "modernization", under a protective irrigation vision and without regulated river flow conditions. Therefore their capacity should be large enough to capture most of the expected rivers flows even in periods of rather high discharges. However in the PRD modernization intervention, canal capacities were designed for full irrigation of an established cropping pattern: a rotational water delivery was scheduled and canals were planned to be lined, then imposing restrictions in canal capacity for economic reasons[5.2].

[5.2] Due to the partial implementation of the project that criteria is only expressed in the re-designed capacity of the "modern canals" La Cuarteada and San Martín

The stated capacities were not field checked during the research, but mean registered discharges and even maximum daily discharge were far below these values in all cases during the study period, as can be seen in section 5.4, confirming the over capacity of most of the canal network.

5.1.2 Water Diversion Structures.

Beside canal capacities, water diversion structures also highly determine type of operation, farmer dependency on management, transparency, operational flexibility[5.3], and definitely they are an important factor in terms of the performance level achievable by the system (Murray-Rust and Snellen, 1993).

Figure 5.2 shows the layout of diversion structures from Matriz to *comuneros* (normally quaternary canals in PRD). As with the canals, different control structures co-exist in the system but this time the diversity is not a result of the unfinished PRD intervention but from different design criteria used during the implementation of the interventions for reasons that could not be uncovered during the field work.

Figure 5.2A shows the gated layout that is characteristic of the "non modernized", "old" canals, Sud I, Sud II, Suri Pozo and Romanos network, and that is also present in the modernized networks of Norte and La Cuarteada (B in figure 5.2) with long throat flumes added at the head of tertiary and *comuneros* water courses. This gated layout (Figure 5.3) with a high number of control regulators is the most common layout and the most important from an operational point of view.

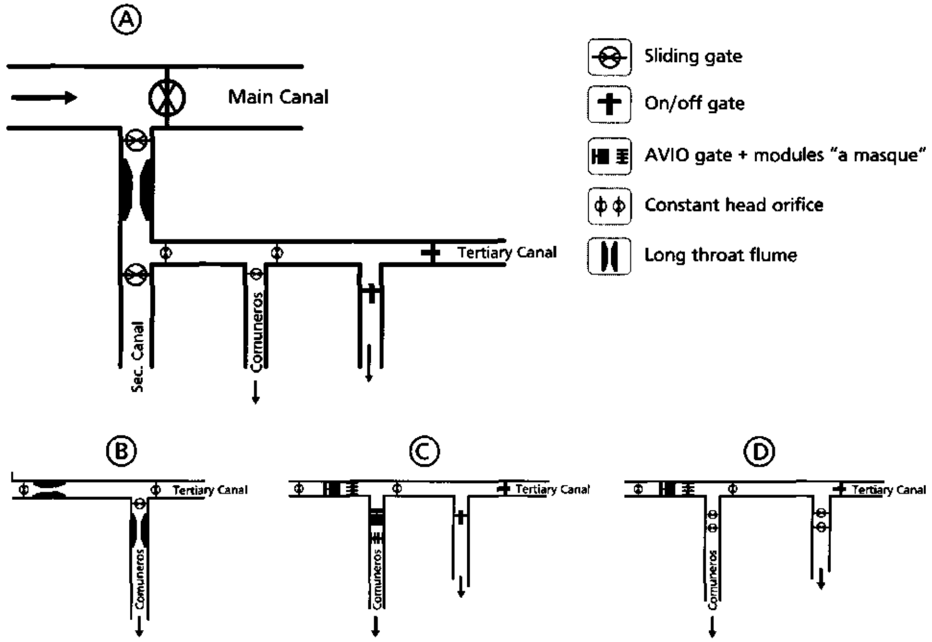

Figure 5.2 Diversion structures la out A) Non-modernized Secondary Canals (Sud I, Sud II, Suri Pozo, Los Romanos) B) Norte and La Cuarteada; C) San Martin; D) Simbolar.

[5.3] Operational flexibility: Capability of the system to comply with changing demands and supplies, Horst, (1998) In the modernized reach of San Martin (figure 5.2C) and Simbolar networks (figure 5.2D) there are Neyrpic AVIO (downstream control) automatic gates at tertiary and even *comunero* off-takes (San Martín) but they are not operationally useful since in both cases the sliding gates located by the designers just upstream for service or maintenance purpose of the automatic gates are manually operated for water distribution.

As sketched in Figure 5.2, sliding and/or on/off gates are used at tertiary and *comuneros* level in both, modernized and non-modernized parts of canal network. Use of one or the other type of diversion structure depends on the number of *caudales* or rotational clusters of *comuneros*/farms[5.4].

On/off gate is the unique type of diversion structure in small *comuneros* (or tertiary canals) with only one rotational unit. Both types of diversion structures are used in a larger tertiary or *comunero* with at least two rotational units. In those cases on/off structures are in the most downstream sections where the available discharge rotates in one cluster, while sliding gates are located in the upstream sections where discharge is at least two *caudales* (for at least two clusters of *comuneros*/farms). Definition of more than one rotation clusters is required to complete the water rotation within the official 28 day frequency, and is common at *comuneros* level in the network of non modernized canals.

Figure 5.3 Typical control and off-take in the PRD (Off-take NT4 from Norte Canal).

Figure 5.4 shows two typical on/off gates. Plate gates are common in the modernized areas, with wooden ones in old areas (however this difference is not so strict at this moment since plate gates are being replaced in the modernized area by wood gates constructed locally). Use of this type of gates makes water distribution very transparent at lower levels of the system, and because they are not easily locked it demonstrates a high trust between users at that level.

5.1.3 Structures for Flow Measurements.

As in the case of diversion structures, different types of structures for flow measurement were constructed during the PRD intervention at the head of all secondary canals and at the head of modernized tertiary and *comuneros*. Figure 5.5 shows some of these.

[5.4] A cluster of *comuneros* within a modernized tertiary canals or a cluster of farms in long "old" *comuneros* refers to a group of *comuneros*/farms that conform one rotational group.

There are long throat flumes at all secondary canals just downstream of their off-take from the main canal, and at the head of all tertiary and *comuneros* water courses in the modernized networks of Norte and La Cuarteada canals. "*A masque*" modules downstream of the Neyrpic Avio automatic gates complete the modernized package at tertiary level in the modern San Martin and Simbolar networks and San Martin's *comuneros*, while constant head orifices were preferred by the designers for *comuneros* in the Simbolar network. Figure 5.5 shows some examples of these.

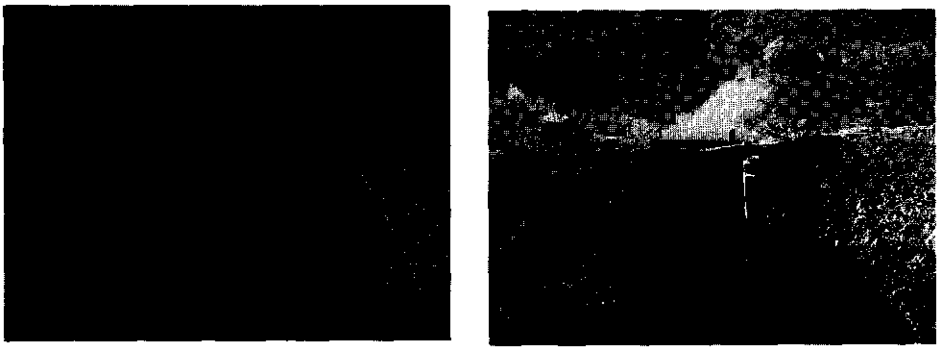

Figure 5.4 Typical on/off gate at *comuneros* level.

Measuring facilities at secondary level started to be used routinely in 1995 as part of a preliminary agreement between the UER and INTA. Data from them was converted to discharge initially using the theoretical rating curves developed by the designer, and if necessary, using new rating curves calculated using Winflume version 1.03 (Whal *et al*, 2000) after checking functioning conditions. Measuring facilities at lower levels have been not used until now for operational purposes.

5.2 The Water Delivery Schedule.

Neither the "modern" automatic gates nor flow measurement facilities have been used downstream for operation or performance assessment purposes. The system continued to be operated as before the PRD modernization using exclusively sluice gates. For this reason the PRD system can be defined as a gated operated system with control regulators according to the typology of Murray-Rust and Snellen, (1993).

In relation to its water delivery schedule, the PRD is officially an upstream control or agency-operated system with a fixed rotation, full supply delivery to tertiary units/farms (Horst, 1998). The fixed frequency of the rotational delivery was adopted by the operational unit of A&EE - changing the proposition of the irrigation expert. The expert had advised to adopt, for matching the changing irrigation water requirements, a frequency variable rotation, full supply delivery in a first stage, later evolving to a downstream responsive delivery scheduling with the expected "modernization" of farmers irrigation practices (Romanella, 1971). This explains the introduction by system designers of the Neyrpic AVIO automatic gates in the San Martin and Simbolar, the latest modernized water course networks.

Officially water rights allocated to each farmer were 300 l/s, for 50 min/ha with a frequency of 28 days, during the whole year, independent of the crop water requirements (the most conservative alternative proposed by the irrigation consultant during the irrigation design, Romanella (1971)). As the systems is closed for maintenance during approximately one month (February at the beginning of A&EE administration, May since 1982) 11 irrigations turns (events) are available for each user: that means a maximum annual gross irrigation supply of 9.900 m^3/ha should be available for each water user in the PRD.

In Zone V, watered by Simbolar Secondary canal, water delivery schedule has changed to arranged rotation, with delivery frequency arranged after user's requests, but keeping a fixed delivery discharge and duration.

Due to the lack of explicit change in the above conditions or any other information about intended discharge, the above delivery conditions have been taken in this thesis as the intended values for calculation of most performance indicators.

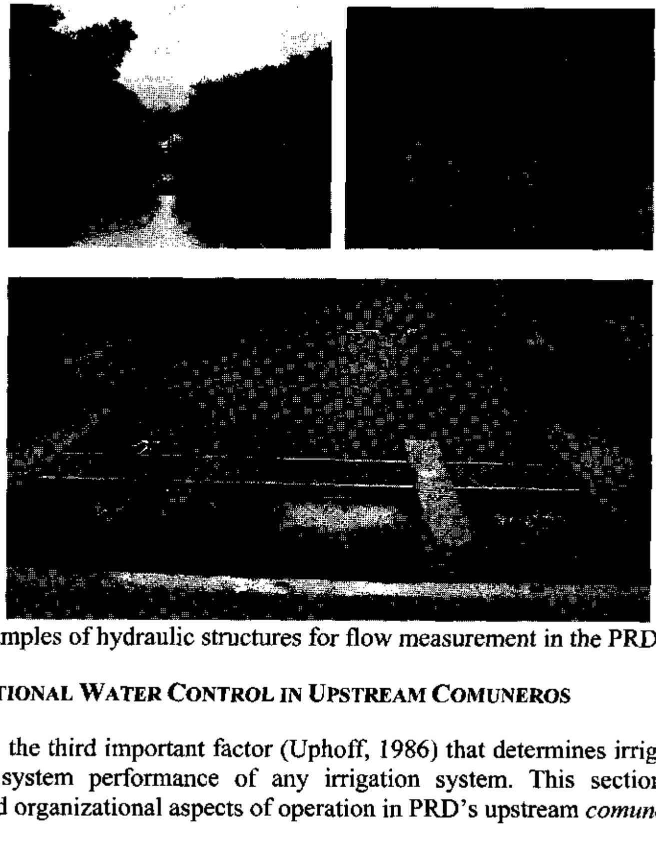

Figure 5.5 Examples of hydraulic structures for flow measurement in the PRD.

5.3 Organisational Water Control in Upstream Comuneros

Organization is the third important factor (Uphoff, 1986) that determines irrigation tasks and definitely the system performance of any irrigation system. This section analyzes the institutional and organizational aspects of operation in PRD's upstream *comuneros*.

Operations have been under the complete responsibility of the Provincial Agency, Unidad Ejecutora de Riego (UER) since 1992, as were under A&EE from 1968. Even in 1995-1998 when four Water User Associations took the responsibility for operation and maintenance downstream from secondary canals, technical decisions about daily water delivery and maintenance were dictated by Agency engineers.

The general organization of the UER includes a department of Operation and Maintenance which executes the daily operation of the systems and small or urgent maintenance works. They also have the responsibility to control private enterprises contracted for execution of the main maintenance work of the system during the shutdown period. Seven subunits of the

Agency are responsible for the system operation from the reservoir to the intake of tertiary units (Table 5.3) where farmers take responsibility for water distribution. Radio communication between these units and the headquarters in Santiago del Estero has been good since the beginning of A&EE operation, and from 1995 until now handheld radios were gradually incorporated, to achieve a 100% communication of *tomeros* with their district office or central units since 1999.

The Rio Hondo unit had the responsibility for reservoir management. Irrigation was the priority user of water stored at the reservoir at the time of its construction. However during the privatization of its hydraulic power station in 1995, a shared reservoir management strategy was established. Electricity production is now the priority use above a certain storage threshold, irrigation below it. The *Los Quiroga unit* is in charge of management of the diversion dam located 73 km downstream Rio Hondo. Both Rio Hondo and Los Quiroga units will be left out of the analysis since they are responsible to demands from downstream units.

Table 5.3 Main operational units of the PRD.

Office/district	Responsible of water diversion	
	From	**To**
Rio Hondo	Rio Hondo Reservoir	Los Quiroga Downstream
Los Quiroga	Los Quiroga	Matriz Canal 1st Matriz's spillway to the River
Darsena	Matriz Canal	Secondary canals: - Del Alto - Norte - La Cuarteada - Sud I - 2nd Matriz's spillway to the river - San Martin - Romanos - Municipal - Suri Pozo - Jume Esquina
Banda	El Alto Norte La Cuarteada Sud I Sud II Municipal A los Romanos	Tertiary canals and comuneros
San Martin	San Martin	Tertiary canals and comuneros
Fernandez	Suri Pozo	Tertiary canals and comuneros
Simbolar	Sec. Simbolar Rodeana	Tertiary canals and comuneros

For the study of performance at secondary canal level, La *Darsena office* is the key in system management. Its personnel controls water delivered from the Matriz canal to all the secondary canals (with the exceptions of Sud II and Simbolar secondary canals that take water from Jume Esquina, far away from Darsena office).

District offices are the administrative units of the UER, as they were for A&EE, dealing with water distribution from secondary and tertiary canals. They actually manage independent subsystems within the PRD. There are four district offices - Banda, San Martín, Fernandez and Simbolar – whose localization and area controlled seems to correspond more with historical rather than operative reasons. La Banda District covers operations in the old "La Cuarteada" system, San Martin District the old San Martin system, Fernandez District covers the system evolved from the old Fernandez private *acequia* (whose connection to the La Cuarteada system was highly resisted by farmers in 1926 and incorporated only many years later after construction of Los Quiroga delivery dam and Suri Pozo secondary canal). Simbolar District operates the late-developed sub-system of Colonia Simbolar.

The District offices operate completely independently of each other: the Darsena office and the Agency headquarters at Santiago del Estero keep control over the whole system.

5.4 Operational Features

Gated systems such as the PRD provide greater flexibility in operation than ungated ones, allowing management of systems under different delivery irrigation schedules (Murray-Rust and Snellen, 1993). However they have high staff requirements and they are dangerous in terms of operation and performance if sliding gates are mismanaged (Murray Rust and Snellen, 1993; Horst, 1998).

The probability of mismanagement is at least theoretically highly related with correct functioning of gates and staff skill, but also by the number of gates, extent of command area, distance to be covered by field staff and other practical factors as mobility and condition of roads. These issues were researched for each secondary canal (Table 5.4). For comparative purpose mean values were calculated for: number of diversions; length of canal; gross extension of the command area; number of water users; and the area with water rights controlled per *tomero* (gate keeper) (Table 5.5).

Table 5.4 Main characteristic of the secondary canals.

Canal	N° Tomero	N° Diversions	Command Area		Water righted area	
			N° plots	Ha	N° plots	Ha
Norte [(1)]	3	59	448	12529	258	6605
La Cuarteada [(1)]	7	84	940	31246	513	10038
Sud 1ª [(1)]	12	122	1592	34822	1317	13621
Sud 2da [(1)]	1	23	695	11231	602	5900
Romanos [(1)]	7	164	1045	23975	459	6649
Suri Pozo [(2)]	20	125	1705	83790	1293	21275
San Martín [(3)]	10	113	1988	54085	1487	14146
Sec. Simolar [(4)]	4	28	351	12547	293	7454
TOTAL	64	721	8854	273258	6256	86860

[(1)] Banda District; [(2)] Fernandez District; [(3)] San Martín District; [(4)] Simbolar District

The canals operated by Banda District appeared as comparatively less controlled than those in other districts in a comparative analysis within the PRD. However even the highest number of turnouts operated per *tomero* in the PRD is close to the lower limit of the range of values presented by Burt and Styles, (1999) for 16 irrigation projects from 10 developing countries.

The mean length of canal controlled per *tomero,* ranging from 4 to 14 km also seems not to be a real problem. *Tomeros* normally live close to the area they control, their mobility (motorcycles) is relative goodly and roads along canals are passable almost the whole year.

Table 5.5 Mean number of diversion, length of canals, number of users, gross and water righted area per *tomero* for each secondary canal

Canal	N° turnouts	Mean length of canals (km)	N° water users	Gross Area (ha)	Area Permanent Water Rights (ha)
Suri Pozo[(2)]	6	4	65	4190	1064
Sec. Simolar[(4)]	7	12	73	3145	1868
San Martin [(3)]	9	12	168	8476	1910
Sud 1a[(1)]	10	4	110	2902	1135
La Cuarteada[(1)]	12	10	73	4464	1434
Norte[(1)]	20	14	86	4176	2202
Sud 2da[(1)]	23	9	602	11231	5900
Romanos[(1)]	23	7	66	3425	950
PRD mean	**13**	**7**	**142**	**5671**	**1959**

[(1)] Banda District; [(2)] Fernandez District; [(3)] San Martín District; [(4)] Simbolar District

Figure 5.6 presents the mean number of days per month on which canal discharge changes. This topic is an indirect indicator of staff operation skill and/or operational procedures, since changes can be intended actions of the agency as part of the operational task or result of a mismanagement of the gates. Matriz canal is included in the table but it was not considered in the analysis because, being directly controlled by Los Quiroga delivery dam, those change cannot have any other cause beside operation actions by the agency.

According to staff interviews, the number of time gates are reset varies considerably across the year and from year to year, with changes more frequent during the summer (rainy) season and more stable during the winter (dry period) - but in average they estimate that it should not be more than 5 times per month in summer and 2-3 times in winter.

Figure 5.6.A shows that the frequency of change in secondary canals including those more upstream (Norte and La Cuarteada) is higher than the mean frequency stated by agency field staff. Discharge fluctuation increase to the canals taken water downstream the main canal (Los Romanos and Suri Pozo) a typical pattern of propagation of flow fluctuations originated by a hydraulic flexibility greater than 1 of the diversion structures when control and diversion gate are mismanaged. The monthly variation shown in Figure 5.6 B confirms the difference between the most upstream secondary canal (Norte) and the most downstream (Suri Pozo) and shows that there difference between summer and winter stated by field staff are unclear.

The research did not include the study of the water distribution from secondary to tertiary canals. However, given the same type of diversion structure along secondary canals and the same type of management, it is expected that a similar propagation pattern of flow fluctuations be present in secondary canals, and in them increasing discharge variation to the tail of the system. Data from Sud II and Simbolar secondary canals - that do not take water not from the Matriz Canal but from Jume Esquina (the canal that transfers water to the Salado River with its offtake at Barrera 4) - support partially the above statement since discharge fluctuations are lower and there is no clear trend between them.

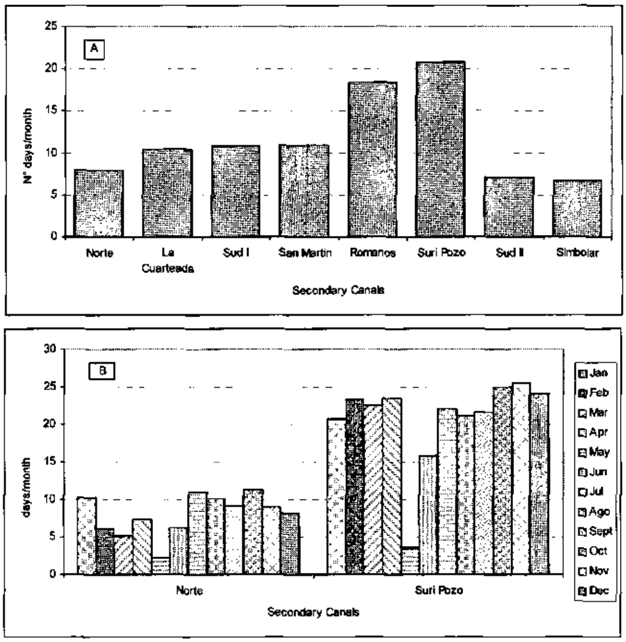

Figure 5.6 A) Mean number of days/month with change in secondary canal discharge B) Mean monthly pattern of the number of days/month discharge change in the first (Norte) and the last (Suri Pozo) secondary canals taking water from Matriz canal. (Based on daily discharge in the period January 1995 – December 2003)

In section 5.1.1 it was shown that the Water Delivery Capacity of most canals was far greater than that required to fulfil water requirements of the cropping pattern, cropping intensity and maximum area assigned by design. This was a result of the fact that the redesign under the productive irrigation paradigm was not finished after truncation of PRD intervention.

Figure 5.7 shows the actual daily Delivery Ratio (DR) of the canals with maximal (A los Romanos) and minimal (San Martín) Water Delivery Capacity (Figure 5.1). Table 5.6 summarizes DR information for the main and its eight studied secondary canals.

Table 5.6 Characteristics of the canal discharges

	Delivery Ratio		
Canal	**Mean**	**Max**	**75%** (1)
Main	0,26	0,63	0,41
Norte	0,18	0,74	0,28
La Cuarteada	0,29	0,92	0,49
Sud I	0,22	0,73	0,35
San Martin	0,36	0,94	0,58
A los Romanos	0,24	0,58	0,39
Suri Pozo	0,25	0,64	0,39
Sud II	0,19	0,44	0,31
Simbolar	0,29	0,72	0,44

(1) DR superseded 25% of the time.

Data confirms that most canals, especially old earthen ones, work far below their maximum capacity while the modernized canals (La Cuarteada and San Martín) work closer to it.

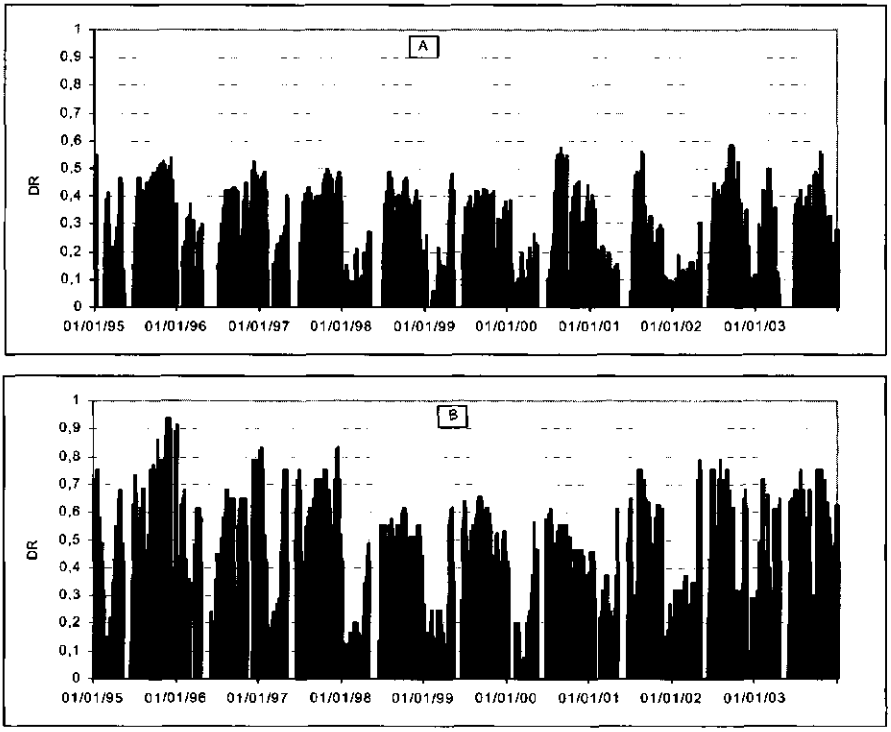

Figure 5.7 Daily Delivery Ratio of and old (A los Romanos) and a modernized (B-San Matín) secondary canals.

These annual values however hide the important monthly patterns along the year presented in Table 5.7 and drawn for the two typical patterns in Figure 5.8.

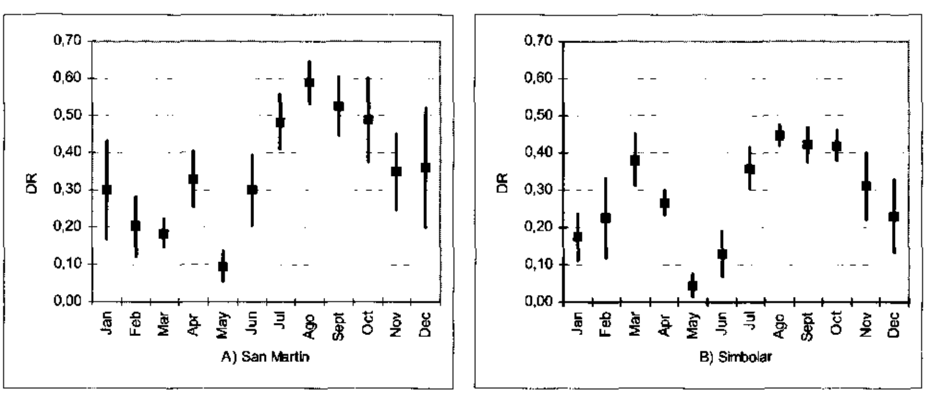

Figure 5.8 DR annual pattern of (with its 95% confidence interval) representative secondary canals of the PRD.

Leaving out analysis of May and June, when the system is normally shutdown for maintenance work, the annual patterns of most secondary canals' DR or discharges are similar. Water is heavily used from the end of winter (July-August) to the first two months of spring (September-October). Simbolar Secondary canal is the unique exception to this pattern with a second peak in the fall season. As will be analyzed in Chapters 6 to 9, these annual patterns are highly determined by cropping patterns, irrigation practice of users and in some extension by the rainy pattern in the area.

Another feature that should be noted from the Figure 5.8 is that the annual variability is low in the months of high water use (end of the dry season) and high in the summer season (the rainy season) that extends from November to March, suggesting a variable use of irrigation according to rainfall.

5.5 PERFORMANCE

5.5.1 Water Supply

According to historical registers of irrigation agencies, there has been a rather high variation of water delivered to PRD (Figure 5.9 and 5.10). There was a peak in the initial period, followed by a positive trend in last years of the 1980's under A&EE administration, reversing under UER administration when the amount delivery to the irrigation system has been lower and more stable. There is no clear explanation for this apparent improvement of water use, since staff and management practices were the same after transfer to the provincial agency. The most important changes in the last period with respect the former were the remarkable improvement of communication, and implementation of the rule to deliver water only to those who pay water fees (for the short period in 1999-2000 to mid 2001. However not evidence was find to relate any of them with less use of water,

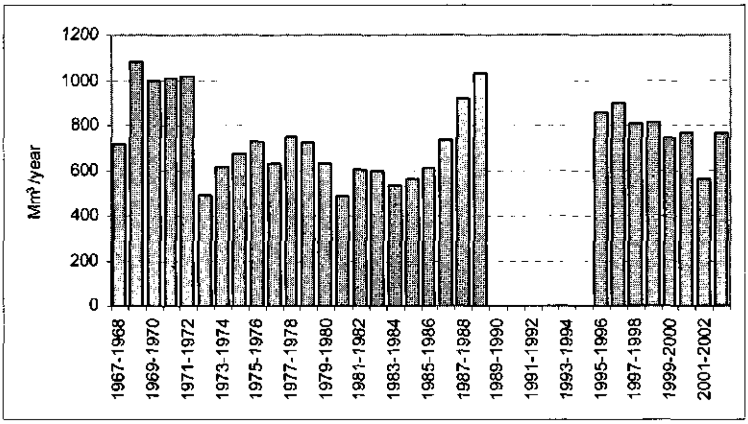

Figure 5.9 Annual water delivery to PRD DR annual pattern of (with its 95% confidence interval) representative secondary canals of the PRD. (Source A&EE and UER).

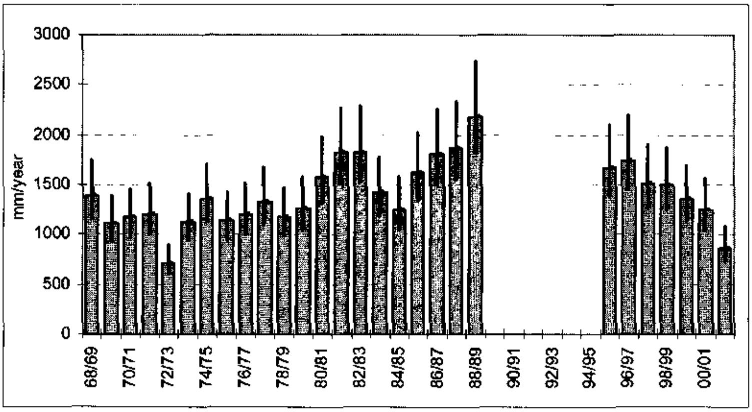

Figure 5.10 PRD Mean annual irrigation water use[5.5]

Figure 5.11 compares mean water use on the secondary canals for the 5 study years with the mean for the same period of the PRD. Canals are presented in the order they take water from the main canal, (Norte, La Cuarteada and Sud I share control structure 1 (CS1) in the Canal Matriz; CS-2 controls San Martín; CS-3 controls Romanos; and CS-4 Controls Suri Pozo and Jume Esquina. The last canal, whose main function is to delivers water to Rio Salado, feeds Sud II and Simbolar (both have control structures) the last two canals in the figure.

The classic pattern of less water at the tail of the system is present, confirming the mismanagement of sluice gates at diversion structures that also produce an amplification of discharge fluctuations to the tail of Matriz (see section 5.4). There are big differences between canals with La Cuarteada and Sud II highly differentiated from the rest, the first for its high value the last for its low one. However all values, including that for PRD, appear high - but this point will be more fully discussed in the next section.

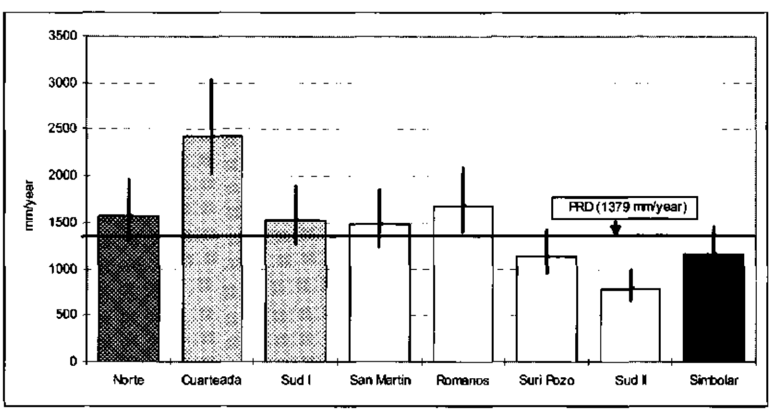

Figure 5.11 Comparison of water use between secondary canals.

[5.5] Due to the uncertainty on cropped area values, values were also calculated considering cropped areas ± 20% greater and 20% lower than reported.

Table 5.7 Annual Pattern of the Delivery Ratio

Canal		Jan	Feb	Mar	Apr	May	Jun	Jul	Ago	Sept	Oct	Nov	Dec
Matriz	**Mean**	**0,19**	**0,16**	**0,18**	**0,22**	**0,06**	**0,11**	**0,36**	**0,43**	**0,43**	**0,42**	**0,27**	**0,22**
	95% upper limit	0,27	0,23	0,22	0,27	0,09	0,16	0,38	0,46	0,48	0,48	0,36	0,31
	95% lower limit	0,12	0,09	0,13	0,17	0,03	0,07	0,34	0,41	0,39	0,37	0,19	0,13
Norte	**Mean**	**0,18**	**0,16**	**0,10**	**0,13**	**0,04**	**0,10**	**0,20**	**0,25**	**0,26**	**0,40**	**0,21**	**0,16**
	95% upper limit	0,24	0,24	0,14	0,18	0,05	0,14	0,24	0,28	0,31	0,48	0,31	0,25
	95% lower limit	0,13	0,08	0,05	0,08	0,03	0,05	0,18	0,23	0,21	0,33	0,11	0,09
La Cuarteada	**Mean**	**0,29**	**0,21**	**0,16**	**0,19**	**0,05**	**0,09**	**0,45**	**0,45**	**0,50**	**0,46**	**0,28**	**0,25**
	95% upper limit	0,38	0,35	0,24	0,25	0,08	0,15	0,51	0,51	0,60	0,55	0,36	0,36
	95% lower limit	0,20	0,08	0,09	0,11	0,03	0,03	0,38	0,39	0,41	0,39	0,18	0,14
Sud I	**Mean**	**0,15**	**0,18**	**0,14**	**0,20**	**0,03**	**0,06**	**0,29**	**0,37**	**0,40**	**0,38**	**0,21**	**0,17**
	95% upper limit	0,25	0,29	0,19	0,25	0,06	0,09	0,32	0,43	0,49	0,50	0,33	0,27
	95% lower limit	0,05	0,08	0,10	0,15	0,01	0,03	0,25	0,31	0,30	0,28	0,09	0,07
San Martin	**Mean**	**0,30**	**0,20**	**0,18**	**0,33**	**0,09**	**0,30**	**0,48**	**0,59**	**0,52**	**0,49**	**0,35**	**0,36**
	95% upper limit	0,43	0,28	0,22	0,40	0,13	0,39	0,56	0,65	0,60	0,60	0,45	0,52
	95% lower limit	0,17	0,12	0,15	0,25	0,05	0,20	0,41	0,53	0,45	0,38	0,25	0,20
Romanos	**Mean**	**0,17**	**0,14**	**0,17**	**0,17**	**0,04**	**0,05**	**0,34**	**0,41**	**0,37**	**0,37**	**0,27**	**0,25**
	95% upper limit	0,26	0,20	0,22	0,22	0,07	0,08	0,38	0,45	0,43	0,43	0,36	0,36
	95% lower limit	0,08	0,08	0,12	0,12	0,02	0,02	0,29	0,38	0,32	0,31	0,19	0,14
Suri Pozo	**Mean**	**0,17**	**0,12**	**0,14**	**0,21**	**0,04**	**0,13**	**0,34**	**0,42**	**0,43**	**0,40**	**0,26**	**0,23**
	95% upper limit	0,24	0,16	0,18	0,26	0,07	0,19	0,38	0,44	0,48	0,45	0,35	0,33
	95% lower limit	0,10	0,07	0,10	0,16	0,01	0,07	0,31	0,39	0,39	0,35	0,17	0,13
Sud II	**Mean**	**0,09**	**0,07**	**0,11**	**0,20**	**0,07**	**0,09**	**0,33**	**0,38**	**0,33**	**0,31**	**0,16**	**0,11**
	95% upper limit	0,13	0,11	0,20	0,31	0,11	0,13	0,40	0,49	0,42	0,44	0,22	0,20
	95% lower limit	0,02	0,02	0,04	0,11	0,02	0,04	0,24	0,29	0,22	0,20	0,07	0,02
Simbolar	**Mean**	**0,17**	**0,22**	**0,38**	**0,27**	**0,04**	**0,13**	**0,36**	**0,45**	**0,42**	**0,42**	**0,31**	**0,23**
	95% upper limit	0,24	0,33	0,45	0,30	0,07	0,19	0,41	0,47	0,47	0,46	0,40	0,33
	95% lower limit	0,11	0,12	0,31	0,23	0,01	0,07	0,30	0,42	0,37	0,38	0,22	0,13

Table 5.8 compares water use per ha of secondary canals with that of the PRD for the five years with reliable information. With some variation the same tendency is present in most years, with canals taking water from Jume Esquina always delivering less water than canals upstream. Contradictory to local belief, San Martín canal - considered highly constrained by capacity of the siphon that cross under the river - has higher water use than the project overall and is similar to most canals at the upper reach of Matriz.

Table 5.8 Relative values of secondary canals water use per hectare respect to the PRD.

	1995/996	1996/1997	1999/2000	2000/2001	2001/2002
Norte	1,00	2,01	1,09	1,15	1,12
Cuarteada	1,13	2,22	3,01	2,16	2,28
Sud I	1,15	1,09	1,96	1,16	0,84
San Martin	1,28	1,28	1,30	1,12	1,44
Romanos	1,80	1,39	1,16	1,29	1,28
Suri Pozo	1,02	1,03	0,85	0,99	1,04
Sud II	0,60	0,94	0,52	0,63	0,49
Simbolar	0,54	0,62	0,56	0,67	0,86

The Mean Annual RWS (after Levine 1982 - see section 1.5.3 and Appendix 1) of the whole system and secondary subsystems presented in Figure 5.12 confirms that the PRD is a well watered irrigation scheme despite the fact of being in a semiarid region, where water is the main constraint for agriculture production. Although there are some differences in calculations procedure (see Appendix 1), annual RWS values for PRD are similar to 2,2 and 2,07 reported for the Alto Rio Lerma irrigation project in Mexico and Seyhan project in Turkey respectively[5.6] by Molden et al., (1998).

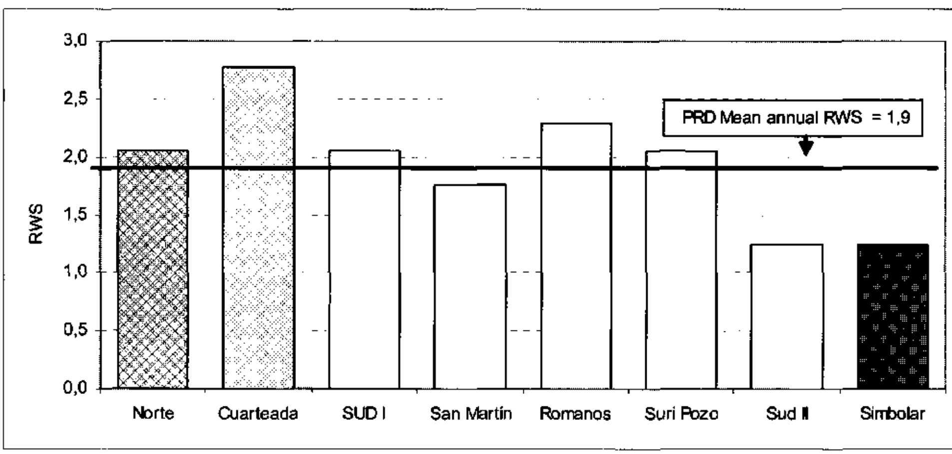

Figure 5.12 Mean annual RWS for the PRD and secondary canals.

The range from 1.2 to 2.8 confirms large in-system differences, with all six secondary canals taking water from Matriz being well supplied, and Sud II and Simbolar with low values that could suggest under-irrigation in some locations or periods in their serviced areas.

[5.6] Values reported by Molden et al., (1998) were for 1994-1995 in the case of Rio Lerma and 1996-1997 for Seyhan irrigation project. Burt and Styles, (1999) reported an annual RWS of 3,2 for the same Turkish project without mention of the year.

Considering only secondary canals fed directly by the Matriz canal (the first 6) there is no head-tail effect and except for San Martín all other 5 secondary have a mean annual RWS greater than the PRD. The low value of San Martín respect to other secondary canals would support the local belief that its water supply is the lowest due the siphon capacity. However that is only a relative assessment since its annual RWS is sufficiently high to assure a good water supply.Annual RWS for the analyzed five years presented in Table 5.9 reaffirms the high water supply in all sub-systems in most years but also a large inter-annual variability, a variability that has been shown in this thesis is a constant characteristic in all water supply aspects of the PRD.

Annual values of RWS for the PRD were calculated from 1968-1969 for all years with available and reliable information, in order to look at any trends and relate values of the researched period with the longer period (Figure 5.13). Coinciding with the administrative transfer from A&EE to UER there is a gap (due to lack of reliable information about cropping pattern) in the series, but also a shift in values with lower values in the last period. Therefore values for the study period should be considered as minimum values for PRD. The reason for this shift are unknown since operators, measuring places and even rating curves used were unchanged over both periods.

Table 5.9 Annual RWS for PRD and Secondary Canals.

	1995-1996	1996-1997	1999-2000	2000-2001	2001-2002
PRD	1,7	1,8	1,9	2,2	1,9
Norte	2,0	3,6	2,0	1,6	1,1
Cuarteada	2,3	3,6	4,4	2,1	1,4
SUD I	2,3	2,0	3,3	1,6	1,0
San Martín	2,2	2,0	2,0	1,4	1,2
Romanos	3,4	2,8	2,4	1,7	1,2
Suri Pozo	2,0	3,6	2,0	1,6	1,1
Sud II	1,3	1,7	1,2	1,2	0,8
Simbolar	1,5	1,1	1,4	1,2	1,0

Although no-one in the Agency used this information for operational purposes the more frequent gaps in the recent period (only 4 years are missing from the 24 years period of Ay EE, while only 5 are available for the 13 years of UER operation) denotes the different resources and data collection routines, but also a different interest in technical information for some years under the new agency.

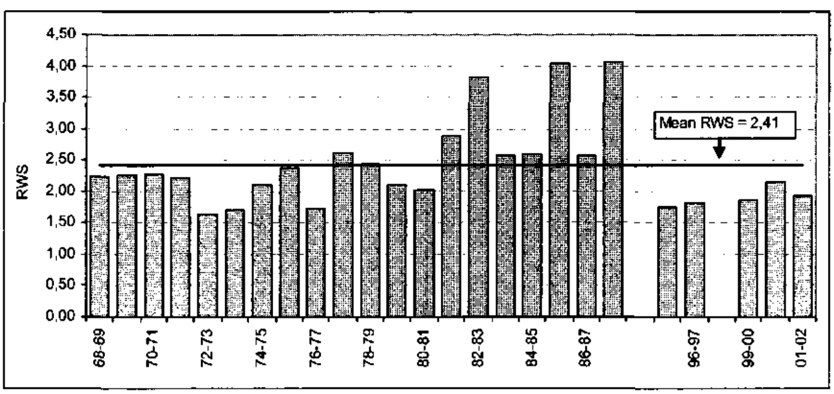

Figure 5.13 Evolution of RWS in PRD

5.5.2 Water Supply and Irrigation Adequacy – Annual Base.

Relative Irrigation Supply (RIS) (Perry, 1996) is a well known performance indicator that expresses how well delivered irrigation water covers irrigation requirements (see section 1.5.3 and Appendix 2).

Mean annual RIS for the 8 secondary canals is shown in Figure 5.14 and related with a mean value for the PRD. Data confirms the high use of irrigation water in relation to irrigation requirements, with a PRD mean annual value of 2,3 and five secondary canals over that value. The mean PRD value was slightly lower than the 3,3 reported by Molden *et al.*, (1998) for the Rio Lerma irrigation project with conjunctive use of surface and groundwater, but similar to the value of 2,15 reported for Syhan project in Turkey.

Again there are big differences between canals, with the two secondary canals (Sud II and Simbolar) that take water from Jume Esquina, always far below the other 6 fed directly by Matriz. Values range from 1,2 to 4,3 -and 5 canals (Norte, Sud I, Romanos and Suri Pozo) double and 1 (La Cuarteada) triples the lowest mean RIS of Sud II and Simbolar.

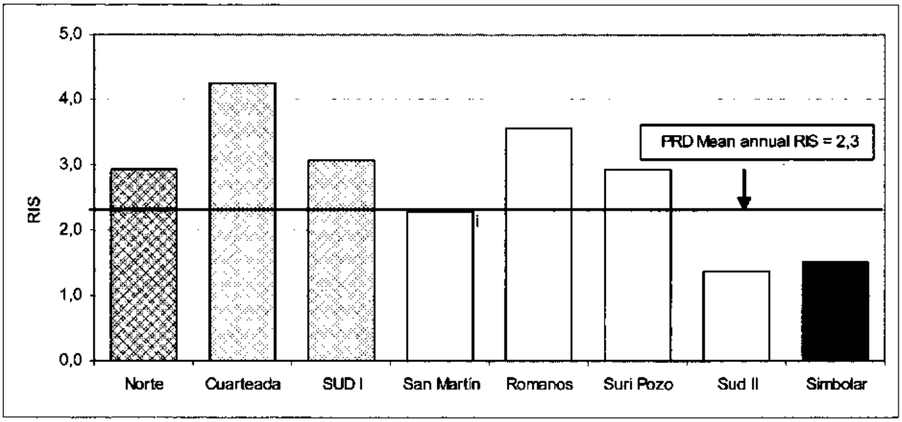

Figure 5.14 Mean annual RIS for secondary canals and PRD.

Again annual variability is the rule as can be seen from RIS annual values presented in Table 5.10.

Table 5.10 Annual RIS for secondary canals and PRD.

	1995-1996	1996-1997	1999-2000	2000-2001	2001-2002
PRD	1,5	1,7	2,1	3,9	3,1
Norte	2,6	5,3	2,8	2,6	1,3
Cuarteada	3,1	5,1	7,3	3,7	2,1
SUD I	3,2	2,7	5,7	2,8	1,0
San Martín	2,9	2,5	2,6	2,0	1,4
Romanos	5,1	4,1	3,9	3,1	1,7
Suri Pozo	2,6	5,3	2,8	2,6	1,3
Sud II	1,4	2,0	1,3	1,3	0,4
Simbolar	1,9	1,2	1,9	1,5	1,1

In the same way than for RWS, RIS annual values were calculated for the whole series of reliable information about discharge, cropping pattern and meteorological information (Figure 5.15). As in case of RWS, the lowest values of the series are in the studied period therefore also in this case value reported should be considered a minimum for the PRD. As mentioned in the RWS discussion, no relationship could be established between administration and results. However a point to be mentioned for future studies is that 1995-1996 and 1996-1997 were years with active participation of WAUs, in operation and maintenance of the system, but also a period of high expectation for agency officials and large farmers related to WAUs.

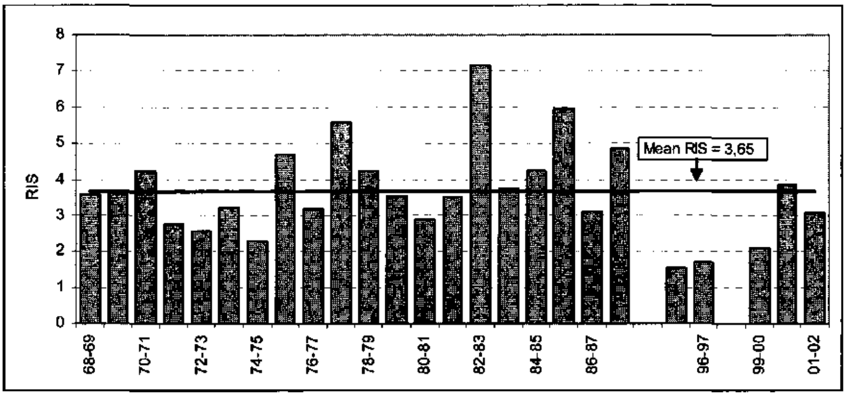

Figure 5.15 Evolution of RIS in PRD.

5.5.3 Water Supply and Irrigation Adequacy – Monthly Base.

Annual RWS and RIS values allow a good comparative analysis between the secondary canals, with the system as a whole, and with irrigation systems around the world with similar characteristics (Moden et al. 1998, Burt and Styles, 1999, Malano and Burton, 2001, Bos et al., 2005) and study of inter-annual variability. However they do not show the effect of irrigation practices that act at shorter time scales and could affect water distribution and water productivity.

Mean monthly RWS and RIS values were calculated with the objective to overcome this restriction of annual values, and research the effect of farmers' irrigation scheduling practices of concentrating use of water in few irrigation events discussed further in Chapters 6 to 9.

With different intensity, all secondary canal data of RWS mean monthly values (Figure 5.16 and Table 5.11) show an uneven distribution during the year, with very high water availability from July to October and a second and lower peak in autumn (March-April)[5.7] before the annual shutdown of the system.

[5.7] Some of the monthly mean RWS values look excessively high. The reason is that since in the calculations only one sowing date was considered for each crop, irrigation requirements concentrate more than in the real situation. The values should then be taken with caution. However they are still highly valid since consideration of different sowing dates would reduce peak values and increase those of the following or previous months, but still the values would be high.

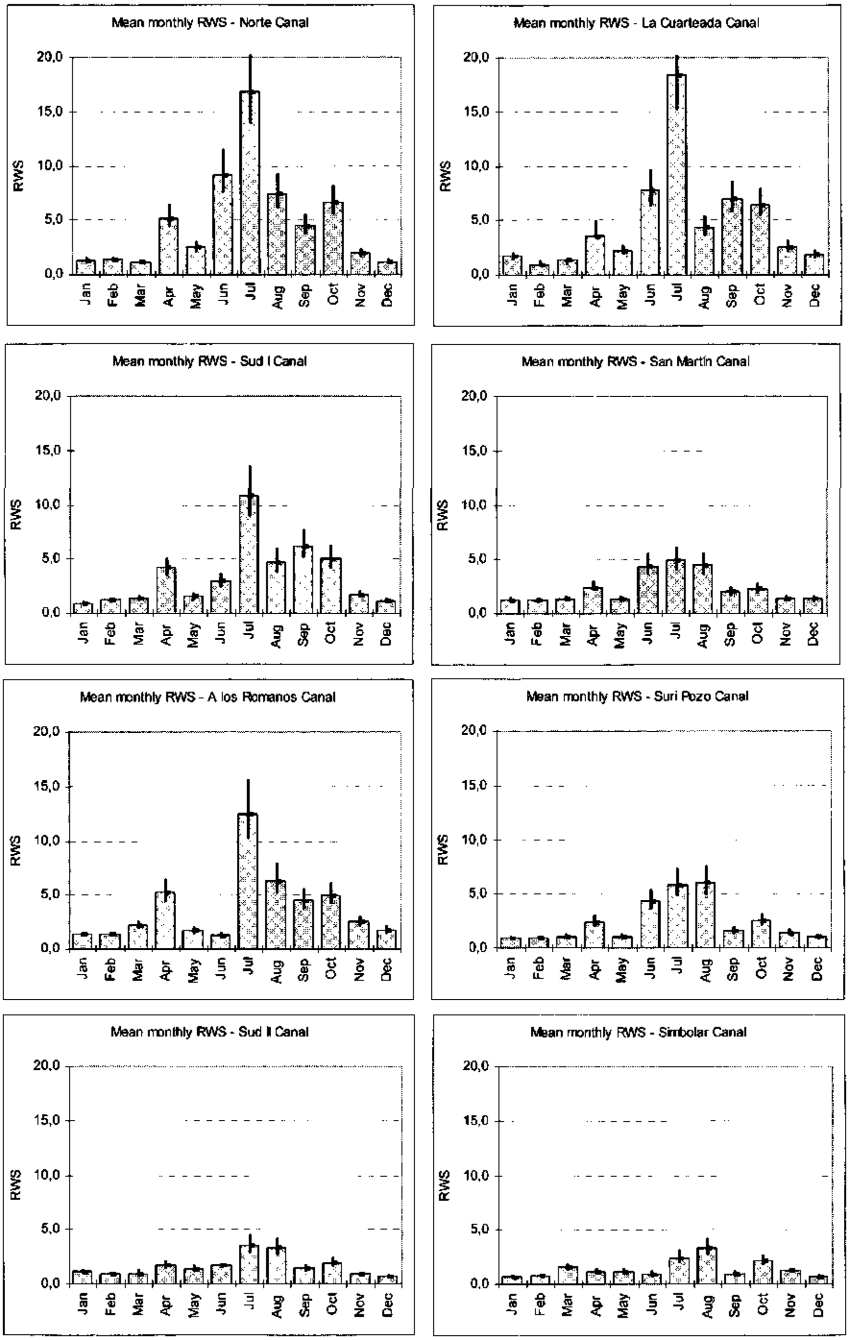

Figure 5.16 Mean monthly RWS for the secondary canals

This water use pattern was already observed in canal discharges (section 5.4) and will be seen in water use at tertiary level (Chapters 6 to 9). It denotes the strong influence of farmers' water management, and the responsive management of the system by the Irrigation Agency.

Table 5.11 Mean Monthly RWS for secondary canals (Period 1995-2002)

Sec. Canal	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Norte	1,3	1,3	1,2	5,2	2,5	9,2	16,8	7,4	4,4	6,6	2,0	1,2
Cuarteada	1,7	0,9	1,3	3,5	2,2	7,7	18,4	4,3	7,0	6,4	2,6	1,8
Sud I	0,9	1,3	1,4	4,2	1,6	3,0	10,8	4,7	6,2	5,0	1,7	1,1
San Martín	1,3	1,3	1,4	2,4	1,4	4,4	4,9	4,4	2,0	2,3	1,4	1,3
Romanos	1,3	1,4	2,2	5,2	1,7	1,3	12,4	6,3	4,4	4,9	2,5	1,7
Suri Pozo	0,9	0,9	1,1	2,4	1,0	4,3	5,9	6,1	1,6	2,5	1,4	1,0
Sud II	1,1	0,9	0,9	1,7	1,4	1,7	3,5	3,3	1,4	2,0	0,9	0,7
Simbolar	0,7	0,8	1,6	1,2	1,2	0,9	2,4	3,3	0,9	2,2	1,2	0,7

But not only high values are important to characterize the outputs of irrigation practices in PRD. Other characteristic features of the "traditional" water management that could affect water productivity are shown by monthly RWS figures. These values, which are close to and lower than 1 in some rainy-summer season months, indicate under-supply of water despite the high values in other months when pre-seeding irrigation is concentrated. This point is even clearer using RIS (see below).

In effect mean monthly RIS (Figure 5.17 and Table 5.12) show more clearly the concentration of irrigation water with very high values from July to October in the dry season. This is the product of farmers' practices of accumulating water in the soil profile at the beginning of the growing cycle of most crops, by applying a heavy pre-seeding irrigation as in time of non-regulated river flows. At the same time - considering that this information refers to adequacy of water delivery at the head of secondary canals, without considering losses from this level to farms - the very low monthly RIS in rainy months (November-February) indicate clearly that irrigation requirements in those months are not fully covered[5,8].

Table 5.12 Mean monthly RIS for secondary canals in PRD.

Sec. Canal	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Norte	1,8	1,9	3,1	12,8	6,1	10,4	17,0	8,1	7,5	13,9	4,1	1,2
Cuarteada	2,8	1,5	3,8	6,5	4,4	4,9	20,0	4,3	11,0	12,3	4,3	2,3
Sud I	0,8	1,9	2,7	7,3	2,8	3,2	12,3	4,8	8,2	8,3	2,7	1,4
San Martín	1,7	1,8	5,6	3,7	1,7	4,8	5,0	4,5	2,6	2,6	2,0	1,4
Romanos	2,0	2,4	6,1	9,3	2,9	1,1	13,2	6,4	5,3	7,6	6,8	1,9
Suri Pozo	1,3	0,8	2,0	4,7	1,6	4,7	5,9	6,1	1,8	3,2	2,2	0,9
Sud II	1,6	0,7	2,0	2,2	2,1	1,8	3,6	3,3	1,8	2,4	0,7	0,4
Simbolar	0,5	0,5	2,9	1,7	4,2	1,1	2,4	3,3	1,0	3,7	2,6	0,5

The above analysis of water supply and water adequacy define clearly the situation of PRD, from a water point of view as *a wet system in a dry area where crops suffer water stress.*

[5,8] Cropwat does not allow accounting for water use from the shallow water table, which could be a possibility in summer months (see Section 10.3). However direct observation of field crops allowed me to state that if that happens it is would not be enough for covering full water requirements in most years

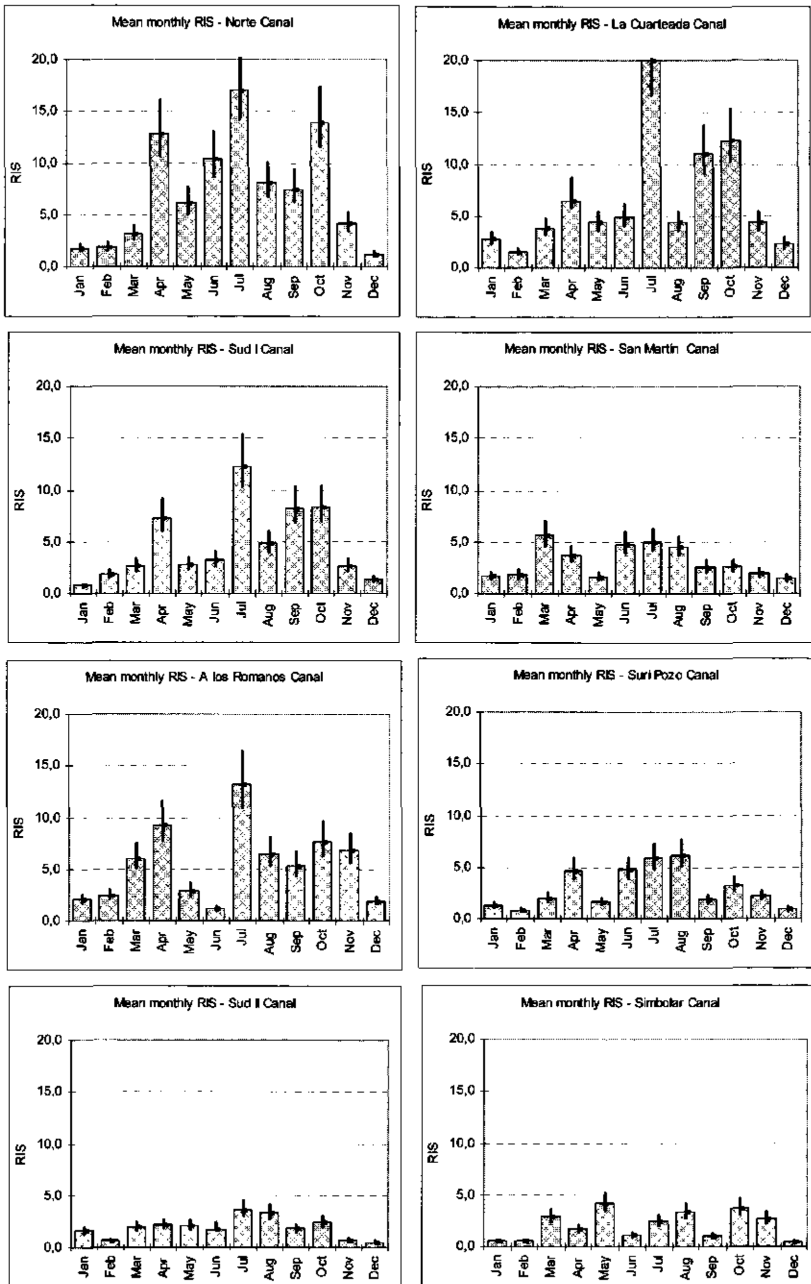

Figure 5.17 Mean monthly RIS for PRD's secondary canals.

5.6 Conclusions

Different types of canals, division structures and water measurement structures co-exist in the physical layout for water control. These are the product of the different irrigation concepts behind the two main modernization interventions - truncation of the most recent one and application of different design criteria during the PRD intervention

From the operational point of view the following should be highlighted: the large Water Delivery Capacity of most canals, with San Martin as a unique exception; the predominance of gated diversion structures with cross regulators; hydraulic flexibility greater than one due the lower operational hydraulic charge of the off-take structures; and use of on/off gates at low levels of the system.

Many of the features required for a responsive "modern" management of irrigation systems describe by Plusquellec, (2002) are present. Seven sub-units of the agency operate the systems, 3 of them in charge of the head of the system and 4 district office operating downstream secondary canals, as completely independent units. Communications among the operation units and even of field staff is excellent. Conditions for turnouts operations also are very good, operators live in the area they control, the number of turnouts they have to operate is low, they do not have in general mobility problems and accessibility of turnouts is good even in the rainy season.

In fact monthly pattern of canals discharges indicate that water delivery schedule has moved away from the official fixed rotational full supply water delivery schedule to tertiary and farm units, and seems to be responsive to water demand dictated by cropping patterns and irrigation practices of the users.

This assessment of system performance indicate that

- PRD is a well supplied with irrigation water on an annual basis (mean annual RWS for the studied period = 1,9; historical mean annual RWS = 2,4).

- There are important differences between command areas of the 8 main secondary canals (mean annual RWS range from 1,2 to 2,8). The two canals (Sud II and Simbolar) fed indirectly through Jume Esquina show the lowest values. There is no "tail" effect among the 6 secondary that take water directly from Matriz canals but La Cuarteada -one of the canals delivering water at the first control structure - are more highly watered than the rest.

- There are also important inter-annual variations, but spatial difference are similar to the above in all years.

- Despite all differences, water supply is high in the 6 first secondary canals and still high enough in the two with lower values.

- Water supply in terms of irrigation adequacy is also high in annual terms (mean annual RIS for the studied period 2,3, historical mean annual RIS = 3,7).

- Differences between canals and inter-annual variation are larger than in terms of water supply for the two canals fed by Jume Esquina and also far below the other 6 that take water from Matriz.

- A joint analysis of annual water supply and adequacy reveals that although there is no well planned and executed water delivery operation (as evident from the high spatial and temporal variability of discharges and supply), PRD could be characterized as ***"a wet irrigation system in a dry area".***

- Analysis of water supply and adequacy on a monthly basis complements the above information and show an uneven distribution of water use during the year.

- Mainly affected by the irrigation water management of its customers and the responsive behaviour of the irrigation agency, there is a high concentration of irrigation use and therefore of water supply to the field months of the dry season - a product of the heavy pre-seeding of summer crops that account for almost 70% of the cropped area. There is a second, smaller water use peak in autumn when pre-seeding of winter crops takes places.

- Both monthly water supply (RWS) and irrigation adequacy (RIS) shows low values in summer-rainy months indicating under-irrigation in these months in many years in all areas. This allows me to extend my PRD characterization as **"a wet system in a dry area with dry crops in the wet season".**

Further reasons and details for this system performance are presented in the ensuing four chapters that document irrigation in different tertiary canals shaped by the different modernization interventions of the PRD.

Chapter 6

JS TERTIARY UNIT: MODERN HYDRAULIC CONTROL AND OLD SMALL FARMER IRRIGATION PRACTICES

JS is a 'modern' rotational unit, organized around the TTC tertiary canal serving seven *comuneros,* located in the command area of the historic La Cuarteada canal but now belonging to the modernized section of the 'new' *La Cuarteada* secondary canal. This unit was selected for study as representative of the modern tertiary units developed during the initial phase of truncated PRD intervention (1968-1973) and because of its homogenous agrarian structure of smallholder farmers.

From a physical infrastructure perspective, nothing seems left out of the modernization package of those days. A typical PRD diversion structure of gated control and offtake structures diverts water flow to a soil-cement lined tertiary canal (TTC). This has a long throat flume at its head for measuring water, and four control structures (sliding gates). These act in conjunction with gated offtakes on the 7 *comuneros* canals (5 sluices, two on/off) to offer a high possibility to control water flow into each of the comuneros which are also soil-cement lined, have their own long throat flumes at the head, and on/off structure at every farm to ensure diversion of intended discharges. The physical infrastructure for water management is completed by a dense network of drainage canals that converge in the area on the way to their disposal area, the Huyamampa saline, 20 km west of the studied area.

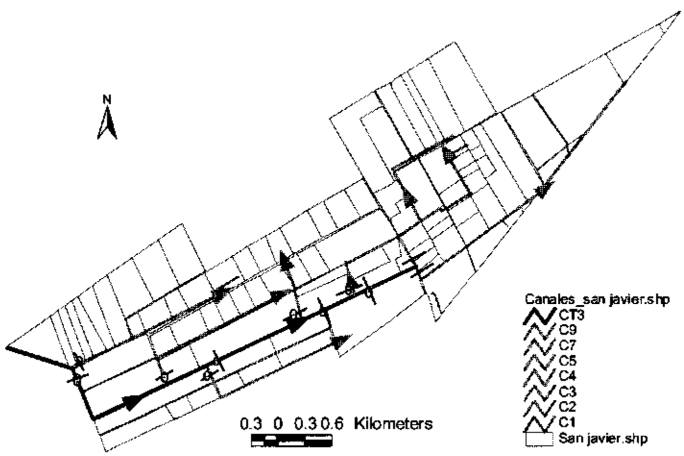

Figure 6.1 Layout of the irrigation network in JS tertiary unit

Responding to modern design criteria adopted during PRD intervention, the *comuneros* in JS are short in length, their command areas are small and number of holdings (and thus farmers) are low (Table 6.1).

Table 6.1 Main characteristics of comuneros in JS

	Command Area (ha)			
Comunero/Tertiary	**Gross**	**Net**	**Length (m)**	**N° Holdings**
C1	173	99	2130	14
C3	80	66	1840	9
C2	115	83	1760	7
C5	64	55	710	8
C7	70	64	410	6
C4	211	195	3290	14
C9	203	150	3420	25
TTC	916	711	5290	**83**

In summary, it shows the positivist technocratic approach. The modern infrastructure given to JS, would combine with a modern system of operation guaranteed by a professional national agency A&EE. This would link with a modern on-farm irrigation package built for small farmers groups and their on-farm support that would be implemented by the autarkic provincial CRD. Together they would yield the sustainable modernization of irrigation and promote a high level of development for the area and region.

6.1. Agrarian Structure and Irrigation Water Allocation

6.1.1. The Official World

According to official records (INTA-UER data base, 1998) for the SJ tertiary unit, the average holding size is 9 ha, and their size distribution is fairly homogeneous (Table 6.2). Ninety seven percent of holdings are smaller than 25 ha, indicating that most of them would have been re-settled as part of the land consolidation and resettlement component of PRD intervention if it had not been truncated in 1973.

Table 6.2 Holding size distribution in JS tertiary unit (Source INTA-UER data base, 1998).

	Holdings		Gross Area		Water Righted Areas			
Holding size (ha)	**N°**	**%**	**ha**	**%**	**Ha**	**%(1)**	**%WR(2)**	**Mean**
Without Water Rights	7	8	82	8	0	0		12
<5	28	34	114	13	83	12	72	3
5 to10	32	39	292	32	205	29	70	6
10 to 25	20	24	337	37	280	39	83	14
25 to 50	2	2	85	9	57	8	67	29
50 to 100	1	1	86	9	86	12	100	86
Total	**90**	**100**	**914**	**100**	**711**	**100**	**79**	**28 (9)(3)**

(1)% of the total water righted area (2) % of the gross area of the class (3) Weighted mean by the number in each class.

The PRD's typical mosaic pattern of irrigated and non-irrigated areas created by the long contested processes of water allocation is, however, present in this historical yet modernized tertiary unit, although more weakly expressed than in other areas of the PRD. There are fifteen holdings and their owners excluded from water rights; of these, 8 never had water rights - although they are within the command area of the tertiary canal and clearly lie within the domain of existing water courses. They are thus neither included in Table 6.2, nor in official maps of the command area of the tertiary unit. The remaining 7 holdings do not have permanent water rights but are registered with the Agency, which indicates they have been irrigated in some periods. The reasons for this could not be properly elucidated during this field research.

Within the group of water-righted holdings, the area with water rights in each class-size ranges from 67 to 100% of the gross area. The water-righted mean area for the whole tertiary unit is 79%, considerably higher than the average across the PRD of 45%. There is only one holding greater than 50 ha which has 100% of its area with water rights: this illustrates the application of the prior appropriation principle during the PRD intervention.

Figure 6.2 shows the spatial distribution of holdings according to their water right and size. Despite a group of holdings of similar dimensions along both sides of the main internal road in the northwest of the unit, there is no regular layout pattern, and holdings of different size are present in all *comuneros*.

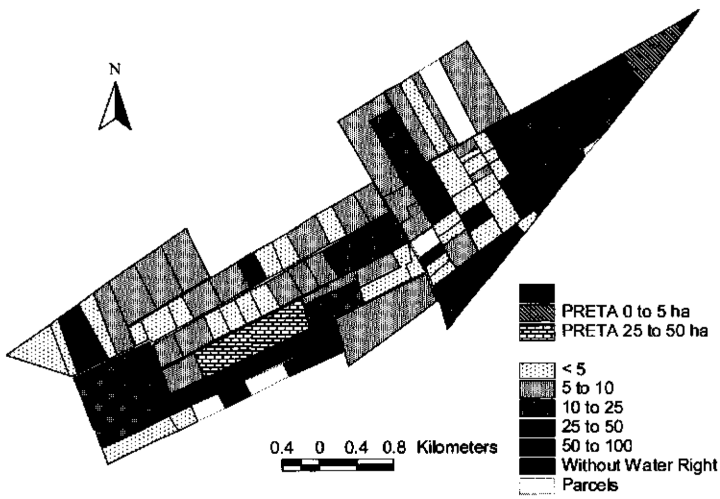

Figure 6.2 Map of holdings and their percentage area with water-rights

Note that the largest holding (86 ha) is at the tail and thus the first user of *communero* (C) 4 of the TTC, is also almost at the tail of the tertiary unit - indicating the old agrarian structure pattern in the times of private *acequias* and water patronage. Holdings without water rights are evenly distributed within the command area and surrounded by water-righted parcels. Thus physical constraints such as topographic or soil unsuitability can be excluded from reasons for not allocating water to them.

6.1.2 The Real World

Field work in this area (1998-2000) showed that actual agrarian structure was different from official information, changing water allocation distribution in various ways. While only 14 holdings were reported as abandoned in official documents there were actually 27 abandoned plots. The 49 active holdings were being cropped by only 37 farmers - half of the number expected from official records. Five farmers were cultivating more than one holding through leasing, or simple occupation of abandoned holdings. In contrast, one of the two old holdings in the 25-50 ha range had been divided in three plots now cropped as independent units by the 3 heirs of its original owner. Thus based on this information the updated agrarian structure of JS in 1998 is presented in Table 6.3.

Table 6.3 Actual agrarian structure in the JS in 1998 (Field survey, 1998).

	Farmers		Gross Area		Water Righted Area		Cropped Area	
Parcel size (ha)	**N°**	**%**	**ha**	**%**	**Ha**	**%(1)**	**ha**	**%(2)**
0 to 5	12	32	124	17	73	15	40,5	9
5 to10	11	30	128	18	114	23	67,75	16
10 to 25	9	24	173	24	111	22	111,5	26
25 to 50	4	11	223	31	150	30	138	32
50 to 100	1	3	71	10	50	10	72	17
Total	**37**	**100**	**718**	**100**	**501**	**100**	**430**	**100**

(1)% of the total water righted area (2) % of the total cropped area

The increased number of abandoned holdings, and lands leased where cultivation had also ceased indicate a great retrenchment in farming activities in the area. Reasons for this include the low income (low product prices, small area, low productivity) of this type of farmers in the last 20 years, highly aggravated in the last ten years by neo-liberal macro-economic policies. The data also show a process of land and irrigation water concentration in this area. Although this has been commented on as a general process in the PRD and the country as a whole, the actors in this case are local successful farmers advancing over abandoned farms with permanent water rights[6.1]. They are not using PRETAs to incorporate new areas, and they still remain within the category of smallholder farmers, and the cropped area is still 20% less than their water righted area.

6.1.3 Production Systems and Cropping Patterns

According to the survey of production systems, most are MAA to Radrizzani's typology (see Chapter 4) The dynamic between those holdings increasing in size, rather than continuing to crop similar areas or where agriculture is abandoned, seems related more with initial availability of land and amount of family labour, rather than crop choice. However, but a detailed analysis of this dynamic is beyond the scope of this thesis

The cropping patterns for JS over the 6 years studied are shown in Table 6.4. Data confirms the prominence of alfalfa and cotton as the main crops of the production systems. The data shows clearly the effect of the national economic crisis and the recovery of agriculture from 1999/2000 in both crop choice and variation in cropped area.

Table 6.4 Cropping patterns in JS

	Agricultural year					
Crops	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	**01-02**
Alfalfa	60	60	101	113	118	126
Cotton	190	196	266	103	220	402
Maize	9	5	29	40	22	2
Water Melon	6	7	10		7	4
Nat. Pasture	6	4	14		14	
Melon	2	2	2			
Others	4	1	9		6	3
	276	**275**	**431**	**256**	**386**	**537**

Source: 96-97 to 99-00 own interviews, 00-01 and 01-02 UER

[6.1] Actually there were 3 PRETAs in JS in 1998 for 5, 11 and 22 has. The last two were used to crop in one 40 has parcel located in the center of the area that had no permanent water right (see Figure 6.2)

6.2 Institutional Arrangements and Operation of Water Distribution

6.2.1 Institutions and Organizations

Water management is formally organized, following the official structure - this means that water distribution in the tertiary canals is done by the *tomero* while SARCCs assume responsibility at *comuneros* level. However since the last years of the A&EE administration (more than 15 years ago), farmers have had to assume maintenance of the tertiary canal[6.2].

To say that SARCC exist for all *comuneros* does not mean that they are organized according to official regulations. Each comunero has its *administrador*, most has been in that position for many years as it can be seen from Table 6.5, A *vice-administrador* and treasurer have been officially appointed in all *comuneros* but these positions are not operational - to the extent that only 46% of farmers in JS remembered who was their *vice-adminstrador*, (with a maximum of 56% in C1 and a minimum of 0% in C2). On average, only 13% of farmers could remember the name of the treasurer of their SARCC (46% in C4 and 0% in C2 and C5).

Table 6.5 Duration of tenure as Administrador in JS's comuneros

Comunero	Administrator	Years in charge
C1	SO	20
C2	YR	11
C3	GE	9
C4	AF	21
C5	GE	9
C7	GE	9
C9	TJ	9
Mean time		13

Source: Field interviews 1998 and 2000

According to interviews, a *celador* has never been appointed in any of the *comuneros* and almost all users (98%) agree this was not required, due the low number of users per *comunero* and the long time they have been working together. (The farmer with the minimum time as a water user in JS (10 years) is actually the son of a former user).

The *administradores* allow a 'soft' control of water distribution, especially in the most recent years - water is being delivered to farms until finished, as in the times of the original La Cuarteada irrigation system. They also have few administrative duties because individual

[6.2] It should be noted that, based on that fact that farmers were maintaining the tertiary canal between 1991 to 1993 a larger WUA was organized that joined together the 7 pre-existing small SARCCs that took responsibility in late 1993 over operation of the tertiary canal. There was one Administrator with a Board made up from the former SARCCs administrators. It was part of a joint INTA-A&EE project that, under my responsibility, had the objective to organize a hierarchical Federation of WUAs that would take control of water management at secondary levels. Changes of A&EE's policy to a top-down approach in 1995 left this project without enough political support to continue. However, the WUA already organized in JS continued working for some years, before the old SARCCs re-assumed control of *comuneros* in JS in 1998 when system operation was re-centralized by the provincial government. Although this young participatively organized WUA was not sustainable in such an unfavorable context, the effort done in those times had other positive results in terms of collective action. A self-organized group of farmers in JS managed to get an extension of electricity and drinking water networks to their area, sharing the costs in the case of tap water by assuming pipe installation by themselves.

registers of irrigation turns (*boletas de riego*) have not been demanded for this area - either for the whole area under Banda District control[6.3] since 1995. The tasks of the *administradores* seemed restricted to checking that users were clear when water would be delivered to them during irrigation turns, and the annual organization of collective maintenance work. In spite of this, two thirds of the water users think that the *administrador* should be a paid position, because it is sometimes a time consuming task. Half of them declared that they would not accept to be appointed *administrador* of their *comunero* for the same reason. The election of *administradores* in JS seems poorly related to prosperity or farm size: with only one exception *administradores* are not the most prosperous and influential farmers of their *comuneros*. Other personal characteristics, such as leadership and friendliness, together with functional aspects such as local residence and availability of time, seem to play major roles in their selection.[6.4].

6.2.2 Collective Action – Maintenance

As mentioned, one of the main activities of the *administrador* is to organize maintenance of *comuneros* and the tertiary canal. The work is done by *reparto*, the preferred method of all JS's users (structured interviews 1998) in which each farmer has to maintain an assigned reach of *comunero* and TTC's banks proportional to their water-righted area. For maintenance of the *comuneros,* their length is directly divided among all users: for the tertiary, users only participate in the maintenance of the section of TTC canal upstream of the off-take of their *comunero*. Table 6.6 shows length to be maintained based on total water righted area (TWRA) and actual cropped area in the 1998-1999 season. The reduction of irrigated area and number of farmers has increased the work required from active farmers by two to three times in some cases.

Table 6.6 Length (m/ha) of canals banks assigned for maintenance to each user based on their location in TTC canal network, water righted areas and cropped areas.

	Length (m/ha) based on Total Water Right Area		Length (m/ha) based on Actual Cropped Area	
	In Comunero	Total	In Comunero	Total
C1	21,5	22,5	29	30,5
C3	28,0	31,6	77	82,6
C2	21,0	25,7	25	32,2
C5	12,0	19,8	22	33,7
C7	6,5	14,9	8	22,3
C4	16,9	26,2	29	44,7
C9	22,8	32,2	56	71,6

Source UER-INTA data base 1998, Interviews 1998 and 2000

Maintenance is normally done twice a year: one event is compulsory during the shutdown period of the whole system (May-June), while a second is normally required in summer due

[6.3] This seriously complicated my research on individual use of water – see section 5.3.1 and 5.4 – since *tomero* and administradores should be asked to register that information. Reliable information at *comunero* level was only available for 1998-1999 year; that is why this is the period is highly analyzed in this chapter.

[6.4] The weight users give to functional aspects was clear during the short work period of the enlarged SARCC for the whole TTC. As meetings at La Banda district office were very frequent in that period, JS's users appointed as *administrador* of that SARCC the owner of the largest farm, who was a part-time farmer without any position in former SARCCs. The pragmatic reason of that election was that, having a part-time job in Santiago del Estero, he could assure them of a better participation in the SARCC in those meetings than other candidates.

to strong growth of weeds. The *tomero* has powers to postpone water delivery to the TTC and/or to some *comuneros* if he judges they are not in acceptable condition.

Organization of maintenance works is the main purpose of SARCC meetings, whose main topics are to reach consensus about dates for the work and type of work to be done. Discussions about the type of work, whether just cutting weeds from the top of the banks or also including external sides of banks and inspections road are frequent during meetings. However, despite the long experience of most users, their work has been restricted to cleaning canals, and never extended to lining repairs or replacement of deteriorating gates, which are considered Agency tasks. This more pragmatic focus seems related with users' scarce availability of resources, as the marked deterioration of JS infrastructure is clear despite this active participation of involved users in canal maintenance (Figure 6.3). As can be seen from the figure, original sluice gates, where functioning at all, are operating as on/off gates.

Figure 6.3 General views of deteriorated infrastructure in JS tertiary unit.

6.3. Irrigation Practices at Comunero Level

6.3.1. Delivery Order

Distribution of water within *comuneros* is under the responsibility of SARCC, but in practice in most of TT3-*Comuneros* it is done by the farmers with minimum intervention of the *administrador*. Lack of individual records in this area precluded detailed field research on this topic. However according to farmers interviews the officially determined order starting with the tail end users is followed in all turns of all *comuneros*, and changed only in a few cases.

6.3.2. Irrigation turns

Table 6.7 shows that the number of irrigation turns used by different JS's comuneros was far below the 11 available under the official delivery schedule. This number of irrigation turns (5 in C5 to 7 in C1, C4 and C9) is greatly determined by farmer irrigation practices. It gives a first and general overview of underutilization of irrigation opportunities offered by the modern system by farmers at JS.

Table 6.7 N° of turns/year in JS tertiary unit in 1998-1999 growing year

		Turn number						
	N°Turns	1	2	3	4	5	6	7
C1	7	Aug	Sept	Oct	Nov	Jan	Apr	May
C3	6	Aug	Sept	Oct		Jan	Apr	May
C2	6	Aug	Sept	Oct		Jan	Apr	May
C5	5	Aug	Sept	Oct		Jan		May
C7	6	Aug	Sept	Oct		Jan	Apr	May
C4	7	Aug	Sept	Oct	Nov	Jan	Apr	May
C9	7	Aug	Sept	Oct	Nov	Jan	Apr	May

6.3.3 Delivery Frequency

Delivery frequency between consecutive turns was rather variable in the season analyzed: it was normally greater than the official 28 days with intervals as large as 40 days, for example as between September and October turns in *comuneros* C4 and C9 (Table 6.8). Most farmers did not complain, and the structured interviews indicated that 96% of active farmers considered the fixing of water delivery date to be a decision of agency officials based on system management that hardly can be influenced by any *administrador's* request.

Table 6.8 Interval (days) between consecutive irrigation turns. Agricultural year 1998-1999

Interval		*Comuneros* [(1)]						
From	To	C1	C3	C2	C5	C7	C4	C9
Aug	Sept	20				29	31	32
Sept	Oct	33				23	29	31
Oct	Nov	34					41	40
Apr	May	32		30		26	27	27
Mean[(2)]		**30**				**26**	**32**	**33**

[(1)] Comuneros are presented in the order they take water from the Tertiary canal
[(2)]Due the small sample size it is included only for reference

However another reason for this low concern about irrigation frequency by users seems to be their different way of assessing frequency of irrigation turns. Field interviews and informal discussions suggested that the users in JS measured irrigation frequency in terms of months rather than days. In this sense the rule for them is that irrigation water should be available each month: thus if water is available monthly deliveries fulfil their expectations.

6.3.4 Delivery Duration

By design, JS is a rotational unit with a permanent water righted area of 711 has and a total water righted area in 1998-99 of 749 ha (711 + 38 ha of PRETAs). Its irrigation roster could be completed in 26 days (624 hrs) with the official delivery time of 50 min/ha, ranging in maximum delivery duration for *comuneros* from 46 hours for C5 to 163 hours for C4.

Table 6.9 compares actual delivery times for the agricultural year 1998-1999, compared with maximum annual delivery times, based on: (i) Total Water Righted area (TWRA), independent of whether land is being cultivated or not. (This represents time assigned by design and the maximum time that should by accepted by the agency in formal terms); (ii) Water Rights of only Active Plots (WRAP); and (iii) Actual Cropping Area (ACA) (which would be the maximum time assigned by a modern real time system operation). By comparing actual and required times, the *comunero* Time Delivery Ratio (C-TDR) can be calculated.

Annual Time Delivery Ratio for TTC was only 35%, 55% and 58% of maximum times calculated based on TWRA, WRAP and ACA respectively confirming the strong underutilization of irrigation facilities in JS on an annual basis.

For a more detailed analysis, Figure 6.4 disaggregates annual values per turn: this leads to a better understanding of irrigation practices by describing their seasonal pattern[6.5]. It shows an uneven use of irrigation across the year and confirms its concentration in late winter and initial spring months, as already seen at secondary canal level. Regarding water delivery duration it is clear that in spite of the lower cropped area and low annual C-TDR, in TTC the delivery times exceeded the maximum duration based on WRAP and CA in two months (August and October). Also, it was almost equal to maximum time according to TWRA in August, although the cropped area was never more than 60% of the total water righted area.

Table 6.9 Annual turns and annual delivery times to JS unit during the agricultural year 1998-99.

Comunero	**N° turns Used**	**Maximum time based on** TWRA days	WRAP Days	ACA Days	**Actual time used** days	**C – TDR** % TWRA	% WRAP	% ACA
C1	7	38	30	28	19	50	63	67
C3	3	25	7	9	4	16	58	44
C2	5	32	19	27	11	35	57	41
C5	4	21	14	12	8	38	56	64
C7	6	24	20	20	15	62	73	73
C4	7	75	62	44	24	32	39	55
C9	7	57	21	23	14	24	67	60
TTC		**271**	**173**	165	**95**	**35**	**55**	**58**

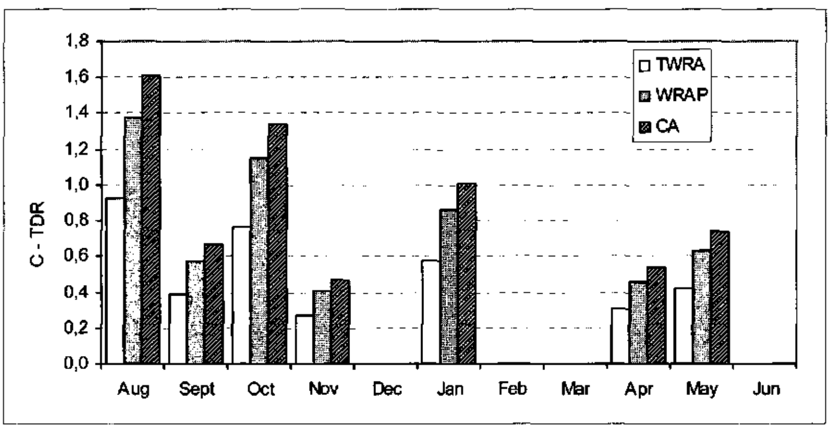

Figure 6.4 Variation of C-TDR based on TWRA, WRAP and CA in JS tertiary unit.

6.5 July, December, February, and March turns were not used by farmers (the system shutdown in June). July is a month of low water requirements while December, February and March are rainy months. In 1998 it was January where irrigation was concentrated during the wet season.

Given the lack of individual registration in TTC, mean irrigation times per hectare were calculated based on available information about water delivery time and actual irrigated area for each *comunero* for each specific irrigation turn. Although this cannot be extrapolated directly to farm delivery time it gives a good idea of that parameter. The mean Time Delivery Ratio calculated at this level was more than 3 times the official 50 minutes/ha allocated to each irrigator (Table 6.10). Figures are higher than those presented in Figure 6.4 based on cropped area (CA) because irrigated area per turn in all cases is less than the water righted area and even less than the actual area cropped - since farmers' irrigation strategies (section 6.4.1) for most crops does not include irrigation in all possible turns.

Table 6.10 Mean delivery time (hr/ha) based on delivery time and actual irrigated area of *comuneros*

	Aug	Sept	Oct	Nov	Jan	Apr	May	Annual Mean
C1	2,5	2,7	2,6	2,4	3,0		2,3	2,6
C3	2,8	3,0	2,3		3,1	2,3	2,6	2,7
C2	3,1	2,4	2,8		2,8	2,1	2,4	2,6
C5	3,2	2,9	3,1		2,0		2,9	2,8
C7	2,7	2,5	2,4		2,5	2,4	2,9	2,6
C4	3,2	3,2	2,8	2,8	2,9	2,8	3,1	3,0
C9	2,7	2,8	2,3	2,6		2,2	2,2	2,5
TTC	**2,9**	**2,8**	**2,6**	**2,6**	**2,7**	**2,4**	**2,6**	2,7
C-TDR	3,5	3,3	3,1	3,1	3,3	2,8	3,2	3,2

6.3.5 Delivery Discharges

The above analysis gives a first indication of how local irrigators have reshaped 'modern' designed delivery schedules in terms of irrigation opportunities. Let us move to discharge analysis, the third critical component that determines water use.

Figure 6.5 presents the discrete series of flow rates in season 1998-1999 based on *caudales* reported by the *tomero* (0, 1 or 2).

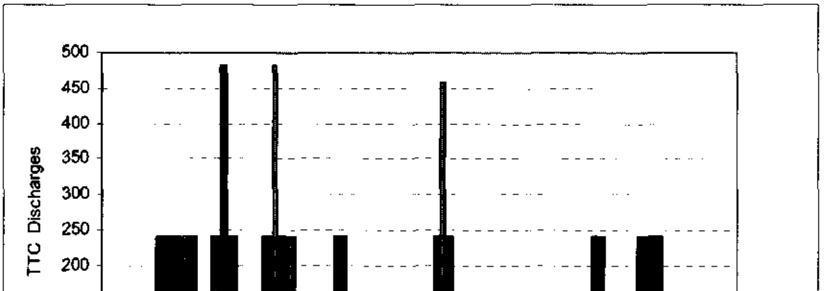

Figure 6.5 Daily discharges in TTC Tertiary canal during the growing season 98/99

Here it is clearly illustrated that TTC operates sometimes with 2 *caudales*[6.6]at least for short periods of time. According to design conditions, 2 *caudales* are not necessary to complete the TTC's rota even with its maximum area cropped (which was not the case in the 1998-1999 season). The reason to deliver two *caudales* to TTC in certain periods is simply derived from the particular under-utilization of many tertiary units, and from the flexible and to some extent decentralized operation of the secondary canal adopted by the Agency. Although *caudales* have been converted to real flow units in Figure 6.5, this can give a wrong idea about discharge because of its real variation of discharge, discussed later in this section.

Let me analyze the researched operational situations that lead to delivery of 2 *caudales* to units designed to use only one. (1) In spite of use of maximum times in some irrigation turns, most tertiary units of modernized La Cuarteada secondary canals are being under-utilized. (2) The operational approach of the Agency to manage this underutilization is to keep canal operation close to its full discharge (Water Delivery Ratio close to one) and reduce the duration of deliveries (low TDR). (3) This results in integration of tertiary units into a larger rotational unit (irrigation section) - minimizing discharge change in parent canals which is one of the classic operational approaches to manage irrigation systems out of periods of peak water requirements (Horst, 1998).

However with water being delivered to "until irrigators have finished" in each tertiary unit, and without knowing in advance which farmer will irrigate and how much time he will take, delivery decisions have to be taken almost in real time. According to the *tomero,* within this framework, there are two basic situations to deliver a free second caudal to TTC. The first is to take a caudal free from another tertiary unit - a possibility that could be arranged beforehand or in real time since all *tomeros* now communicate by radio between themselves and with La Darsena. The second is by taking free water that would be available for a short time after the resetting of the secondary canal discharge by La Darsena[6.7]. One particular circumstance that made the first situation more frequent and easy, and that applies to TTC, is when the same *tomero* operates more than one tertiary unit[6.8]. It must be stressed that these local operational procedures that makes water delivery more flexible are not hidden activities of *tomeros*. In most cases they are communicated to District and *La Darsena* offices and known by engineers at district office and headquarters.

However, operational practices are not the only the reason for delivery of two caudales, there is also a service-oriented behaviour of *tomeros* and many field level agency workers, as explained by Mr. LP,

> *With two caudales, two comuneros can* irrigate simultaneously *and that allows farmers from upstream comuneros* (remember that water is delivered from downstream to upstream) *to receive water earlier than expected. Therefore, why should I release a caudal to others before all the irrigators of **my** tertiary finish their irrigation? If others are waiting for it can be a possibility but because most of the time there is no urgency for water is better to finish properly in **my** area first.*

[6.6] During theses periods, the canals sometimes operate above their design capacity infringing on free boards and above the module limit of their long-throat flumes. However spillage and flooding were not important.

[6.7] The modernized La Cuarteada secondary canals is not so modern as to include spillways to the drainage network (San Martin secondary canal does) as is advocated in the modern irrigation package

[6.8] In the specific case of TTC, Mr. LP also operates TTCT, a tertiary unit formerly operated by his father that takes water at the same diversion structure as TTC. His brother is also a *tomero* who operates the upstream tertiary unit and a pair of *comuneras* that take water directly from the Secondary Canal.

A clear commitment to his work is underpinned in this expression of Mr LP, in talking about 'my tertiary' and 'my area'. Mr LP is highly accountable to users. Although in his case that relationship could be stronger because he grew up in the area and is related to one user[6.9], this accountability has been noticed also for other *tomero*s.

Field research showed that another feature hidden in the use of caudales as the unit of delivered water is the unintended variations of discharge, produced mainly from mismanagement of diversion structures. Table 6.11 is based on direct flow measurements at TTC done during the research, and shows that discharges reported as one or two caudales can be rather different.

Table 6.11 TTC Discharges reported as one or two *caudales* by the tomero

N° Caudal Reported	N° Measurements	Mean Measured Discharge (l/s)	Limits 95% confidence interval	
			95% max	95% min
1	25	241	273	219
2	11	505	535	474

Figure 6.6 shows discharges at the head of TTC during September and October 1998 irrigation turns[6.10]. It shows that besides the changes from 1 to 2 *caudales* already discussed, there could also be smaller but important discharge variations even within a turn. For example, during the October turn, discharges gradually increased from 200 l/s at the beginning of the turn to almost 300 l/s one day before the short jump to 2 *caudales* (500 l/s), keeping close to 300 l/s until a sudden drop on October 14th to almost 200 l/s, to recover in the following days but without reaching the official 300 l/s.

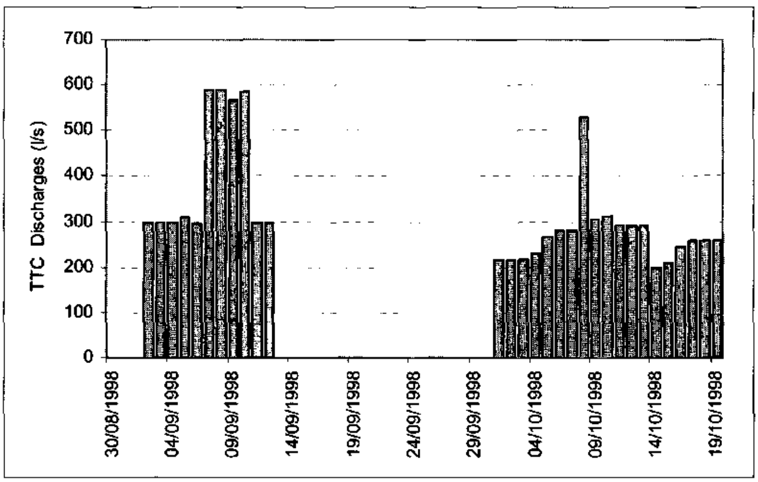

Figure 6.6 TTC's discharge variation during September and October 1998 irrigation turns.

6.9 Mr. LP used to live in a house constructed by A&EE close to the La Cuarteada secondary canal and the diversion structures for TTCT and TTC, where he also continued living after marriage to a daughter of a TTC user. Some years ago he moved to a neighboring village 8 km from the area.

6.10 These discharges were calculated assuming 100% efficiency from discharge measured at the head of comuneros. For measuring at that level administradores were asked to record water height at observation well of long trough flumes located at the head of their comuneros. Rating curves adjusted for each flume by our group during a previous work in the area were used. They were not checked in this period

Figure 6.7 shows discharges at the head of 4 selected *comuneros* during the same September and October 1998 irrigation turns. As the product of the different discharges at TTC head, the discharges received by these *comunero* in different turns also varied (C2 is the only exception to this case). There are discharge variations among *comuneros* within the same turns (compare C9's discharge with discharge of others in the October turn) and there are also variations of *comunero's* discharge during turns (C1 and C4 in the October turn). Frequently differences could be as large as 40 to 50 l/s - almost 25% of the original discharge. These are variations that would be unacceptable in the context of precision irrigation and 'modern' systems operation based on agreed service between different levels of the system. Yet they do not seem to seriously constrain farmers in JS.

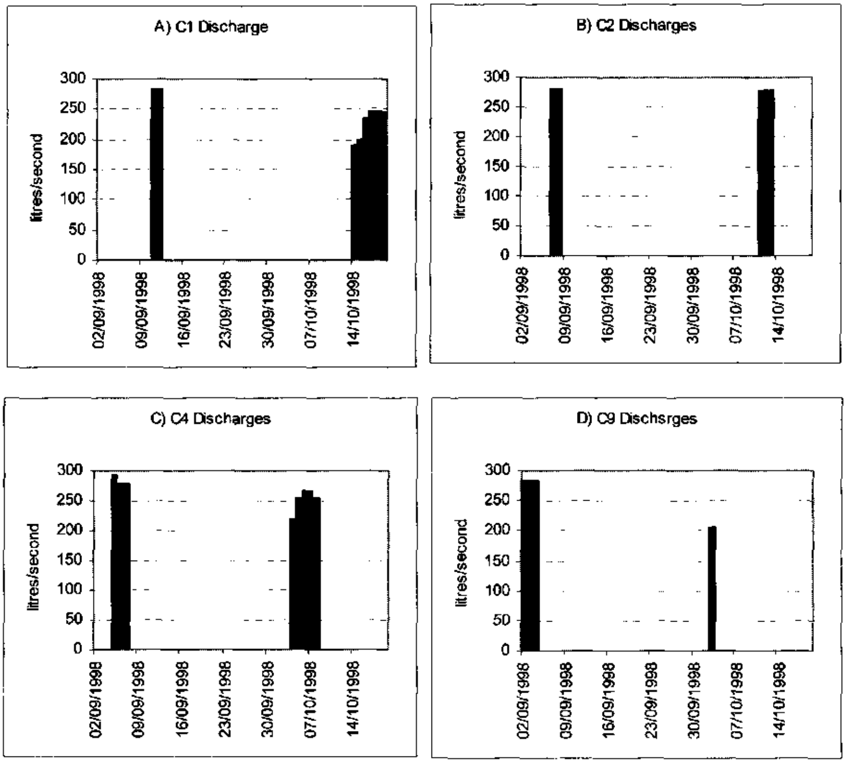

Figure 6.7 TTS-*Comuneros'* discharges from July to October 1998 (3 irrigation turns).

More than 50% of farmers interviewed considered there was no significant variation of stream flows among irrigation turns (See Table 6.12). Most of them, (78% but with the exception of farmers from C4[6.11]) including those recognizing discharge variations, considered that variation was unavoidable and stated that it did not seriously affect their irrigation practices.

[6.11] During INTA's previous work in the area, farmers of that *comunero* always argued that they received less water than others, especially those at the tail of canals because a negative slope of the canal bed. That was certainly proved by our work, and a time compensation was accorded for them at that time.

Table 6.12 Perception of users about existence of discharge variation at *comunero* level.

Comunero/Tertiary	Yes	No
C1	4	5
C3	0	4
C2	1	4
C5	5	2
C7	1	3
C4	9	4
C9	3	6
CT3	22	28

The need to supply other farmers upstream and variation of La Cuarteada secondary canals were the most frequent reasons for discharge variation mentioned by farmers. Few of them considered that water is sometimes stolen by upstream users. No one expressed any concern about the differences between *comuneros*.

6.3.6 Water Use at Comunero Level

Figure 6.8 presents the calculated annual gross irrigation used per hectare for each *comunero* and for TTC for the 1998-1999 agriculture year. Despite the lack of continuous records of actual discharges, water supply was calculated from the number of hours used, the *caudales* reported and the mean and 95% confidence limits estimated from direct measurements of the *caudales*.

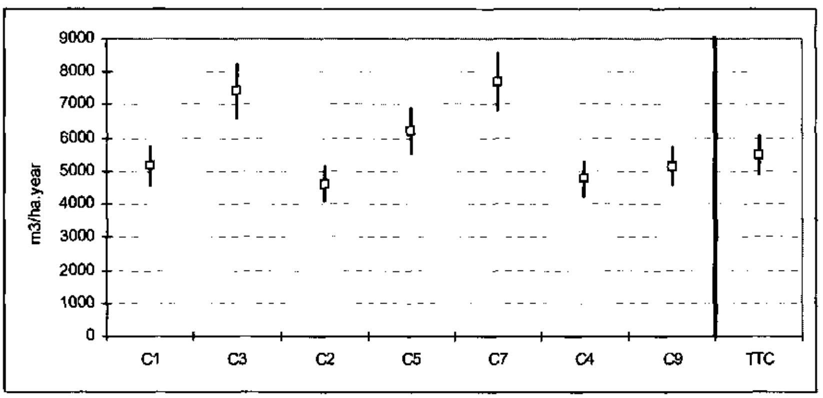

Figure 6.8 Annual gross irrigation water per ha for *comuneros* and TTC canal

There are clear differences between *comuneros*, with C7 as the maximum user of water and C2 the least. The annual mean water use of the tertiary (5485 m^3/ha) is around two, three and four times lower than the allowed amount of water according to water rights, and the mean values for the whole PRD and La Cuarteada secondary canal respectively. This would give a first indication of a strong uneven distribution of irrigation water in PRD and/or of high water losses in upstream tertiary units.

Table 6.13 completes the comparison of irrigation practices between TTC *comuneros*, by showing the mean irrigation depth per *comunero*. This shows that the mean Water Delivery Ratio (WDR) for the 1998-1999 season of individual turns is 2,6 greater than the official depth of 90 mm. However due to the low number of times (turns) farmers used irrigation the annual water use remains far below the allocated amount, yielding an annual WDR for TTC of 0.6.

How and why farmers manage irrigations that can supply such large depths of water when irrigating, and yet still apparently under-irrigate their crops overall, is explained by their irrigation practices at farm level as discussed in the next section.

Table 6.13 Mean irrigation depth applied per *comunero* in the growing year 1998-1999.

	Irrigation Turns								**Annual water use (mm)**[1]
	Aug	**Sept**	**Oct**	**Nov**	**Jan**	**Apr**	**May**	**Mean**	
C1	217	234	226	208	260		200	**224**	518
C3	243	260	200		269	200	226	**233**	743
C2	269	208	243		243	182	208	**226**	461
C5	278	252	269		174		252	**245**	622
C7	234	217	208		217	208	252	**223**	769
C4	278	278	243	243	252	243	269	**258**	476
C9	231	243	200	226	0	191	191	**213**	515
TTC	**250**	**242**	**227**	**226**	**202**	**205**	**228**	230	**549**
WDR	2,8	2,7	2,5	2,5	2,6	2,3	2,5	**2,6**	**0,6**

[1]The annual water use is not the sum of the mean irrigation depth per turn because the irrigated area per turn varied considerably.

6.4 Irrigation Practices at Farm Level

6.4.1 Irrigation Strategies

Irrigation water use per land unit at farm level has two main components: the irrigation scheduling adopted by farmers and the application itself. The irrigation scheduling adopted by farmers at the planning stage (also being explicit or not) depends on many different variables - production styles, resource availability as well as other agronomic factors - sharply affects water productivity in terms of physical yield and farmer income. A study of these diverse relations is beyond the scope of this thesis. However irrigation strategies for the most relevant crops in TTC are described here, as they are an important and direct component of water demand and affect the satisfaction of farmers with the water delivery service. These irrigation strategies were researched through interviews with users and could not be cross-checked in this case with the real irrigation management applied by each user[6.12] due to the lack of any individual register. Table 6.14 summarizes interviews' results for the main crops of the area, cotton, alfalfa, maize and water melon.

With the above irrigation strategies those farmers with the highest cropping and irrigation intensity (cropping alfalfa and cotton and applying pre-seeding irrigation and 5 and 3 irrigation on the growing cycle of each crop) and irrigation the same plot every time[6.13], would need a maximum of 6 to 7 irrigation turns per year and they would concentrate in

[6.12] Research of irrigation scheduling and irrigation time used per unit of land based on farmer's interview was contrasted with individual register or irrigation because a bias to practices recommended by INTA was expected in the interviews. However in this case because not individual register was available that was not possible and calculation can be done until *comuneros* level.

[6.13] To irrigate each turn smaller area than they are righted is a common practice of some farmers to apply a large irrigation gift depth. That is possible in combination of their practices of drop some turns.

winter and spring months. This is in agreement with the number of irrigation turns used by comuneros showed in section 6.3.2.

Table 6.14 Irrigation scheduling in the main crops of JS

Crop	Pre-seeding irrigation	Irrigation scheduling after seeding	Farmers
Alfalfa	Always – March/April	3 times from march to October	8/25
	Always – March/April	All winter months (4 to 5 irrigations)	7/25
	Always – March/April	Two times in winter months	3/25
	Always – March/April	Others	7/25
Cotton	Always - Aug/Oct	1 irrigation at 50-60 days from sowing	21/33
	Always - Aug/Oct	No irrigation during crop growth	7/33
	Always – Aug/Oct	Others	5/33
Maize	Always – Oct/Nov	1 or 2 if dry summer	8/10
	Always – Oct/Nov	No irrigation during crop growth	2/10
W, Melon	Always -	No irrigation during crop growth	12/12

Standard technical recommendations for irrigation of these two crops include monthly application in alfalfa from June to November. For cotton there is no standard recommendation since irrigation is supplementary in this crop and the number of application depends of the rainfall during the growing cycle. On average with modern cotton varieties the minimum number of irrigations should be three. There are different and complex reasons why these recommendations are not closely followed by many farmers. For instance in the case of small farmers some of them would be: resource availability for irrigation and other agronomic practices needed under more intensive crop watering such as weed control.

6.4.2 *Application Practices at Farm Level*

Due the lack of individual registers (*boletas de riego*) in JS, it was not possible to identify the number of irrigations and amount of irrigation applied for each holding. However irrigation application practices were researched through structured interviews with all active farmers (37 farmers) and by direct observation and unstructured interviews during water applications.

All farmers use the traditional basin irrigation in pre-seeding and during crop growth with very low water control (Figure 6.9). Results related to use of *bordos* (small earth levees) along direction of water flow) and *trabas* (earth ridges perpendicular to water flow) and average distance between them in case of positive answers are presented in Figure 6.10.

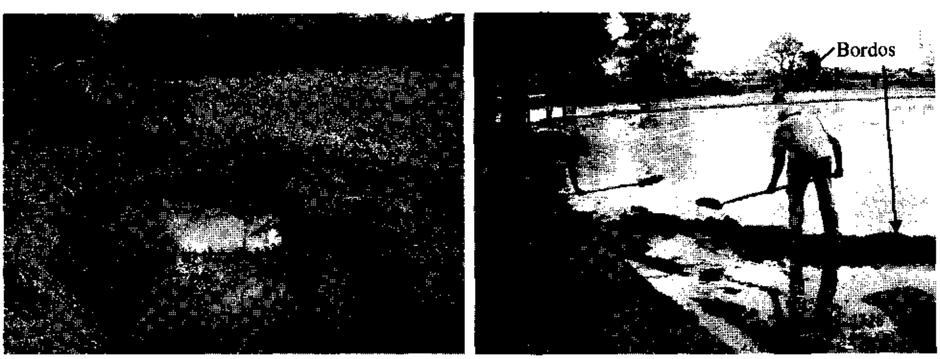

Figure 6.9 Traditional basin irrigation practices by JS small farmers

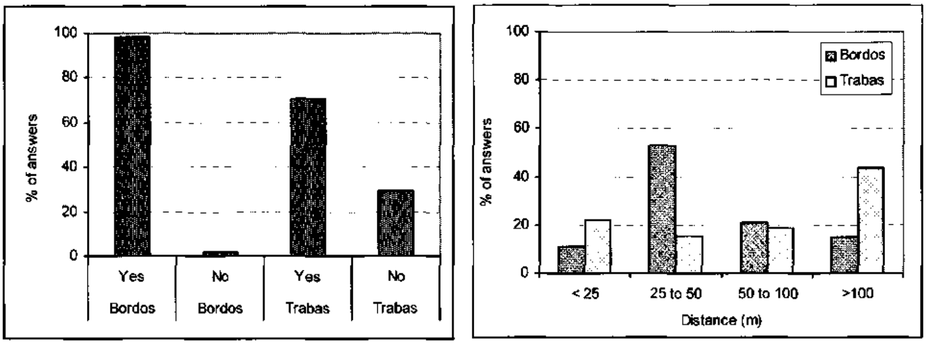

Figure 6.10 Use of *bordos* and *trabas* in JS and distance (m) between them.

Almost all users (there was only 1 negative answer) use *bordos* to define irrigation strips within their plots. Many also used *trabas* to decrease the flow velocity of water and increase infiltration opportunity time, but 30% of them do not. Twenty five to fifty meters is the most frequent distance between *bordos*, and more than 100 m for *trabas* (this defines basin areas from ¼ to ½ ha). However structured interviews did not represent well the distance between *bordos* and *trabas* observed in the field. Actually the most frequent situation found in practice was that both *bordos* and *trabas* were not constructed with regular spacing between them: many times they were not even straight but followed roughly a contour line, this results in basin areas of 1 ha or larger. Bordos and trabas are constructed by this type of farmers using horse pulled tools, therefore height of them are not more than 20 cm.

Due the fact that is not a common practice to split up the flows and the usually uneven surface of the plots, a good localization of *bordos* and *trabas* is relevant for a good control of water during application and for the uniformity of irrigation depth. The relatively long distance between *bordos* and *trabas* (large basins) should therefore be interpreted as weak infrastructure to control water application.

Also weak is the operational control, as can be concluded from the fact that the most frequent answer about number of irrigators used to control application was 2, which means a main d'eau of around 150 l/s per irrigator which is a high *main d'eau* even under basin irrigation. That could be verified under JS's farms conditions where many times water flows out of the basins. The application control was even worse during night irrigations where field observations revealed that that it was not uncommon to leave water flowing unattended to largest irrigation unit.

The long delivery times exposed earlier, that yield high irrigation depths, reflect farmers' preferences but also are to some extent a consequence of the poor control during water applications or as Levine (1980) suggests, a use of water as a substitute of other less available resources.

6.5 Conclusions

Findings in JS, a tertiary unit modernized during the PRD intervention, showed that it is functioning far from design expectations in many ways.

In relation to water allocation the mosaic of irrigated and non-irrigated areas developed within the PRD command area by the negotiated process - through which the government was able to impose their political criteria of limiting a water right to a maximum of 50ha, and imposing the prior appropriation principle for a holder to have water rights - is expressed in JS with less intensity than in other areas. That is because JS is a former section of the old La Cuarteada system, with a majority of user plots far below the limit of 50 ha even in their gross area. The presence of PRETAs, the functional tool developed to reset water allocation after the PRD, is weakly present in this area of smallholder farmers because cropping areas have been reduced rather than increased.

However water allocation has changed in practice from time of PRD intervention due the negative effect of economic policies on the smallholder production systems predominant in JS that decreased numbers of actual farmer from 93 to only 37. In this sense, although with less intensity there has been concentration of land and water by more successful local farmers, and they still remain with the same type of production system.

In organizational terms water distribution in *comuneros is* officially under responsibility of SARCCs but their practical constitution does not follow official rules but has re-assumed the historical organization around a farmer leader. However the modern short comuneros with few users has reduced his role and increased the direct influence of the *tomero* within *comuneros*, whom many users access directly. Water distribution almost always starts from the tailend plots, confirming the power of the strong institutions developed earlier under former farmer-managed irrigation systems around private *acequia*s. Maintenance of the tertiary and *comuneros* is the main collective activity of JS's farmers. The work is done by the traditional method of *reparto*.

Irrigation practices of JS farmers have also not changed so much from historically reported farmer practices before construction of improved irrigation facilities by the government, despite the two main interventions. Irrigation strategies in the predominant crops (alfalfa and cotton) presuppose few irrigation events during crop development in a reminiscence of the former protective irrigation practiced before PRD intervention. Basin irrigation continues to be the predominant application method, with a low control of water during application and water clearly substituting for the other labour and capital resources that farmers find scarce.

Water delivery schedules have been reshaped according to farmers' preferences. The mean gross irrigation depth per irrigation event has risen to 230 mm, that is 2,6 times greater than the gross official irrigation depth of 90 mm despite a delivery discharge on average 20% lower than the official 300 l/s, by increasing up delivery duration to three times the official 50 min/ha. This is possible because the irrigated area per turn is far below the water righted area but also lower than the actual cropped area.

In spite of the high use of water in individual events average annual water use by JS farmers is not more than 60% of the volume allocated to them, due a reduction of cropped area to 57% of the water righted area and the afore-mentioned farmers' irrigation strategies including few irrigations events in most crops.

However the fact that irrigation practices at tertiary level have moved away from design expectations is not only related to farmers' actions. Agency activity has focused on avoiding user complaints. Also the high commitment and accountability of its frontline workers in TTC had contributed greatly to development of the flexible water delivery schedule functional to farmer preferences - even sometimes increasing TTC discharge over its design capacity.

On the other hand, actual farmer water application practices also had to be functional in relation to the technical limitations of agency operations. These include discharge variations between and during irrigation turns and changed turn frequency, affecting timeliness and reliability of water delivery that would be highly unacceptable for other application methods. Rather such potential problems are highly buffered by the basin application method, the large irrigation gift applied by farmers, and their irrigation strategies.

In this context, many of the modern technical facilities such as water measuring devices and sluices, and gated control and off-takes have been irrelevant for JS irrigation performance. While the former have never been used, the latter have been affected by the low maintenance capacity of the Agency and users - they are highly deteriorated and operate only as on/off gates.

In short, research in JS tertiary unit suggests that modernization of irrigation structures and operations have largely solved farmer water acquisition so it is a not restrictive factor of their production systems. However, this is done by allowing flexibility to supply large amounts of water rather than refined crop-based delivery. Also they have not able to reverse the impoverishment process that other political and economical factors have imposed over the type of production systems and farmers predominating in the JS tertiary unit.

Chapter 7

TTS TERTIARY UNIT: ARRANGED ROTATION DELIVERY SCHEDULE AND TRADITIONAL WATER APPLICATION

The TTS is, in all aspects, a 'modern' tertiary unit. It is part of the Colonia Simbolar, a complete new irrigated area developed within PRD by the land consolidation component of PRD intervention (1968-1973). Smallholder farmers from other places within the command area were re-settled in 25 ha farms in this new area. The re-settlement model adopted included construction of farmers' houses in small villages not far from their farms (there are three of these small villages, Sector A, B and C) in order to provide them collective services such as electricity, tap water and primary school education. All physical infrastructures including irrigation facilities were built during the PRD intervention.

The area is fed by the Simbolar secondary canal that takes water from the large primary Jume Esquina canal constructed for transferring water from Rio Dulce to Rio Salado. Neyrpic AVIO gates (downstream control) with their corresponding module *à masque* controls divert water to this secondary canal, and to its 5 tertiary canals, while water diversion to *comuneros* is controlled by constant head orifice structures. A network of drainage canals completes the water management infrastructure.

Irrigation facilities at farm level were also designed and built by PRD's engineers. These included mainly embanked internal irrigation ditches that were a novelty in the area at that time, and land levelling of each individual farm. At initial stages there was both social and technical support to re-settled farmers by the autarkic provincial agency CRD, but this decreased with the abrupt drop in the CRD budget after 1975 and has been almost zero in the last 25 years.

Arranged rotation[7.1] (Horst, 1998) or rate-duration restricted arranged schedule (Clemmens, 1987) water delivery schedule was adopted for this area in the time of the A&EE, the system operation[7.2] completing a modern irrigation package on which PRD proponents and designers based an optimistic hope of sustainable development.

It was this difference in water delivery schedule that was one of the main reasons to take TTS tertiary unit - one of the tertiary units within Colonia Simbolar – as one of the study cases. Additional key differences with other cases are the symmetry and homogeneity of holdings that can be seen in figure 6.1 that shows the general layout of TTS command area.

As can be seen from the Figure 7.1 the main TTS water course splits into two branches, B1 to the north east of the area, B2 to the south east, thus defining three independent water management units - the initial TTS section, B1 and B2 units.

[7.1] Keeping delivery duration and rate unchangeable, delivery frequency is arranged between users and the agency.

[7.2] Actually the area was defined as a pilot area for assessing the applicability of the arranged rotation delivery schedule that would be extended to other areas if its results were positive as regards water use efficiency and users' satisfaction. In practice there was not any assessment of the results and the official water delivery schedules remained unchanged during the last 30 years in all zones

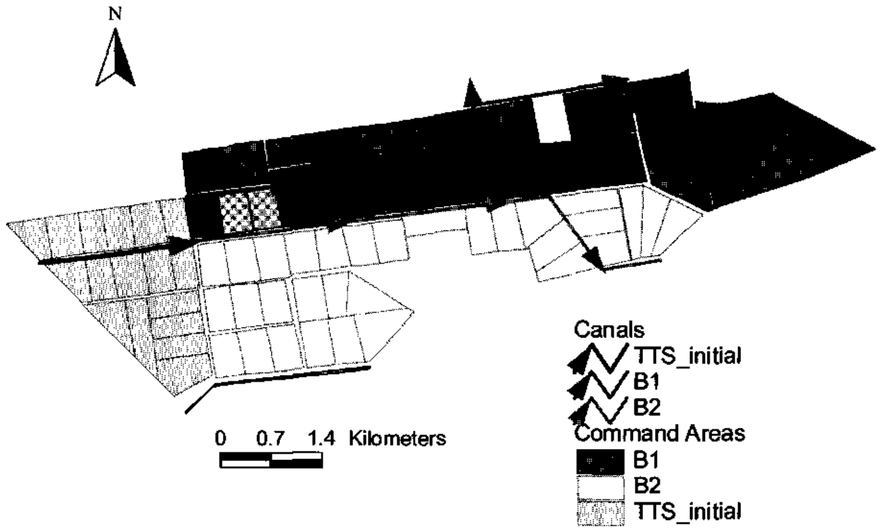

Figure 7.1 The layout of the TTS tertiary unit

7.1. Agrarian Structure and Irrigation Water Allocation

7.1.1 The Official World

The official water allocation and agrarian structure of TTS are presented in Table 7.1. The Water Righted Area of TTS is larger than JS (Chapter 6) and of RS and SMFN (Chapters 8 and 9).

Table 7.1 Main characteristics of agrarian structure in the TTS command area (source UER-INTA data base, 1998).

	Presence of	Holdings		Gross Area		Water Righted Area			Mean
	Water Rights	N°	%[1]	Ha	%[1]	ha	%[1]	%WR[2]	ha
	Without	1	6	24	6				24
TTS initial	With	16	21	387	20	387	21	100	24
	Total	**17**	**18**	**410**	**18**				
	Without	15	83	412	86				24
B1	With	29	39	710	39	710	39	100	25
	Total	**44**	**47**	**1122**	**49**				
	Without	2	11	45	9				23
B2	With	30	39	729	40	729	40	100	24
	Total	**32**	**34**	**774**	**34**				
	Without	18	18	481	21				24
TTS total	With	76	82	1826	79	1826	100	100	24
	Total	**93**	**100**	**2307**	**100**	**1826**	**79**		

[1]% of the total of its class [2] % of the gross area of its class

Although, the number of holdings (93) is similar to the JS (90) and SR (83) units, and the gross area (2307 ha) is similar to the SMFN tertiary unit (2401 ha), the permanent water righted area is double those of other areas. The percentage of water-righted area would be

100% if a particular situation of land deterioration had not led to withdrawal of water rights from 14 holdings in B1 branch[7.3]. Although the TTS area was studied as a whole, the B1 command area (dark in Figure 6.1) was selected for a detailed analysis of irrigation practices, given its similarity in terms of permanent water righted areas to other units. The irrigation practices are similar in both branches and they are considered highly representative of the whole Colonia Simbolar or Zone V of the PRD.

Table 7.2 presents the agrarian structure and permanent water allocation of B1-TTS in 1998 according to official information. Obviously in this case of a newly developed re-settlement area, all holdings are close to the same designed norm of 25 ha (the actual water righted area ranges from 23,2 to 25,6 ha only because it was not physically possible to fit all exactly equal parcels) and the percentage of water righted area respect to their gross area is 94%.

Table 7.2 Size distribution and active areas in B1-TTS in 1998 (source UER-INTA data base).

PERMANENT WATER RIGHTED HOLDINGS								
	Holdings		Gross Area		Permanent Water Righted Area			
Size Class	N°	%	ha	%	Total (ha)	%(1)	%WR(2)	Mean (ha)
10 to 25	13	43	307	0	307	42	100	24
25 to 50	17	58	478	0	433	58	94	25
	30	100	785	58	740	100	94	24

(1)% of the total water righted area (2) % of the gross area of its class

Table 7.3 completes information about water allocation, adding the area under PRETAs in the agricultural years studied. All these PRETAs are used to irrigate in 25 holdings that for some reason lost their permanent water rights.

Table 7.3 PRETAs and Total Water Righted Area (TWRA) in B1- TTS

Holding size	1998 -1999				1999 -2000				2000 -2001			
ha	N°	ha	%(1)	TWRA(2) (ha)	N°	ha	%(1)	TWRA(2) (ha)	N°	ha	%(1)	TWRA(2) (ha)
0 to 5									1	3	100	3
5 to10									2	20	100	20
10 to 25	5	70	19	377	5	68	18	375	4	66	17	372
25 to 50				433			0	433				403
	5	**70**	**9**	**810**	**5**	**68**	**9**	**808**	**7**	**88**	**11**	**798**

(1)% of the total water righted area of its class (2) TWRA = Permanent + PRETAs Water Rights

As can be seen from Figure 7.2 most PRETAs (five in 1998 and 1999, six in 2000) are in the command area of B1-TTS and four of them are taken to irrigate some of the 14 holdings close to Jume Esquina canal from which permanent water rights were removed. In three cases only part of the 25 ha holdings is registered for irrigation with a PRETA, showing how smaller areas are registered for a PRETA. Three of the farmers working these plots came to the area after the main resettlement period and took them as their only production area. The

[7.3] These 14 holdings are located at the north edge of the area, close to the Jume Esquina canal (see figure 6.2). Seepage from that canal provoked a fast process of soil salinization in these holdings that necessitated reallocation of their farmers in other holdings and water rights were taken from them.

other farmer involved owns holdings in another area but also worked with his father and father-in-law in their holdings within the B1-TTS command area[7.4].

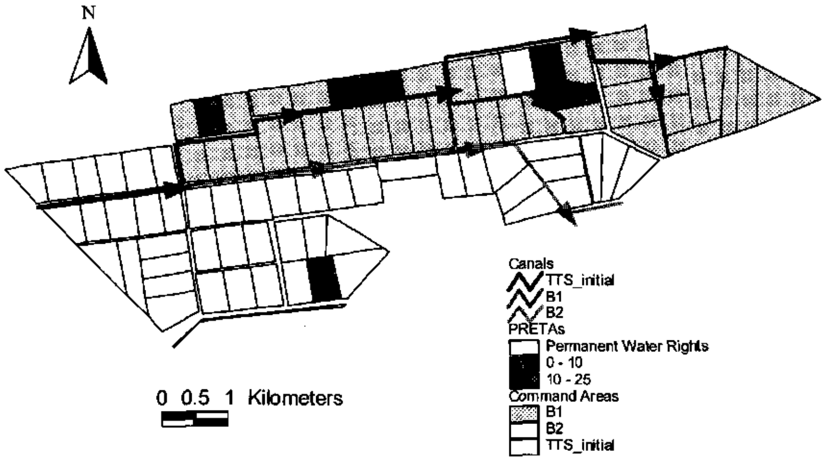

Figure 7.2 Locations of PRETAs in TTS

7.1.2. The Real World

All permanent water righted holdings were officially reported as active (cropped) in 1998 and the surveyed situation in 1998 confirmed this: only holdings without permanent water rights were abandoned. However, 5 holdings with permanent water rights were not cropped in the last study season of 2000-2001. Although for 1998 there were no differences between surveyed and official information about active holdings, differences were large in terms of cultivated areas. Table 7.4 (based on actual cultivated area) shows that there has been a great decline and involution of farming: only one farmer worked the whole area of his farm[7.5], most farms actually had around 16 ha in use, and the mean cropped area per farm in the area had fallen to 10 ha.

Table 7.4 Agrarian structure based on actual cropped area per farm in 1998 (source: field survey).

	N°	Gross Area Ha	Cropped Area ha	Mean Area Ha
0 to 5	3	74	10	3
5 to 10	3	75	22	7
10 to 25	25	608	409	16
25 to 50	0	0	0	
Total/Mean	31	1122	441	10

However, figures refer to physically worked area. Some plots are cropped twice in the year: 40% of the area was found to be double-cropped in the 2000/2001 growing season (with

[7.4] Acceptance of these farmers to cultivate holdings earlier prescribed and abandoned due soil salinization processes, shows both farmers' empirical knowledge to deal with salinization in PRD conditions and acceptance of this in PRD, and marks a big difference from the apocalyptic generalized view of the salinity problem formerly sustained by engineers. They have cultivated these plots for 14 years with results no different from other farmers.

[7.5] Actually he is the above commented case that crops two other holdings in B1-TTS command area.

more reliable data), taking up a short growing cycle of winter vegetables. Due to various production stresses but especially price and market constraints, some of the area is only partially cultivated, and sometimes not even wholly harvested. According to the official information (only available for the 1998-1999 growing season) only 8 % of the cropped area was not harvested, although the level depended on the crop (20% for onions, 10% for carrots and lettuce and 0 for most extensive crops, cotton, maize, alfalfa). However, data from structured interviews (56% of the active farmers) indicated that the mean area not harvested was as high as 22 % for the three agricultural years studied. Of the 49 crops sown, 7 were 100% not harvested in 1998-1999, 6 crops remained not harvested in 1999-2000 and 5 remained not harvested in 2000-2001, while 2 farmers did not harvest any of their 3 crops sown in the first year and 3 farmers did not harvest 2 crops sown in the second year.

7.1.3 Production Systems and Cropping Patterns

All farmers of B1-TTS belong to the Settler – agriculture – vegetable production system defined by Radrizzani, (2000) (Chapter 4) whose main characteristics are: mechanized agriculture activities; work by family members predominating over hired labourers; and irrigating 85% of their water righted area. Interviews and field research in B1-TTS revealed, with only three exceptions, differences with this Radrizzani characterization that confirmed impoverishment of this type of farmer, already suggested by reduction of cropped area and increase of abandoned holdings towards the end of the study period. One key change was the number of families with non-farm income coming from themselves or other family members. This grew from 9 in 1998 to 19 in 2000, 75% of which were involved in urban activities (commonly by women – the wife or daughters). In 5 cases in 1998, external income was 100% of the household income, doubling to 10 in 2000. These last results agree with Renolfi, (2003) who found that only 47% of large and medium farmers in the PRD covered their economic needs with the income from their farms.

Although a deep analysis of B1-TTS farmers' impoverishment is beyond the scope of this thesis it is important to highlight that the irrigation practices and performance presented in this chapter are not directly related to problems of access to water[7.6]. Rather reasons should be sought in the endemic marketing problems related with perishable vegetable products and limitations to organized collective action after decrease of government support that might otherwise give better possibilities in marketing and service supply.

Table 7.5 presents the B1-TTS cropping pattern over winter (W) and summer (S) seasons across three agricultural years 1998/99-2000/01. The profile of B1-TTS farmers as vegetable producers is clear from the data although they incorporate some extensive crops such as cotton for marketing and maize largely for self consumption while wheat was produced by only one farmer. The short growing periods of most vegetables crops gave B1-TTS farmers the possibility to crop twice their land in one year, an option not available to farmers cropping extensive annual crops until the recent introduction of minimum or zero-tillage cultivation methods. To show the importance of the two crops per year, the effective physically cropped area has been added in the last line of the table.

[7.6] Actually the real situation is also complex. Some 60% of the farmers think that to change their water right status from permanent to PRETAs would help them to adjust their water righted area to that effectively cropped and therefore to reduce the water charge they have to pay. In this way they will have more secure access to water if agency continue with its policy of restricting water delivery to those paying water fees.

Table 7.5 Cropping area (ha) and effective cropped area in B1-TTS (Source:UER)

Crops	GS(1)	Agriculture Year 98-99	99-00	00-01
Carrots	W	170	175	175
Onion	W	123	144	163
Lettuce	W	39	42	51
Wheat	W	23	23	62
Cotton	S	56	26	54
Maize	S	88	32	95
Melon	S	55	73	85
Small Pumpkin	S	29	9	29
Guinea Corn	S	23	33	33
Water Melon	S	30	22	25
Others		15	20,5	25,5
TOTAL (ha)		**651**	**600**	**798**
Effe. Area (ha)		434	369	437

(1) GS = Growing Season; W = Winter; S = Summer

The high response of this type of farmer to market opportunities can be confirmed by shifts since 1995. In 1995/96 at the end of a 3 year period with very high cotton lint prices, cotton was 66% of the cropped area while carrots were not sown at all in that year but became the most cultivated crop from the 1998-99 growing season.

7.2 INSTITUTIONAL ARRANGEMENTS AND OPERATION OF WATER DISTRIBUTION AT *COMUNERO* LEVELS

7.2.1 Institution and Organization

As in the JS, the other modernized tertiary unit, the two *comuneros* canals in B1-TTS are short, the number of users on them are low, and in this case the number of plots taking water directly from the tertiary canal (DO) are high (Table 7.6).

Table 7.6 Number of users per *comunero* and with direct offtake (DO) from B1-TTS.

Comunero/DO	N° users	Active farmers 1998-1999	2000-2001
C – 6	10	7	7
C – 8	14	12	11
DO	20	15	12
	44	34	30

Here as in JS, SARCCs are formally in charge of water distribution and maintenance of *comuneros*: and as in JS they also take control over maintenance of the tertiary canal. Structured[7.7] and unstructured interviews show that the SARCCs here are constituted according to official rules. Most users answered positively about appointed positions in addition to the *administrador* and could give their names, but they recognized that in practice the *administrador* is the only effective position in everyday operations.

[7.7] Only qualitative assessments are given for this case since due to response levels. Although interviews covered 47% of the active users, evenly distributed between users of the *comuneros* and those with direct offtakes, the number sampled from B1-TTS was too small for statistical analysis: 3, 4 and 8 respectively for C-6, C-8 and DO.

It is the *adminstrador* who organizes collective action such as maintenance of water courses, and who receives or collects and then transfers a user's water request to the *tomero*. However, users also frequently transmit requests directly to the *tomero* or even to the district office (which is located in Sector A where most B1-TTS users live). Requests are analyzed daily at the UER's local office by the district head and Simbolar's *tomeros* and the delivery date scheduled based on water availability in neighbouring canals or in consultation with Darsena and main offices. Their decisions are communicated to the *administrador* and/or directly to user by *tomeros*.

In B1-TTS as in JS, the roles of tertiary unit SARCCs and the *administrador* in water distribution in these 'modern' units appeared limited by the low number of users within the *comunero* and their direct contact with the *tomero*, who plays a more relevant role than in the old tertiary units. Even the daily irrigation register (*boletas de riego*) is done by *tomeros* in this case. This frequent direct contact with *tomeros* and district office is clear from the interviews. Almost two-thirds of farmers answered that they turned to *tomero* when facing some irrigation problem: for the other third they turned evenly to the district and *administrador*. For the whole TTS tertiary unit, 82% contacted the *tomero* or district office directly.

7.2.2 Collective Actions – Maintenance

Maintenance of the tertiary unit *comuneros* is done by the "administration" using the tractors of local farmers, while the rest of the users cover fuel cost. However the preferences of user are evenly distributed between maintenance approaches. While administration supporters stress homogeneity and timeliness as the advantages of their mechanized method, supporters of *reparto* see this method as more appropriate due to the lack of cash of many users who thus cannot afford direct payments to the administration.

Regarding maintenance of the secondary canal, most farmers stated that it has been under the charge of farmers since 1995. They told how they used to share works at that level but in the last years, large farmers who irrigate downstream have done this. This point suggests that most farmers in this area do not have complete knowledge of the maintenance decentralization process practiced from 1995 to 1998 in which WUAs executed work maintenance, but works were paid for by the Agency. However they know about the transfer of responsibility from Ay EE to UER, and also about the short period when WAUs had more responsibilities. All users of B1-TTS state that they used to participate in APAZ V (the local WUA) meetings. Nevertheless they consider that in terms of field practice in maintenance nothing has changed since the time of the A&EE.

7.3 IRRIGATION PRACTICES AT COMUNERO LEVEL

7.3.1 Water Delivery Order

Although the water distribution schedule has been under arranged rotation, there exists an official order of turns starting from tail enders, as in other areas. In practical terms this means that if more than one request needs to be covered, the downstream user must irrigate first. Figure 7.3 compares theoretical with the practical order taken by active farms in 1998-1999, for the peak use months of July and August.

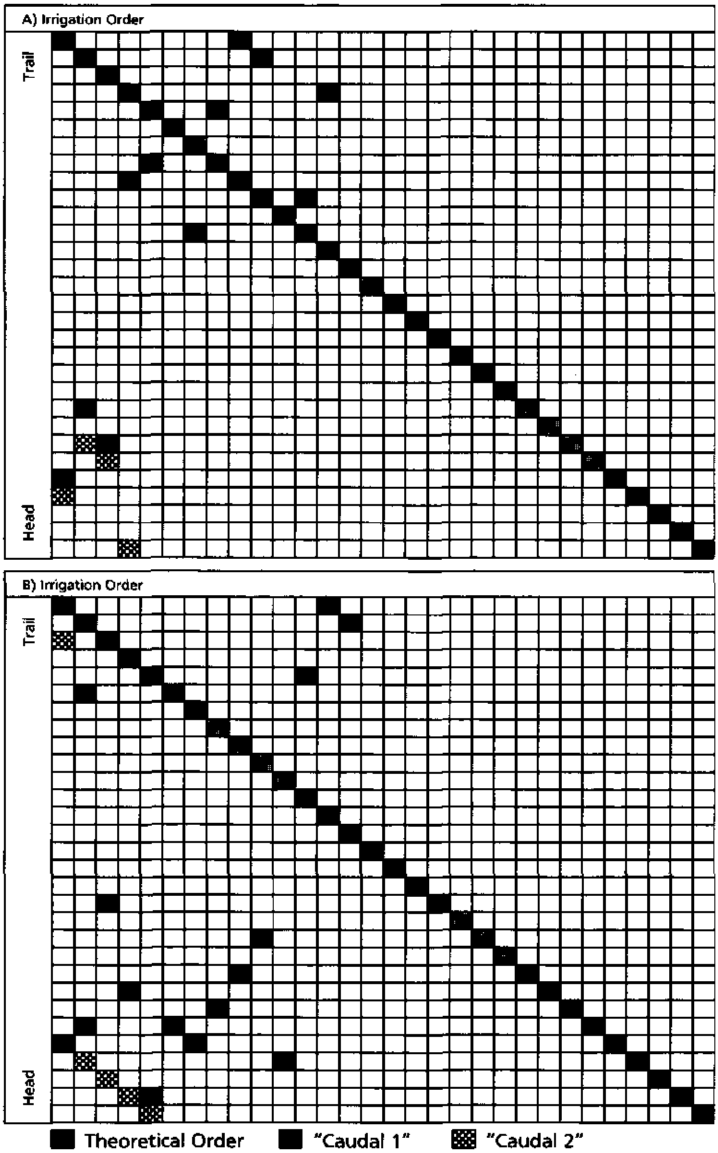

Figure 7.3 Farms and irrigation order in B1-TTS. A) July/98; B) August/98

Figure 7.3 shows that effectively there was no fixed order in irrigation delivery in B1-TTS but there is a general trend from head-end- to tail-end users - just the opposite to the official mandate. In addition, the system is very flexible in B1-TTS, to the extent that some farms irrigate twice in one month or use two *caudales* to irrigate two farms simultaneously (actually in some months even three farms irrigated at the same time, albeit one of them with a low discharge). But the figure also gives a good picture of the low number of farms irrigating during July and August (together with March, the months with more water use) with respect to active farms (number of square in the vertical direction).

7.3.2 Irrigation Turns

The use of arranged rotation as a water delivery method does not allow analysis of irrigation turns as in the other case studies. As can be seen from Figure 7.4 effectively there is no regular pattern in B1- TTS operation across the year.

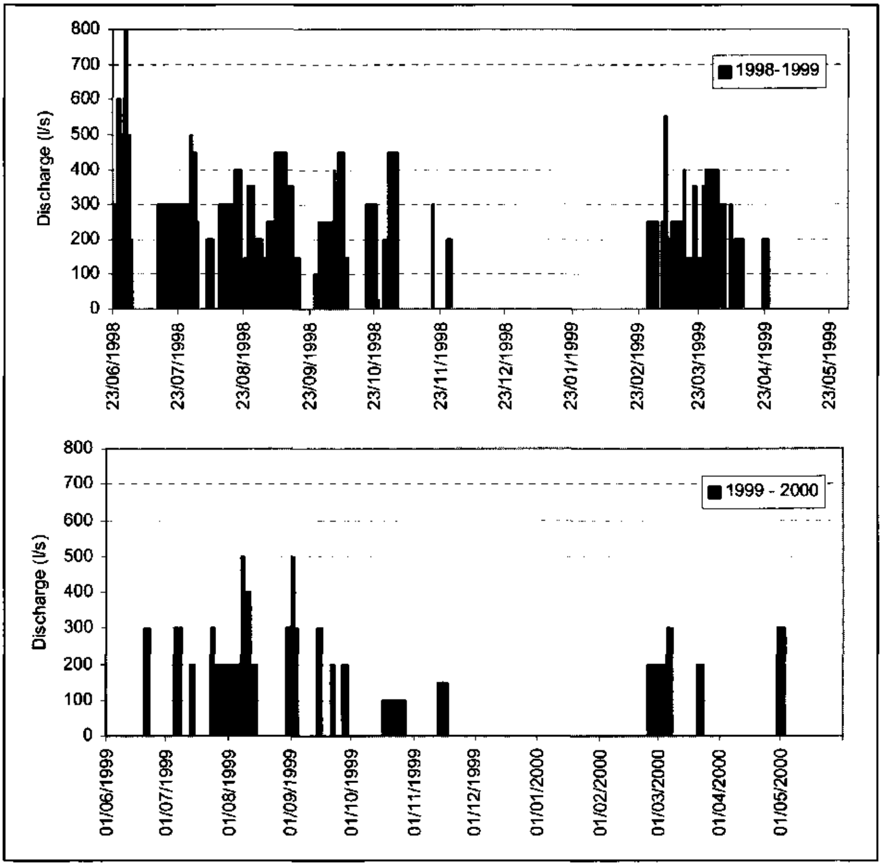

Figure 7.4 Operational periods of B1-TTS in 1998-1999 and 1999-2000 years.

However only to enable comparison with other sampled areas, irrigation events at B1-TTS were grouped in monthly intervals (Table 7.7) independent of their individual duration.

Table 7.7 N° of turns/year in B1-TTS tertiary unit.

Growing Year[(1)]	N°Turns	Initial Month of Irrigation Turns									
		1	2	3	4	5	6	7	8	9	10
98-99	7	Jun	Jul	Aug	Sept	Oct	Nov	Mar			
99-00	10	Jun	Jul	Ago	Sept	Oct	Nov	Feb	Mar	Apr	May

[(1)] 2000-2001 information is not presented because it is incomplete.

These results show different patterns between the analyzed years. In 1998/99 the pattern was similar to other areas - with a low number of irrigations used and concentrated during winter and initial stages of spring and autumn. However, in 1999-2000 with the only exception of January and May (the shutdown period of the system) irrigation water was demanded in all months. However this should not lead to wrong conclusions about greater water use in the second year, since as Figure 7.5 shows (also section 7.3.4) operational periods were very short in all months in 1999/2000 and there was much less water used than in the previous year, when the water course was almost continually in operation from July to October.

7.3.3 Delivery Frequency

Turn frequency also cannot be analysed under controlled demand, however irrigation frequency at farm level is analyzed later in this chapter.

7.3.4 Delivery Duration

To understand more about performance, it was decided to compare actual main components of water use with different possibilities for intended values. Maximum delivery duration was calculated based on Permanent Water Rights (PWR), Total Water Righted Areas (Permanent + PRETAs) (TWRA), the water righted area of active plots (WRAP) and Actual Cropped Area (ACA). The official delivery duration of 50 min/ha was used in all cases. Maximum times are presented in Table 7.8.

Table 7.8 Maximum time (days) required to complete B1-TTS roster considering PRETAs.

PWR		Based on TWRA				Based on WRAP				Based on ACA[1]			
		98-99		99-00		98-99		99-00		98-99		99-00	
Ha	Day	ha	day	ha	day	ha	day	ha	day	Ha	day	ha	Day
710	25	780	27	778	27	730	25	511	18	434	15	369	13

[1] Depending on the year 40 to 45% of this area has been cropped twice in the same year (see section 7.1.2).

This data confirms that, working with one *caudal*, the B1-TTS roster could be finished within the official frequency applied to areas under rotational water delivery, as would be the case here if all holdings required water at the same time. However this has very little likelihood. In practice as can be seen from Figure 7.4 the B1-TTS has worked with discharges greater than the official *caudal* of 300 l/s, shortening the actual time required to complete the roster. This will be analyzed in the following section,

Table 7.9 compares theoretical maximum values for delivery time with those in years with a complete set of data (1998/99, 1999/2000). As in the other cases, annual delivery times were below maximum when calculated on the basis of TWRA and WRAP in both years. However it was 25% greater than the maximum in 1998-1999, when calculated on the base of actual cropped area - showing that low land use intensity gives farmers in this area room to extend their water application.

Monthly values (Figure 7.5) shows that irrigation use concentrates mainly in winter and early spring, with a second peak in autumn which is sometimes very high as in March 1999. In these periods, at least in the study years, delivery time exceeded maximum times required according to cropped area, but they are still well protected from possible bureaucratic complaints behind the shield of maximum times based on official water righted areas.

Table 7.9 Maximum and real annual delivery time at B1-TTS tertiary unit.

	Max time based on			Actual			
	TWRA	WRAP	ACA	used time	C-TDR		
	days	Days	Days	Days	% TWRA	% WRAP	%ACA
	Agricultural Year 1998 – 1999						
	298	279	166	207	70	74	125
	Agricultural Year 1999 – 2000						
	298	195	141	129	43	66	91
Mean	**298**	**237**	**153**	**168**	**56**	**70**	**108**

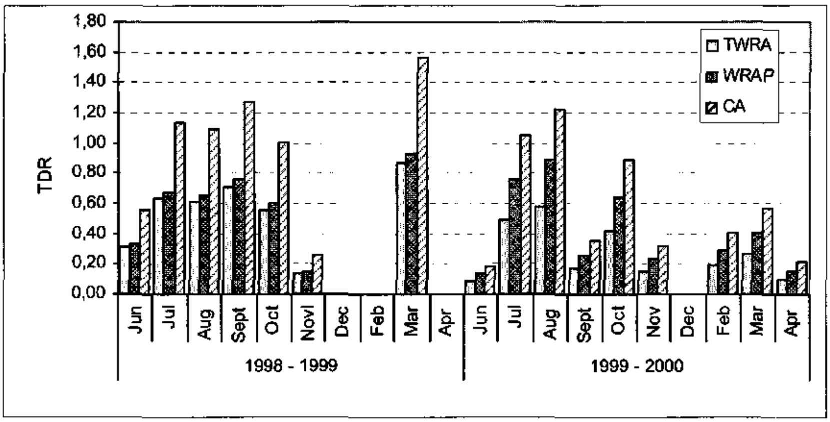

Figure 7.5 Time Delivery Ratio (TDR) of B1-TTS

7.3.5 Delivery discharges

As in the other case study areas, daily discharge of B1- TTS is recorded in daily registers done by *tomeros*. However, unlike those other areas, discharges here are recorded in litres/second and not in *caudales* and there is a greater differentiation in reporting 100, 150, 175, 200 and 300 l/s received at the farm gate. Based on field measurements, a relationship between reported and measured discharge was determined and reported discharge adjusted. On average measured discharges were 33% greater than reported ones.

The variability of discharge evident in this tertiary unit (see Figure 7.4) is accepted and reported by the *tomero* in his daily registers and highly accepted by all users who distinguish discharge variations between turns and during irrigation turns. Use of water by other tertiary canals up and downstream are seen as the main source of B1-TTS discharge variations between turns. Management of water by upstream farmers of TTS tertiary canals are argued as the main cause of discharge variation within turns. Also some farmers recognized that users ask or arrange with the *tomero* to receive lower discharges for different operational reasons (e.g. initiate their irrigation earlier, small area to be irrigated). Normally most users refer to a reduction of discharge when talking about such in-turn discharge variation but some of them also mentioned the frequent increase of discharge when gates upstream are closed, a practice that is frequent at nights.

Discharge variation seems to be more frequent and important here than in other areas and part of the flexible delivery schedule implemented in this area. Nevertheless as in the other cases almost all users stated that such variations did not seriously affect their water management at farm level because discharge changes are compensated for by change in delivery time. This was another proof of the important role of *tomero:* at least one third of the interviewed farmers answered that he moves around irrigating farmers, and always allows them to finish their water application.

7.3.6 Water Use at Comunero Level

According to available information, annual use of water was 862 and 437 mm/year respectively for the agricultural years 1998/99 and 1999/2000. The reasons for such big differences between years could not be fully ascertained. Agency staff talks about an effective reduction of water use related with Agency policy implemented that year to restrict water delivery to those who had paid water fees. It is also possible however that water deliveries were not properly registered that year for the same reason, since there was no parallel drop in cropped area. What is evident from Figure 7.5 is that B1-TTS operation times were shorter than in previous year but registered discharges were also much lower in 1999-2000 than in the first year of the research (Figure 7.4).

The reason to implement this type of unpopular policies by a provincial government with patronage relationships as source of its power was not a sudden interest to improve the system's administration, or promote better water use by farmers. Actually the Agency was pushed to increase collection of water fees by the deep economic crisis that affected the whole country. The irrigation rosters that were issued daily at Agency headquarters included the new pA&EErs. However, once again this policy was decoded on the ground by field officials and users, and most users still got water, confirming to me the close relationship between field official and users. One of these field officials confided to me that it was very difficult for them to reject water to users that needed it and who have been his neighbours and friends for many years.

7.4 Irrigation Practices at Farm Level

7.4.1. Irrigation Strategies

Farmer irrigation strategies in provision of irrigation were surveyed through interviews and cross checking with individual irrigation registers (*boletas de riego*). The results are shown in Table 7.10.

According to interviews answers and field registers with the only exception of onions that receive a subsequent irrigation land for vegetables was only irrigated at the pre-seeding stage. Most farmers plan to irrigate cotton once and maize twice in the crop cycle. This differs from other areas, where irrigation strategies commonly include only pre-seeding irrigation in cotton and a pre-seeding and irrigation at flowering stage in maize. Data from the *boletas de riego* confirms coherence between discourse and practice of farmers

7.4.2 Irrigation turns (events)

Table 7.11 summarises irrigation events (independent of their frequency) per farm in the three agricultural years: it shows clearly there is a low use of irrigation with respect to available possibilities, and the continuous reduction in active holdings.

. **Table 7.10** Farmers' irrigation strategies for predominant crops in TTS tertiary unit.

Crop	Pre-seeding	N° irrigation after seeding	Responses of Farmers Interviewed	Actual Practice of farmers
Carrots	Always (Mar/Apr)	0	20/21	12/12
	Always (Mar/Apr)	1	1/21	
Onions	Always (Mar/Apr)	1⁽¹⁾	11/21	8/12
	Always (Mar/Apr)	0	5/21	1/12
	Always (Mar/Apr)	2	5/21	3/12
Melon	Always (Jul/Aug)	0	6/7	4/4
Water Melon	Always (Jul/Aug)	0	6/6	5/5
Cotton	Always (Aug/Sept)	1⁽²⁾	10/20	6/12
	Always (Aug/Sept)	0	4/20	1/12
	Always (Aug/Sept)	2	4/20	5/12
Maize	Always (Aug/Sept)	2	7/14	4/5
	Always (Aug/Sept)	1	3/14	
	Always (Aug/Sept)	3	3/14	1/5
Small Pumpkins	Always (Sept/Oct)	0	5/5	3/3

(1) Mostly at bulb formation; (2) Mostly between 45 and 60 days after seeding.

Table 7.11 Number of farms and the number of irrigation events in B1-TTS

	N° of irrigation events used									
	1	2	3	4	5	6	7	8	9	10
1998 - 1999	3	8	6	7	4	1	3			
1999 - 2000	8	11	4							
2000 – 2001⁽¹⁾	10	9	1	1						

(1) Incomplete information for initial months of 2001.

Figure 7.6 shows Relative Active Farms (RAF) in each month (the number of farms irrigating in that particular period/total number of active farms in that specific year). There is no regular pattern, showing how farmers adapt their decision-making according to external and internal factors and opportunities.

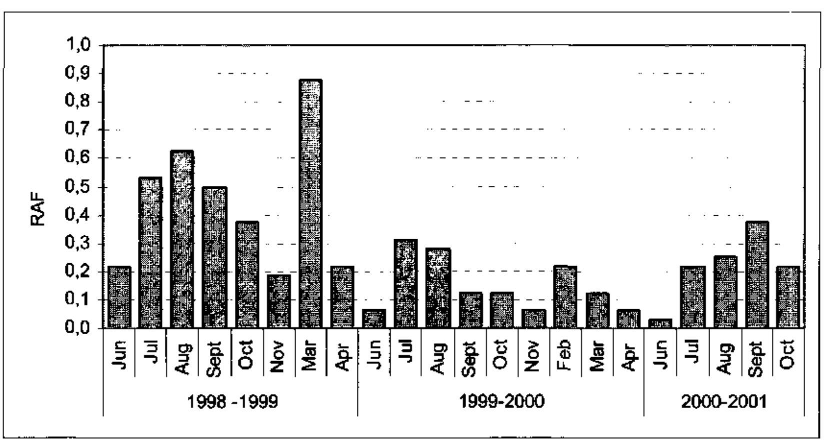

Figure 7.6 Relative Irrigated Farm Activity in TTS

The pattern of 1998-1999, was the most close to expectations according to farmers' declared irrigation strategies, and recommendations for the cropping pattern of the area (see section 7.4.1). Many farms irrigated from July to October and there were a high concentration in March for a pre-seeding irrigation of onion and carrots that should be irrigated later during their growing stages (although according to interviews not all farmers did this). However the number of registered farms irrigating per month in 1999-2000 decreased sharply with respect to the previous year.

Figure 7.7 compares RAF with accumulated rainfall in the first two growing years in order to study whether this reduction in demand was related to high rainfall.

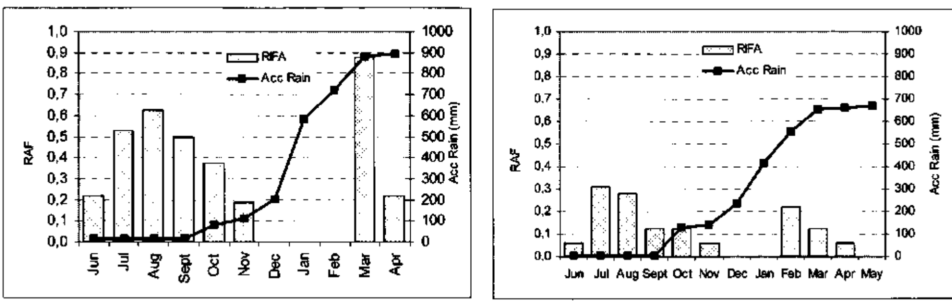

Figure 7.7 RAF in TTS and rainfall in 1998-1999 and 1999-2000 growing years.

In 1998/99 there was a logical high irrigation activity during dry months where predominant crops needed water, and there was a heavy irrigation demand in March for pre-seeding (although the previous rainy season was one of the wettest in history with rainfall almost doubling the 550 mm historical mean annual precipitation). On the other hand, irrigation activity in 1999-2000 was very low during in the dry season and also very low even at the beginning of the next crop season after a rainy season (which was again higher than historical mean though more than 200 mm drier than the previous year).

The above analysis suggests the dependency of B1-TTS farmers' irrigation practices on factors others than rain - in this case the aforementioned Agency policy of delivering water only to those who paid water fees.

7.4.3 Time per Farm

Water is delivered 'until finished' in B1-TTS. Therefore the time used by farmers is considered not only to express their wish or preference but also to demonstrate their internal resources to control water under the specific physical conditions of their fields. Analysis of individual registers (Table 7.12) revealed that the mean annual irrigation time per ha was 3,3 hr with a relatively low variation across the year, but with rather high variability within irrigation events resulting from differences between farmers, as shown in Table 6.10. This information was basically confirmed by structured interviews: 50% of 40 farmers stated that they needed 2 to 3 hr/ha, 20% between 3 and 4 hr/ha, 13% between 1 to 2 hrs, and 10% between 4 to 6 hr/ha.

Table 7.12 Mean irrigation time per ha in B1-TTS.

	Irrigation Turns								Annual
	Jun	Jul	Aug	Sept	Oct	Nov	Mar	Apr	Mean
Mean irrigation time (hr/ha)	3,3	3,1	3,1	4,2	3,4	3,6	3,2	2,1	3,3

Taking the official delivery duration of 50 min/ha as the intended time, the above figures yield an annual Time Delivery Ratio at farm level (F-TDR) of 1,5 considering Total Water Righted Area (Figure 7.8A), and 3,9 if only Actual Cropped Area (Figure 7.8B) is considered. In both cases there is an important variability among turns and among farms within the same irrigation event.

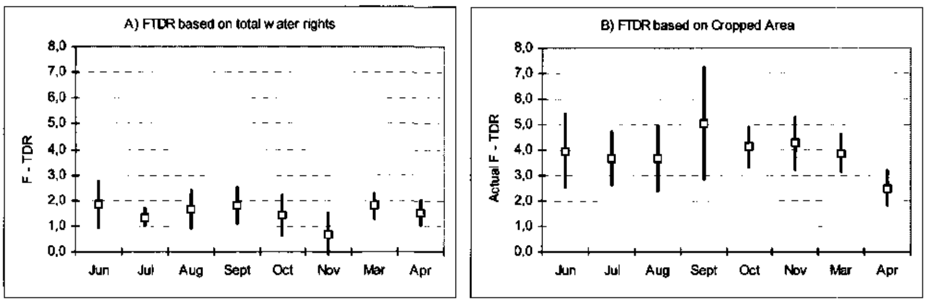

Figure 7.8 Mean and 95% confidence interval for Farm Time Delivery Ratio based on Total Water Righted Area and Actual Cropped Area.

Data shows clearly that despite the arranged rotation delivery schedule, delivery duration is still computed based on total water righted area rather than actual cropped area. At the same time they prove that farmers, even though they have the opportunity of taking water with higher frequency than their colleagues from other zones, use the additional water received due their smaller cropped area to over irrigate their crops.

7.4.4 Water use at farm level

As in all the case studies, water use at farm level was calculated based on delivery time at each farm, discharges reported by *tomeros*, which mainly refer to discharge at the head of the water course and actual cropped area (ACA). Figures could result in higher than actual values at farm level since they hide operational losses in the distribution process, which could be more important in this case than in the other study areas due the arranged rotational delivery schedule. However results are considered sufficiently representative of reality for comparative analysis.

Table 7.13 presents mean irrigation depth for each irrigation event, its mean annual value and the calculated Water Delivery Ratio at farm level (F-WDR) taking as intended delivery the 90 mm/irrigation event officially assumed for the whole PRD. Due the high influence of double cropping, the area effectively worked at each farm were used in this case to calculate the mean water use per ha. Use of total cropped area independent of growing season would decrease mean annual water use from 862 to 517 mm/year.

Table 7.13 B1-TTS mean irrigation depth and mean annual water use at farm level in 1998/1999 irrigation season.

	Irrigation events									Mean water use (mm/year)
	Jun	Jul	Aug	Sept	Oct	Nov	Mar	Apr	Mean	
Mean irrigation depth (mm)	331	306	307	421	344	356	323	207	327	862
F - WDR	3,7	3,4	3,4	4,7	3,8	4,0	3,6	2,3	3,6	0,9

Mean irrigation depth of individual events was shown to be rather higher than that estimated by using the design norm for irrigation depth (90 mm/event). However the lower number of irrigation events (turns) per year used by farmers, yielded an annual mean water use of 862 mm/year and a Farm Water Delivery Ratio of 0,9 taking the righted 990mm/year as intended water allocation per farm and year.

7.4.5 Application Practices

Farmers' application practices were researched through interviews (46% of the total registered farmers at TTS and 56% of those at B1-TTS) and direct field observations.

All 40 farmers interviewed used basin irrigation in pre-seeding irrigation: 28% of them changed to furrow irrigation during crop growth depending on the type of crop and cultivation practices. In basin irrigation the most frequent distance between longitudinal earth ridges (*bordos*) ranged from 20 to 30 m. However around 50% of farmers do not use a constant distance between them, stating that by trial and error they know the best position of *bordos* to improve uniformity of water application and make the irrigators work easier. There are two particular characteristics of this area in relation to *bordos*. The first is that a great majority (93%) build them with some angle with respect to main slope, the second is that their height is normally higher than 30 cm (in most other areas of PRD they do not surpass 25 cm). Half of the interviewed farmers use ridges perpendicular to water flow (*trabas*) and only one farmer used contour *bordos*. Half of them knew about this technique which was then currently expanding as an alternative to costly land levelling, but most of them were not clear about the purpose of, or construction methods for, these contour *bordos*.

A consistent reason for the great height of *bordos* could not be found from the interviews. Some farmers talk about an old advice from engineers at the initial time of irrigation in the area to settled and leach the new lands. Others state that by using high bordos was the only way to irrigate initially due localized soils subsidence also at the beginning of irrigation.

In 18 cases out of 32, there were 2 irrigators present to control water during its application, while in 9 cases only one irrigator performed water application – although five of these admitted that 2 irrigators is the best number for good water control they could not afford to hire extra labour. Most farmers stated that irrigation is not too demanding, since the irrigation sub-units defined by *bordos* and *trabas* are always the same, water off-takes are also at the same place (although there are no permanent structures and they continue cutting and re-building ditch banks). Therefore the task is restricted to controlling unexpected breaks in *bordos* or *trabas* and deciding when to leave the water to flow to downstream units.

Because this final decision is taken when water is almost at the top of *bordos* and *trabas* their height controls water depth, farmers in B1-TTS normally apply higher irrigation depths than in other areas.

Ninety percent of farmers recognized they had land levelling problems in their holding and stated that their only possibility to increase application uniformity is to find right location of *bordos* and *trabas* as they can not afford land levelling. Also 36 out of 38 farmers accepted they had soil salinity spots in the highest parts of their lands, and that this was potentially the result of smaller irrigation depth applications to these areas because of uneven water application.

Rather than contradicting the high mean water application shown in section 7.4.5, this stresses the main consequences of uneven land under basin irrigation, low uniformity of water application and development of salinity spots already found in other areas of PRD (Prieto *et al.*, 1994, Angella, 1999).

It is clear that B1-TTS farmers face resource and technical constraints to control water application and that they are aware of most of their technical problems. However, it is also true that water for them a less scarce resource than labour and capital. Water use is optimized only if these other are present, and there can be land levelling, construction of more *bordos* and *trabas* or use of a greater number of irrigators to improve water control.

In short, despite the 'modern water supply', the irrigation practices at farm level in B1-TTS have stA&EEd within the traditional field water management practices of the area, with only a few particular elements such as greater height of *bordos* that allow application of greater irrigation depth.

7.5 CONCLUSIONS

The findings in B1-TTS show that function of the modern units implemented during the PRD intervention is in many aspects far from designed and expected, an assumption that can be extended to the whole TTS and most areas of the Colonia Simbolar given their design similarities.

Water allocation covered almost 100 % of the designed homogeneous plots. Unlike other PRD areas, there was no mismatch of water rights with existing stakeholders. The presence of only a few PRETAs reflects some very particular situations where they served to allow a few farmers to establish themselves in plots where permanent water rights had been withdrawn. Now change of their permanent water right to PRETAs is seen by many farmers with permanent water rights (who were forced to reduce their cropping areas by factors other than water availability) as a possible solution, to avoid problems in water access given the recent agency policy of restricting water delivery to those paying water fees

Water distribution within the *comuneros* is under the responsibility of SARCCs whose functional constitution, as elsewhere, is restricted in practice to an *administrador*. However, as in JS the other modern tertiary unit under study, the low number of users per *comunero* and the active presence of *tomero* considerable diminish their role in water distribution issues. Users frequently contact the *tomero* and/or District Office directly. This is strengthened by the fact that under the settlement model implemented most B1-TTS farmers live in the small village where the district office is and *tomero* lives.

The modern irrigation delivery package implemented in B1-TTS and in the whole Colonia Simbolar was less reshaped by users here than elsewhere, because the proposed water delivery schedule and its 'soft' application by field officials brings them flexibility to implement their irrigation preferences.

Farm irrigation practices in B1-TTS are characterized (as in the other cases) by a low number of irrigation events and large irrigation depth and a product of long delivery times and rather large delivery discharges. In 1998-1999 these practices yielded a mean annual water use of 8620 m^3/ha that was 90% of the water allocated to them but the highest among study areas.

The three irrigation events per year used on average by farmers in B1-TTS were mainly concentrated in times of pre-seeding of the predominant crops. A maximum of 5 irrigations were apply by farmers with the most diversified cropping.

The mean discharge delivered, 398 l/s was 30% greater than the official 300 l/s and discharge variation between turns and during irrigation turns were more important than in other areas. However, this was still highly accepted by users who also recognized that delivery of low discharges are many times arranged with *tomero* and even requested by them for operational reasons.

Although there was variation during the year and between farms, mean time delivery duration at farm level was 3,3 hr/ha, the greatest among the study areas, and almost 4 times greater than official 50 min/ha. It is possible to extend delivery time per cropped area without bypassing the maximum bureaucratic rule by using the free time available from not cropped areas (almost half of the righted area) and because many time only half of the cropped area is irrigated in each irrigation event.

High discharges and long delivery times led mean gross irrigation depth (327 mm) to be on average 3,6 times greater than the official gross irrigation depth of 90 mm and obviously the greatest among study areas. This is related with irrigation practice. Basin irrigation is the predominant water application method. There are a few particular specific characteristics of field cultivation here, of which the high height of *bordos* and *trabas* (30 cm minimum) is the most relevant in terms of irrigation practice and performance. Together with the almost unlimited delivery times it determines the high irrigation depth since to fill each irrigation pond to its maximum is the practical criterion during application practices.

The implementation of arranged demand in this area by Agency from the beginning of the PRD was to demonstrate the 'modern', 'service' approach promoted by some of their engineers at that time. However the actual objectives of 'no complaints', and use of water allowances as the main strategy to achieve this, has predominated in its operation in the subsequent years.

In this way, farmers' on-farm water management practices have appeared as the principal ally of the Agency and allowing it to reach its objective of minimizing users complaints, again buffering all kind of mismanagement that would be highly unacceptable under more precise water application methods Clearly the modern irrigation package implemented in Colonia Simbolar solved any difficulties in water acquisition by farmers, but did not lead to any change on on-farm water management. Nor was the irrigation design, with the wider resettlement package it came with, enough to prevent the persistent process of impoverishment that B1-TTS farmers have experienced under negative macro-economic contexts and lack of other government policies to promote their development.

Chapter 8

RS -TERTIARY UNIT: INTEGRATING MODERN WATER DISTRIBUTION IN OLD *ACEQUIA* AREAS

The RS is a rotational unit in the complex network of the Suri Pozo secondary canal in zone II. It is defined around an old earthen excavated acequia some 5,7 km long, that splits midway into two branches RS-B1 and RS-B2 (Figure 8.1), completing a network of 23,4 km of watercourses. The RS-B1 branch is a simple watercourse that distributes water directly to farms: B2 is more complex with 7 short sub-branches.

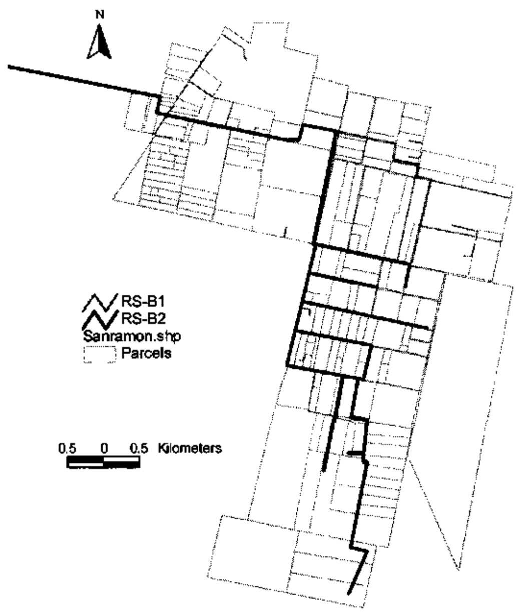

Figure 8.1 The layout of RS tertiary unit

8.1 AGRARIAN STRUCTURE, IRRIGATION WATER ALLOCATION AND CROP PRODUCTION

8.1.1 The Official World

According to official information[8.1] (Table 8.1) the gross command area of RS is 1793 ha and comprises 113 holdings with a complex pattern of holding size and water rights, summarised in Table 8.1. Thirty of these holdings, covering 30% of the gross area, never had any type of water right until 2002. While the 83 water-righted holdings cover 1250 ha (70%) of the gross area, they have water rights for only 801 ha; that is 64% of their gross area and 45% of the whole RS command area. As can be seen from the bottom part of Table 8.1, the water-righted

[8.1]Note that official information about holdings with permanent water rights reflects conditions after the land tenure and water allocation consolidation done by PRD intervention (1968-1973) and not necessarily contemporary field conditions area of holdings smaller than 50 ha accounts for 86% of the area with permanent rights while the remaining 13% belongs to only one large holding of 108 ha gross area.

Table 8.1 N° of holdings, gross area and permanent water righted area in RS (source UER-INTA data base, 1998).

ALL HOLDINGS								
	Holdings		**Gross Area**		**Permanent Water Righted Area**			
	N°	**%**	**Ha**	**%**	**ha**	**%[(1)]**		**Mean**
Without Water Rights	30	27	544	30	0			18
With Water Rights	83	73	1250	70	801	64		10
Total	**113**	**100**	**1793**	**100**	**801**	**45**		**16**
WATER RIGHTED HOLDINGS								
	Holdings		**Gross Area**		**Permanent Water Righted Area**			
	N°	**%**	**Ha**	**%**	**Ha**	**%[(1)]**	**%WR[(2)]**	**Mean**
<5	23	28	122	10	64	8	53	3
5 to10	34	41	300	24	204	25	68	6
10 to 25	21	25	395	32	300	37	75	14
25 to 50	4	5	325	26	127	16	39	32
50 to 100	0	0	0	0	0	0		
100 to 500	1	1	108	9	106	13	98	106
Total	**83**	**100**	**1250**	**100**	**801**	**100**	63	**15 (10)[(3)]**

[(1)]% of the total water righted area [(2)] % of the gross area of the class [(3)] mean weighted by the number of holdings in each class

These figures show the results of the following processes:

- An early process of exclusion from water allocation by state interventions (Los Quiroga and PRD) that left 27% of holdings within the command area without water rights;

- Successful implementation, during those interventions, of the political criteria of spreading benefit of irrigation to a greater number of people by limiting the area with water rights to a maximum of 50 ha;

- A simultaneous application of the prior appropriation principle reflected in the presence of one holding with 106 ha with water rights, which is 98% of its gross area.[8.2].

They also confirm that the above political decisions created a mosaic pattern of irrigated and non-irrigated areas characteristic of PRD command area, leaving in this case 56% of suitable land out of irrigation. This obviously puts irrigation water under high pressure especially in key growth periods of most profitable crops. That is the reason for the higher presence of PRETAs in RS than in the previous cases. As can be seen in Table 8.2, the area under PRETAs in 1998 (the same year of permanent water rights information presented in Table 8.1) represented 27% of the RS's water righted area; a percentage similar to that of the whole PRD (see Chapter 3).

[8.2] Its presence resembles the agrarian pattern in time of old private *acequias*, but this origin could not be effectively proved for RS.

Table 8.2 PRETAs in growing season 1998-1999.

Holding Size (ha)	PRETAS N°	PRETAS ha	PRETAS %(1)	Total Water Righted Area (ha) (2)
<5	3	9	12	73
5 to10	4	24	11	228
10 to 25	5	77	20	377
25 to 50	0	0	0	0
50 to 100	0	0	0	0
100 to 500	1	175	62	281
Total	13	285	30	959

(1) Percentage of the total righted area (2) Permanent Water Rights + PRETAs

The fact that 2 of the 13 plots with PRETAs also have permanent water rights while 11 (including the largest one of 175 ha) do not is a clear sign that PRETA is a functional institution within the PRD context for cropping new areas and/or for expanding cropped areas within a holding without full water rights.

Figure 8.2 presents the spatial distribution of holdings in RS, differentiating holdings with permanent rights, PRETAs and without water rights. It has to be stressed that most PRETAs are at the tail of branches or sub-branches which, according to the well accepted mode of water distribution in the PRD, means that they should be watered before many permanent water righted areas. This is not a small second sign about the solid acceptance of PRETAs in the PRD.

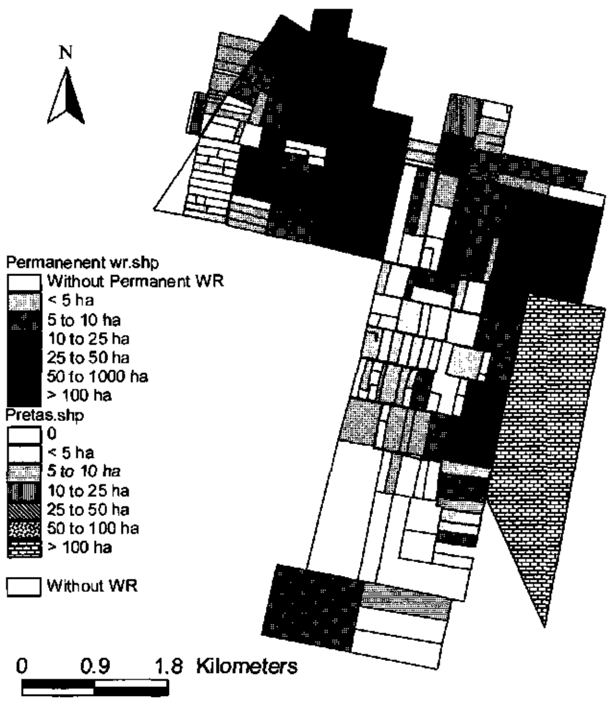

Figure 8.2 Location of holdings with PRETAs in the 1998 season (Source own survey)

8.1.2 The Real World.

As in previous cases field surveys revealed differences between the real and official worlds in JS, as summarised in Tables 8.3 and 8.4. There was not much difference between official and actual records about the number of permanent water righted holdings that were not cropped as shown in Table 8.3. More significant from the perspective of water use and social relations is the real agrarian structure of the above 60 to 70 active holdings, especially when related with numbers of farmers, as shown in Tables 8.4 and 8.5.

Table 8.3 Cropped and abandoned holdings in RS (Source UER-INTA 1998 users data base and own survey).

			Surveyed					
Holdings	Official		1998		1999		2000	
	N°	HA(1)	N°	HA(1)	N°	HA(1)	N°	HA(1)
Abandoned	18	246	18	246	14	250	21	272
Cropped	65	555	65	555	69	551	62	529
Total	83	801	83	801	83	801	83	801

(1) Permanent water rights

Table 8.4 Real agrarian structure (based on N° of farmers) of RS in 1998 (source own survey).

Active holdings	**Total Water Rights Area(1)**				**Cropped Area**			
Size (ha)	**N°**	**%**	**Ha**	**%**	**N°**	**%**	**ha**	**%**
<5	6	18	19	2	10	29	22	2
5 to 10	13	38	81	8	10	29	65	7
10 to 25	9	21	93	9	6	18	90	10
25 to 50	2	6	81	8	2	6	79	9
50 to 100	3	6	165	17	3	9	209	23
100 to 500	2	12	555	56	3	9	451	49
Total	**34**	**100**	**993**	**100**	**34**	**100**	**914**	**100**

(1) Permanent + PRETAs Water Rights

The number of farmers (34) is only about half of the number of cropped holdings (65). Farmers with less than 25 ha are 28% of the total number of farmers with water righted plots rather than the 94% concluded from information based on number of holdings (compare with Table 8.1) and they are cropping only 19% of the cropped area instead of the expected 70%. On the other hand the cultivated area of the tertiary unit increased from 801 to 914 ha over the study period and land ownership was highly concentrated (eight farmers cultivate 81% of the area[8.3])

[8.3] Most of the 8 largest farmers crop a relative large number of small plots as it can be seen in following table.

Holding Size	Farmer	N° holdings	> 10 ha	< 10 ha
25 to 50 has	1	7	0	7
	2	1	1	
	3	11	1	10
50 to 100 has	4	3	1	2
	5	9	2	7
	6	19	4	15
100 to 500	7	5	2	3
	8	1	1	

There is no evidence that the main reason of this process of land and water concentration is a struggle about water. Rather it seems to be around the low profitability of irrigated agriculture in the PRD since the 1980s, and the neo-liberal model implemented since the 1990s in particular. These no longer protect smallholder farmers and push entrepreneur farmers to increase their production scale to keep up. No less important has been the lack of concrete and effective support to small farmers by provincial policies.

8.1.3 Production systems and cropping patterns

Field surveys showed that most farmers fall in the classification of small household systems (M, in the classification of Radrizzani, 2000 see chapter 4), that have left agricultural activities due the lack of profitability and lack of official support. Most of them are still living in their farms and have assumed a livelihood strategy of leasing their lands to entrepreneur farmers who gradually are dominating the RS unit and driving a new production scenario. In fact two groups can be distinguished within the now predominant type of production system. On is composed of local farmers, who, using their excellent knowledge of the area and local people are expanding their cropped area by cropping a relative large number of small plots, through different agreements with their owners. The second group is made up of newcomers or 'outsiders' who concentrate their production by leasing large plots with or without permanent water rights (they use PRETAs in this case)

Both groups have a diversified cropping pattern. The group of local farmers has incorporated new cash crops such as soybean but still base their production on the traditional alfalfa and cotton crops. The 'outsiders' group has a more dynamic cropping pattern that changes annually based on market opportunities. Although analysis of these dynamics is beyond the scope of this thesis it has clearly been a result of national and provincial economical models, especially of the neo-liberal policies implemented during the 1990's that greatly reduced opportunities of smallholder farmers and were completely unrelated to their excellent access to water.

The cropping pattern for the 6 agricultural years 1996/7-2001/2 is shown in Table 8.5. This confirms the continuing strong presence of traditional crops like cotton and alfalfa but also the increment of areas of soybean and commercial crops of maize and wheat.

Table 8.5 Cropping pattern (ha) for the agricultural years 1996/97 to 2001/02

	Agricultural Year					
Crop	**96-97**	**97-98**	**98-99**(1)	**99-00**(1)	**00-01**(1)	**01-02**
Cotton	84	187	152	46	0	20
Alfalfa	65	58	157	152	163	136
Soybean	175	85	333	194	186	107
Maize	27	60	106	156	151	34
Guinea Maize	0	4	55	43	33	16
Vegetables	3	24	60	90	164	75
Pastures	0	3	32	34	34	88
Alamo	0	0	24	46	82	33
Wheat	198			147	143	286
Total Area	**552**	**419**	**918**	**908**	**955**	**805**

(1) Studied irrigation seasons

Although beyond the scope of this thesis it is worth highlighting that the outdated official information allows some of these farmers, (1, 3, 5 and 6) to get benefit from periodic political decisions of the provincial government in favor of smallholder farmers (less than 10 ha) not having to pay water fees.

The great reduction of cotton area in the study period and changing area of other extensive crops such as soybean, maize and wheat support the earlier statement on the dynamism of crop choices based on market opportunities.

8.2 Institutional Arrangement and Operation of Water Distribution at Comunero Level.

8.2.1 Institutions and Organizations

As in *comuneros* of the modern tertiary units, water distribution in RS is entirely under the responsibility of a SARCC. However in this case the SARCC's role appeared *a priori* more relevant, and in terms of this socio-technical analysis gives users' greater *room to manoeuvre* The *tomero's* role is restricted to his main task of controlling RS's gate from the tertiary canal. However, because the RS is not gated and is the last *comunero* served from the tertiary canal, its discharge should be controlled by a correct management of cross regulators and offtakes upstream.

The actual constitution of RS-SARCC does not strictly follow official regulation as dictated in 1971. There is only one functional official position, the *administrador* (*vice-administrador*, secretary, treasurer do no exist in practice[8.4]) and in spite of the rather long length of the water course, a *celador* has never been appointed. The organization of users revives clearly the historical features of former times, with the *adminstrador* as the key actor in the water distribution process, a role blurred in modernized units by the increased role plA&EEd by *tomeros.*

Mr. AJ, the *administrador*, was appointed 12 years ago after the death of his father, who was in that position for many years. Mr. AJ combines his daily task as *administrador* with his own rural activities. During irrigation turns, early in the morning he visits key places of the water course to check (based on his own benchmarks) ongoing discharges. If something is detected (the most common is a reduction of discharge) or he is notified by any user of some problem he goes upstream himself or asks someone else to look for the reason. He has the skill and leadership to organize collective actions, and to mobilize required resources to solve most common problems. Only in exceptional cases does he ask for help from the district office.

He has a close control of who is irrigating and of the needs of most users (by talking with them or receiving requests) and if necessary he consults with involved users over changes on irrigation order. In general there is a collaborative attitude from most users. Specifically, however, he is normally assisted by his brother who controls the most downstream third of B2-branch where his main farming activities lie, while Mr. AJ concentrates his own activity in the most upstream third of the water course before the main bifurcation.

Internally, the *administrador* is responsible for organization of annual meetings of the SARCC, for collective activities and for the administrative issues required by the agency, and completing the of *boletas de riego* (individual irrigation register) that should be returned to *tomero* at the end of the irrigation turn. They should be signed for each user independent of whether they have used or rejected that specific irrigation turn.

[8.4] Actually none of the interviewed farmers (80% of farmers) remembered the name of the vice-*administrador* and secretary and most doubt about their appointment. Only 11% could give the name of the treasurer.

Externally, the *administrador* has a close contact with the *tomero* and with the *capataz* (the second position in the administrative structure of the district office who is in charge of daily operation of the irrigation district). He frequently visits the district office to know in advance what is going on upstream and to transmit specific requirements of RS users. If the importance of the topics is high, the *administrador* action is typically reinforced by the largest of RS's farmers.

It was clear during the field work that Mr AJ is *administrador* not because nobody else accepts that position. Rather it is that his leadership and power is well recognized and accepted by both smallholder and entrepreneur farmers who both pointed out his collaborative attitude and friendly relationships with most of them. Both types of farmers turn to him when they face some irrigation problem (commonly a need to extend irrigation time or to move forward their irrigation turns) and almost all of them trust Mr. AJ's work (90 % of the registered farmers are highly satisfied with his work). The very few (5%) expressing some disagreements are mainly tailenders facing frequent low discharge problems.

In RS it is more evident than in previous cases that being *administrador* is a time consuming position, justifying that 71 % of RS's users consider this should be a paid position: 96% of them state that they would reject the appointment if they were proposed. But also, at least in this case, it was clear that the *administrador* is also a position that gives opportunities. This can be concluded from the fact that Mr AJ and his brother have established joint businesses with some smallholder farmers (production of charcoal and alfalfa bales) and they have expanded their cropped area by cultivating various small plots whose owners have left agriculture.

8.2.2. Collective Actions - Maintenance

According to interviews, 78% of the farmers consider *administración* the best approach to undertake maintenance of SRs *comunero*. Preferences were not highly correlated with farming type and potential capacity for resource mobilization: 51% of the those preferring *administración* were smallholding farmers with less than 10 has, while they represented 62% of those who select *reparto* as the best method. In accordance with farmers' preferences water course maintenance is done by *administración* in RS. The work is done using tractors from entrepreneur farmers and hiring labourers for manual cleaning of watercourse banks. Water users should pay for that work according to their water righted area (including PRETAs) independent of their location within the water course. The amount paid in 1998/1999 season was A$2/ha (one tenth of the annual water fees[8.5]). In fact, in the recent years of higher farmer differentiation many small farmers have not contributed to maintenance of the watercourse. According to the *administrador*, their debts are registered and mostly written off after some years. From the smallholder farmers' side, the fact that large farmers have to assume the whole maintenance cost is seen as fair since they are the large water users.

[8.5] Independent of the fact that the opportunity cost for large and small farmers is certainly different, A$ 2 is lower than the cost by *reparto* that would have ranged from 2,5A$/ha to 5A$/ha (values obtained considering 50 to 25 m of water course banks should be maintained per ha depending of the cropping area and a mean yield of 10m/man-hour and a cost of 1 A$/man-hour).

8.3 Irrigation Practices at comunero level

8.3.1Water Delivery Order

As stated for all the case studies, it is a strong institution within PRD to start water distribution at the last (tail) holding and progress upstream during the irrigation turn. Although that principle was followed in both RS branches, the actual water delivery order was rather different from the official one. Figure 8.3 compares the official and actual delivery sequence of 5 of the 6 irrigation turns of RS-B1 in the agricultural year 1998-1999. It shows that at least for RS actual delivery order is made more flexible than the official schedule by frequent interchange among groups of neighbours. These changes are well known and accepted by all users (100% of positive support in structured interviews).

The *administrador* argues that changes are made when those farmers that should receive water are not ready to do it, or when an upstream user (when close to the farmer with the official turn) has a clear urgency to bring forward his irrigation turn. In both cases he can change the watering order after consulting with involved farmers.

Officially farmers who are not ready to receive their irrigation turns should wait until the end of the turn to receive irrigation water. However, the criteria in the users' world is that they should receive water as soon they are ready - except if for practical reasons it is more convenient to finish the rota (for instance when the irrigation turn and water has progressed too far from their farms). The *administrador* has complete authority over this type of decision.

8.3.2. Irrigation Turns

The number of irrigation turns used by farmers in RS ranged from 5 to 7 (Table 8.6), far from the 11 available according to official delivery schedule. In the three agricultural years studied, farmers used consecutive irrigation turns (after the shutdown period) from June to November, but rejected summer (rainy season) turns and then re-started irrigation in March or April just before the shutdown period of the next year.

This low pattern of use is determined by farmers' irrigation practices and not by lack of available water and leads to an annual operation time per year ranging from 35 to 60% of the available duration time according to their water rights.

Table 8.6 N° of turns/year in RS tertiary unit. (UER daily irrigation registers)

	Agricultural Year	N°Turns	Month of Irrigation Turns 1	2	3	4	5	6	7
B1	98-99	6	Jun	Jul	Aug	Sept	Nov		April
B2	98-99	6	Jun	Aug	Au				
B1	99-00	6	Jun	Aug	Sept	Oct.	Nov	Dec	
B2	99-00	6							
B1	00-01	5	Jun	Aug	Sept	Oct			March
B2	00-01	7	Jun	Aug	Sep	Oct	Dec	Jan	March

8.3.3 Delivery Frequency

The frequency of irrigation turns is another parameter that differs from the stated official delivery schedule, as shown in Table 8.7.

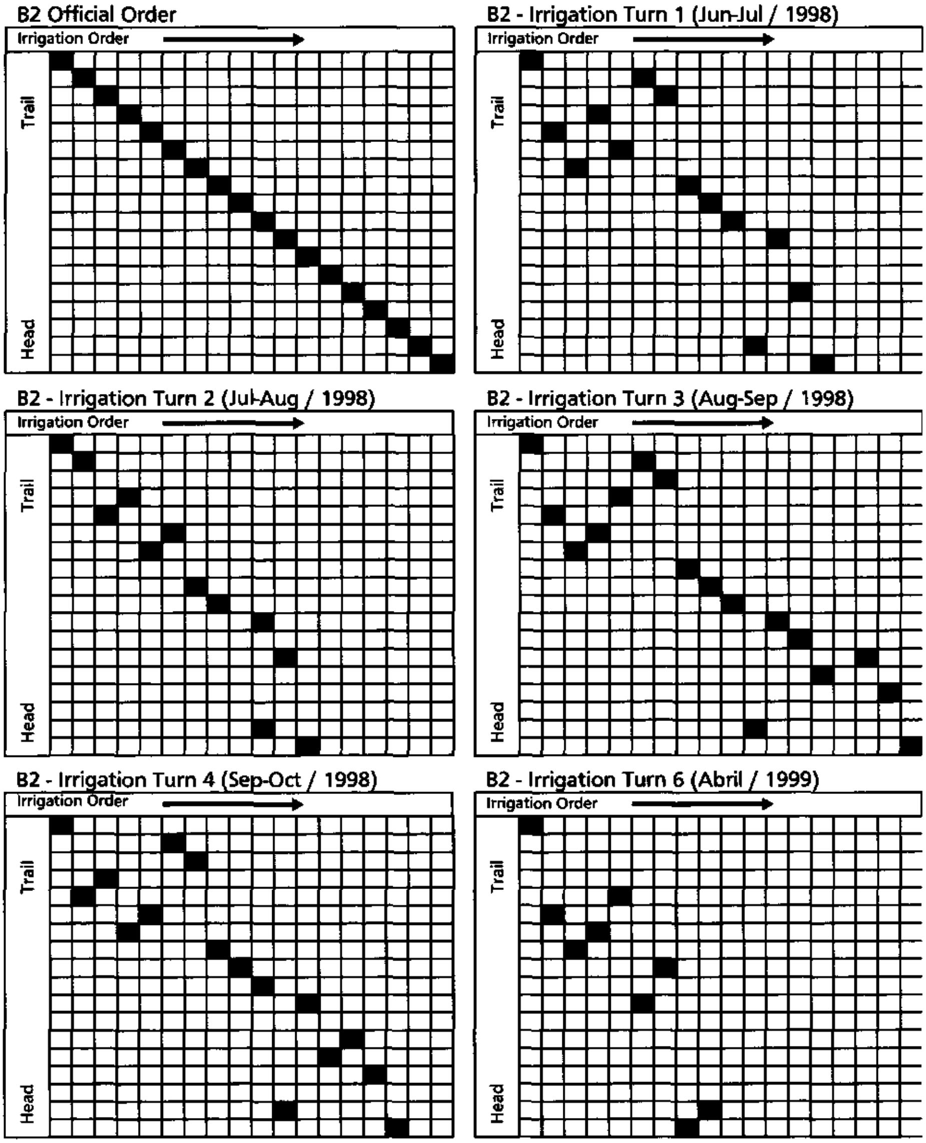

Figure 8.3 Comparison of official and actual irrigation order in RS- Branch 2. Agricultural year 1998-1999

In almost all cases the interval between irrigation turns is greater than the official 28 days. However, there are some exceptions especially for branch B2 where intervals can be as short as 10 days. These exceptionally short frequencies are not only associated with possibilities of delivering 2 *caudales* in the RS water course, but also with the existence of 'free' (surplus) water from any of the other upstream *comuneros* fed by the tertiary canal.

Table 8.7 Interval (days) between consecutive irrigation turns in RS *comunero.*

			Agricultural Year 1998 – 1999			
From To	Jun-Jul Jul-Aug	Jul-Aug Aug-Sep	Aug-Sep Sep-Oct	Sep-Oct Nov-Dec		Average
B1	30	34	42	38		36
B2	36	39	36	49		40
RS	30	34	42	38		36
			Agricultural Year 1999 – 2000			
From To	Jun-Jul Aug	Aug Aug-Sep	Aug-Sep Sep-Oct	Sep-Oct Nov-Dec	Nov-Dec Dec-Jan	Average
B1	42	26	36	45	31	35
B2	40	10	27	48	44	32
RS	42	10	27	48	44	32
			Agricultural Year 2000 – 2001			
From To	Jun-Jul Aug-Sep	Aug-Sep Sep-Oct	Sep-Oct Oct-Nov	Oct-Nov Dec	Dec Jan	Average
B1	36	55	53	24		42
B2	29	42	24	81	19	39
RS	34	42	24	68	32	40

Long intervals between irrigation turns are influenced by water management upstream of RS, but there is also a great local component related to the duration of RS irrigation turns. Figure 8.4 shows that there was a continuous flow to RS *comunero* from June 26th, 1998 at the start of the first irrigation turn in agricultural year 1998/99 until September 14th, 1998 when B1 finished its third turn. This proves that the long interval between irrigation turns (30 and 34 days) in that period was caused entirely by a long internal irrigation cycle within RS. On the other hand the long interval between Jun-July and August irrigation turns in the 1999-2000 agricultural year was caused by a lack of available water for RS determined by management of the systems upstream.

8.3.4. Delivery Duration

RS is one of the many existing water course converted into a rotational unit during the PRD intervention. With 781 ha of permanent water rights and one day of *recorrido*[8.6], officially it would take 28 days, exactly the official water delivery frequency, to irrigate the whole area with the scheduled water delivery duration of 50 min/ha.

However, as can be seen from the second to the fourth column of Table 8.8, with the increased water righted area by PRETAs the required duration of irrigation turn extends beyond 28 days if only one caudal is used (keeping water course as one rotational unit). Actually, longer durations (32 to 40 days) are needed to complete the roster while maintaining water delivery duration of 50 min/ha even if only water righted of active parcels (as should be) were considered (see the right half of Table 8.8). This makes clear the need to work with 2 *caudales* in the RS comunero after inclusion of PRETAs, at least during some periods.

[8.6] *recorrido* is the time taken by water to fill the water course until the last holding (first irrigator) to assure the normal delivery discharge at the beginning of irrigation turn.

Table 8.8 Turn duration (days) required in RS considering PRETAs.

	PWR	Based on TWRA[1]			Based on WRAP[1]			Based on ACA[1]		
		98-99	99-00	00/01	98-99	99-00	00-01	98-99	99-00	00-01
	days	Days	days	days	days	days	days	days	days	days
B1	17	25	23	28	21	18	24	20	20	21
B2	10	11	11	13	11	11	8	12	12	12
RS	**27**	**37**	**34**	**40**	**31**	**29**	**31**	**32**	**32**	**33**

[1] Permanent + PRETAs

Figure 8.5 confirms this point. Two caudales have been used in different periods in the growing years 1998/99, 1999/00 and 1900/01[8.7]. This irregular use of 2 *caudales* - twice in 1998/99; four times in 1999/00 and three times in 2000/01 - suggests that it is based more on an arranged responsive approach of the management rather than on a fixed planned operational schedule.

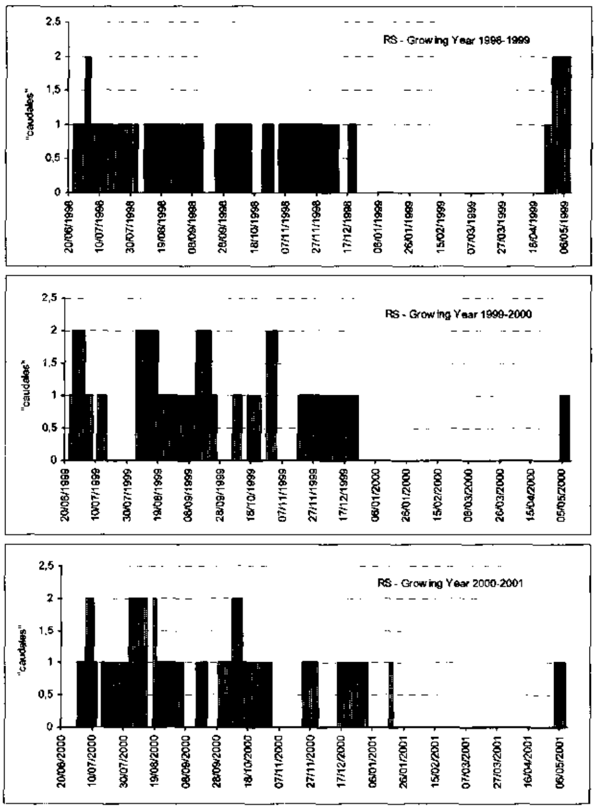

Figure 8.4 RS' daily discharge during the growing years 98/99, 99/00 and 00/01.

The real annual water delivery duration of the RS *comunero* and its two branches was compared with their theoretical durations, based on the official 50 min/ha and considering total water rights (TWRA), water rights of active parcels (WRAP) and active cropped area (ACA). The results are given in Table 8.9, and show that these real deliveries were 32% to 45

[8.7] As in previous cases discharge variations within the stated *caudales* will be analyzed later in this chapter.

% lower than expected according to TWRA, 41 to 53% lower considering WRAP and 39 to 52% lower if ACA is taken as the base for calculation.

Table 8.9 N° of turns/year, real and theoretical annual working time.

		Maximum time based on			Actually	C - TDR		
	N° Turns	TWRA days	WRAP days	ACA Days	used time days[1]	% TWRA	% WRAP	% ACA
				Agricultural Year 1998 – 1999				
B1	6	280	226	219	127	45	56	58
B2	6	126	118	131	66	52	56	50
RS	6	407	344	351	182 (193)	45(48)	53(56)	52(55)
				Agricultural Year 1999 – 2000				
B1	6	256	203	217	119	59(47)	59	55
B2	6	120	118	130	53	45	45	41
RS	6	376	321	347	141 (173)	37(46)	44(54)	41(50)
				Agricultural Year 2000 – 2001				
B1	5	305	261	231	119	39	46	51
B2	7	138	85	133	50	36	59	38
RS	7	443	346	365	141 (169)	32(38)	41(49)	39(46)
				Mean Values				
B1	6	281	230	223	122	44	53	55
B2	6	128	107	132	56	44	53	43
RS	6	408	337	354	178	38(44)	46(53)	44(50)

[1] For comparative purpose this column includes between brackets apparent time – time of days used if one caudal is considered.

However as in the other case studies these annual figures give a rather incorrect and exaggerated idea of underutilization of water and hide even existing overuse during individual irrigation turns. For that reason analysis of delivery duration of individual irrigation turns (Figure 8.5) allows a better analysis of real irrigation practices and water use in RS.

Data shows clearly how flexible water distribution is in RS. Delivery times were greater than allowed time based on Actual Cropped Area (ACA) and even on Water Righted Areas of Active Parcel (WRAP), several times in each individual branch. However due to compensation among branches and mainly by the use of 2 *caudales* that allowed simultaneous irrigation in both branches, delivery times for the whole RS overpass few times the allowed time based on WRAP and ACA and never the maximum times stipulated by the TWRA (Permanent + PRETAs). This fact protects field officials from any bureaucratic complaints and gives active farmers room to apply more water per unit area without affecting the official duration of the delivery schedule for the whole RS.

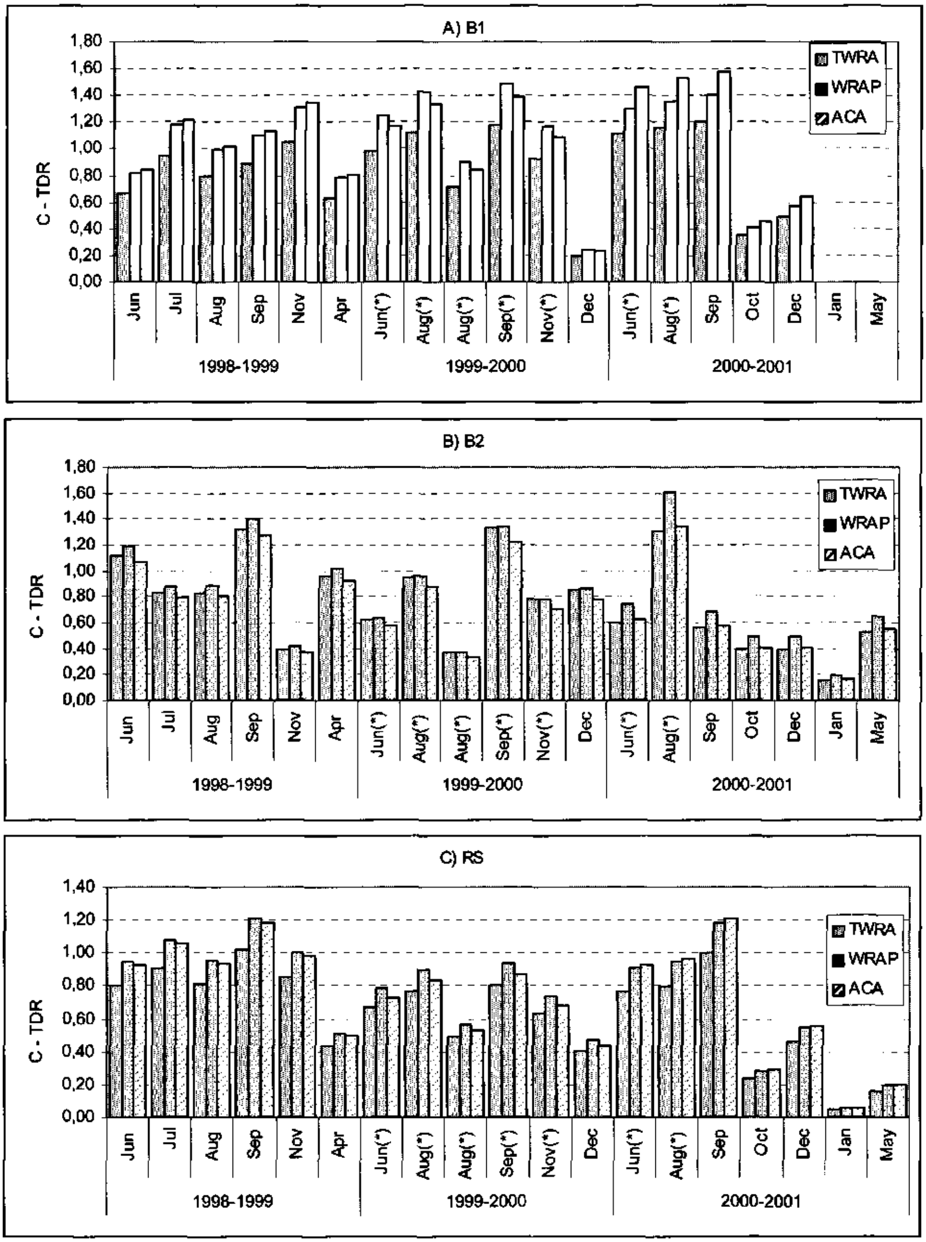

Figure 8.5 Comparison of delivery duration of individual irrigation turns in relation to water righted area of all parcels, active holdings and actual cropped areas (*) months with 2 *caudales*).

8.3.5. Delivery discharges

Delivery discharges are another important component of operations by which to assess water use. As in the previous analysed areas, in RS official use of *caudales* as the discharge unit at tertiary level hides a discharge variation among irrigation turns and even during the same turn. Table 8.10 shows mean and 95% confidence interval of discharges reported by the *tomero* as 1 or 2 *caudales*. Mean discharges are more than 50% higher than official scheduled flows, and their variation is rather high. There are also important differences from the other study cases, for instance the flow reported in RS as 1 or 2 *caudales* were 100 % and 66 % greater respectively in relation to JS's discharges.

Table 8.10 RS Discharges reported as one or two *caudales* by *tomero*.

Caudal reported	N° Measurements	Mean Discharge (l/s)	Limits 95% confidence interval (l/s)		Variation Coefficient (%)
			95% max	95% min	
1	14	487	572	402	32
2	8	805	928	682	25

The reasons for this discharge variability could not be deeply investigated since that would require a complete and precise analysis of the whole tertiary canal and the Suri Pozo secondary canal. However users' visions about discharge, discharge variation and their effect on on-farm irrigation practices were surveyed through structured and non-structured interviews. These findings about the amount of water received at farms offtakes are presented in Table 8.11

Table 8.11 Users' assessment about delivery discharge received (%)

	SCARCE	ADEQUATE	ABUNDANT
RS-B2	0	27	10
RS-B1 (DOWNSTREAM)	6	14	2
RS-B1 (UPSTREAM)	3	17	21
RS	9	58	33

n=100 (34 farmers answering separately for each farm they crop)

There were different responses between branches: none of the farmers from RS-B2 qualified delivery discharge as scarce while 9 over 63 cases did in RS-B1. Within branches there were clear differences between head and tail enders, with most users assessing water as abundant concentrate in the upstream segments and most scarce answers coming from the downstream half of RS-B1.

Based on the above results stream flows were measured downstream of the diversion of the second small RS-SB1's sub-branch. Although the number of measurements (6) was too low to be conclusive discharges at that level was found to be on average 30 % lower than stream flows at the head of RS, but their average (414 l/s) still 30% higher than the official delivery discharge (300 l/s) justifying the high number of adequate answers collected even in this area. These differences are the main reason for frequent complaints of farmers from the lower reach of the watercourse. The *administrador* admits differences in some turns and declared that he compensates for this by allowing longer irrigation duration to affected farmers.

Similar to findings from the other studies, not all farmers perceived discharge variations. Only 33% of the RS's farmers answered positively that there are discharge variations worth mentioning. However there were differences between RS branches; 43% users of RS-B1 branch answered that stream flows varied among irrigation turns and often during an irrigation turn, while only 17% of RS-B2 farmers observed the same. In spite of these differences, both groups agreed however that discharge variations do affect their irrigation practices at farm level, since low discharge can be compensated for by longer delivery durations.

There were two well differentiated types of answers about reasons for that variation. The upstream users, the administrator and *tomero* attributed discharge variation in the RS *comunero* to uncontrolled water use upstream. Farmers at mid-course and especially at the tail of the water course attributed them more to the permission (by the *administrador*) or refusal (*stolen*) of use by upstream users. Certainly both groups were correct in their appreciations, since variation of discharge at the head of the RS *comunero* highlighted by upstream users and the *administrador* and water leakage at upstream farms gates (intentionally or not) were clearly observed during the field work and seepage along the earthen water course is also logically assumed.

8.3.6 Water Use at Comunero Level

Figure 8.6 compares the official or intended water allocation and the mean gross water annual use for RS and its branches in the agricultural years under analysis[8.8]. There is no clear pattern. While annual water use was over the official water allocation in the first year, it was almost 10% lower in the second and third years. Difference between branches were also unstable, while their water use was similar in the first year, RS-B1 consumed almost 1000 m^3/ha more in the second year and RS-B2 water use surpassed RS-B1 by almost 2000 m^3/ha in the third year.

Since the cropped area were similar in the three years (see table 8.6) these differences in annual water use per ha could be explained by a change in the cropping pattern, with more vegetables and less cotton in the last two years with respect to the first. The almost uncontrolled irrigation practices could be also other source of variation.

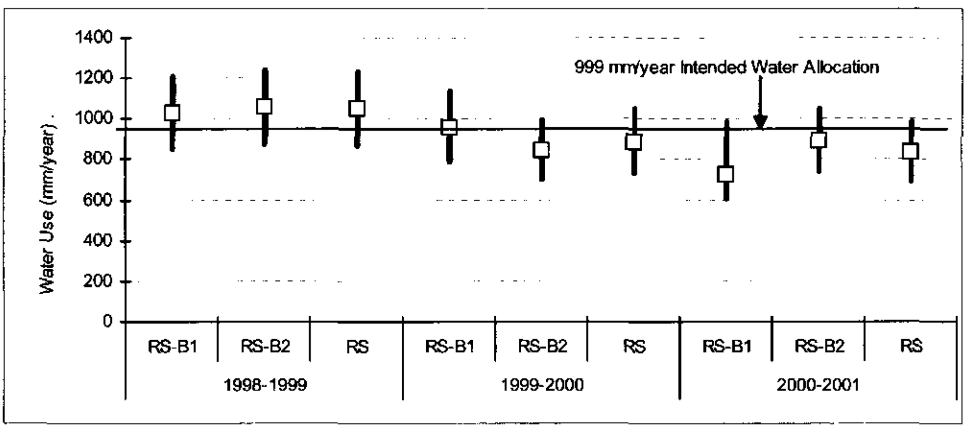

Figure 8.6 Mean annual water consumption in RS tertiary unit

[8.8] The intended scheduled delivery (9.900 m^3/ha) was calculated from the official delivery discharge of 300 l/s; the official delivery duration time of 50 min/ha and the maximum number (11) of irrigation turns/year. Mean annual gross water use or gross irrigation depth per turn in Table 8.12 and Figure 8.10 were calculated from the water volume derived and the area effectively irrigated. Due the qualitative daily register of discharge by *tomeros* the mean discharge and its 95% confidence limits (table 8.10) were used to calculate the volume derived. This procedure, that was the only one available due the failure of direct daily measurements of water depth by *tomeros* adds some uncertainty to the absolute values presented, but it is enough accurate for description and comparative studies.

Table 8.12 presents mean annual gross irrigation depth for each irrigation turn of the 1998-1999 year for the RS and its branches. Although annual values as stated before are close to the official scheduled amount in this particular year, the gross irrigation depth for each irrigation turn is 3 to 4 times greater than designed (90mm). This shows that the irrigation gift used and irrigation scheduling are the main departures from the designed schedule.

Table 8.12 Mean gross irrigation depth for each turn in 1998-1999

	Irrigation Turns						
	1	2	3	4	5	6	**Mean**
RS-B1	410	345	320	384	332	388	**363**
RS-B2	370	312	323	279	252	357	**316**
RS	**390**	**335**	**321**	**331**	**317**	**375**	**345**
C-WDR	**3,5**	**3,0**	**2,9**	**2,9**	**2,8**	**3,3**	**3,1**

To close this section, Figure 8.7 summarizes the above information of the 1998-1999 year for the whole RS and its branches and introduces the variability, another important feature of the real practice in RS and in the whole PRD.

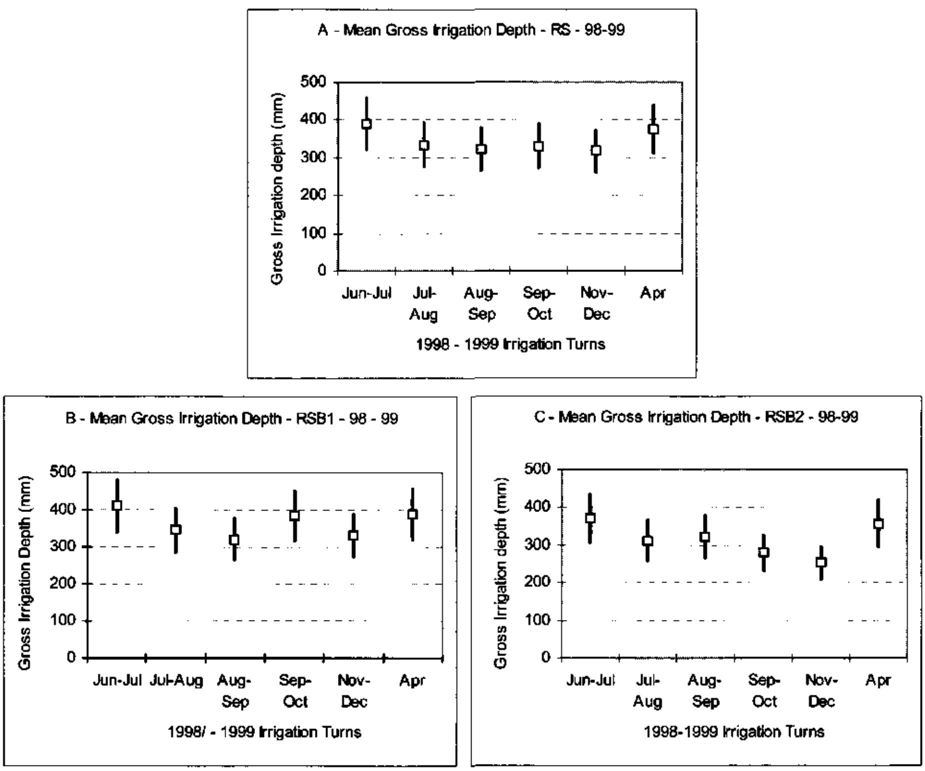

Figure 8.7 Mean and 95% confidence interval of gross irrigation depth in the growing year 1998-1999 (A – whole RS; B – RSB1; C - RS B2)

The annual pattern of the gross irrigation depth of the whole RS (Figure 8.7 A) shows its higher values in the irrigation turns after (Jun-July) and before (April) the annual shut down of the systems normally scheduled in May. This denotes the farmers' practice of storing as much water as possible before, and of recovering a good moisture profile after, the system shut down period that normally lasts more the one month. The even irrigation depth in between can be explained by the crop pattern (see below) and traditional farmers irrigation strategies on most crops (section 8.4.1).

There is some difference between branches explained rather by a higher presence of cotton and maize in RS-B1 cropping pattern of that year than by the type of farmers. It was the pre-seeding irrigation of these two crops that increased the gross irrigation depth applied in Sep-Oct and Nov-Dec irrigation turns in RS-B1 over RS-B2 values that decreased as a consequence, in that it is normal farmers' practice not to irrigate alfalfa in this period and soybean was the predominant crops in that particular branch in that year.

8.4. Irrigation Practices at Farm Level

8.4.1. Irrigation Strategies

Farmers' irrigation strategies were researched through structured interviews and farmers' answers contrasted with data in the individual irrigations registers (*boletas de riego*) to confirm the real fit of discourse and practices (Table 8.13).

There were only slight differences between stated and practiced irrigation strategies during crop growth. However information from individual irrigation registers for each holding unmasked two irrigation practices missed in structured interviews; irrigation of fallow lands during winter and a frequent application of two pre-seeding irrigations in all spring-summer crops.

Another point to be highlighted is the fact that no crop is irrigated more than 5 times per year even those that received a winter and two spring pre-seeding irrigations. This practice differs considerably from the technical advice based on CROPWAT 7.2 approach.

8.4.2. Irrigation Turns

Table 8.14 presents the number of turns used per farm in both the different branches of RS. In agreement with farmers' irrigation strategies in most crops, the mean number of irrigation turns used ranged from 3 to 4 with slight differences between years and branches. Actually those farmers that used 6 or more irrigation turns did not irrigate their crops 6 or more times, but partially irrigated their cropped area in one turn and completed it in the following irrigation turn.

Figure 8.8 show RAF (N° of farms irrigating/Total number of active holdings). As in other study units there was a logical general tendency to use irrigation during the dry season (April-November). However the low number of irrigation turns used in both branches in the dry 2000-2001 irrigation season suggest that differences between years would respond more to operational (systems functioning) or bureaucratic reasons (demand of water fees payment to get irrigation water) than to specific climatic conditions.

Table 8.13 Farmers' declared irrigation strategies in RS tertiary unit and actual irrigation strategies followed in the growing season 1998/1999

Typo of Crop	Declared irrigation strategies: Irrigations – Pre-seeding	Declared: Irrigations – After seeding	Declared: N° of Farmers	Actual irrigation strategies: Irrigations – Winter	Actual: Irrigations – Pre-seeding[1]	Actual: Irrigations – After seeding	Actual: N° of Farmers
Alfalfa	Always = March/April	Every month (April to Sept)	10/21			5 times Jun to Oct	5/13
	Always – March/April	2 times in winter	8/21			4 times Jun to Sept.	4/13
	Always – March/April	Others	3/21			3 times Jun – Aug – Oct	4/13
Cotton	Always - Aug/Oct	1 time (45-60 days) if dry summer	10/18	1 time	2 times	1 time	4/10
	Always - Aug/Oct	1 time (45-60 days)	5/18	1 time	2 times	2 times	2/10
	Always – Aug/Oct	Others	3/18		2 times	1 time	2/10
					2 times		2/10
Maize	Always – Sept/Oct	1 time, 2 if dry summer	8/16	1 time	1 time	1 time	6/12
	Always – Sept/Oct	1 if dry summer	5/16		1 time		4/12
	Always – Sept/Oct	Others	3/16		1 time	1 time	2/12
Soybean	Always – Oct/Nov	Not irrigated	4/6	1 time	2 times	1 time	3/7
	Always – Oct/Nov	1 time at flowering	2/6	1 time	2 times		2/7
					2 times	1 time	2/7
Wheat	Always – April	2 times	4/4		1 time	1 time	3/5
					1 time	2 times	2/5
W, Melon	Always	Not irrigated	12/12		1 time	Not irrigated	3/3
Squash	Always	1 time if dry summer	4/4		2 times	Not irrigated	2/2
Tomato	Always	1 time (plant height = 0,30 m)	3/3		1 times	2 times	2/2

[1] There was not pre-seeding irrigation because alfalfa crops were not seeded that season.

Table 8.14 N° of farms vs. irrigation turns uses per year.

	N° of irrigation turns used per year						
	1	2	3	4	5	6	7
1998-1999							
B1	3	5	9	3	5	12	0
B2	1	1	3	4	7	2	0
RS	**4**	**6**	**12**	**7**	**12**	**14**	**0**
1999-2000							
B1	9	9	8	8	9	2	0
B2	3	8	2	2	1	1	1
RS	**12**	**17**	**10**	**10**	**10**	**3**	**1**
2000-2001							
B1	3	9	17	9	1	0	0
B2	10	3	1	0	0	1	0
RS	**13**	**12**	**18**	**9**	**1**	**1**	**0**
Mean Values							
B1	5	8	11	7	5	5	0
B2	5	4	2	2	3	1	0
RS	**10**	**12**	**13**	**9**	**8**	**6**	**0**

It was anticipated there would be a close relationship between number of irrigations turns used by farmers and cropped areas (normally highly related to farming type as discussed in chapter 4) or type of crop (for example, it was expected that alfalfa a crop growing the whole year around should be irrigated more times than the main annual crops – cotton, maize and soybean that growth during the rainy season). However these types of relationships were not found (Figure 8.9A and 8.9B) denoting similar irrigation strategies of entrepreneurs and small farmers.

The relationship between number of irrigation turns used per year and location along the water course was also researched because of a hypothesis that farmers at the tail of the water course compensate an assumed lower irrigation gift with a more frequent application. Results (Figure 8.10) showed however that the hypothesis was false since no relationship could be found between number of irrigation turns used and location along the water course (represented in this case by the official irrigation order).

8.4.3. Time per Farm

In general water was delivered to plots 'until farmers finished' during the 3 years studied. Without any significant time restriction, the time used to irrigate should express the actual time required by each farmer, according to physical conditions of their holdings, the discharge received and their labour supply and skills. Table 8.15 summarises the duration of irrigation taken under different water rights, to show the Time Delivery Ratio (F-TDR[8.9]) for RS as a whole for the season 1998-1999 but data were similar to other seasons.

[8.9] The F before TDR denote that TDR has been calculated at Farm level

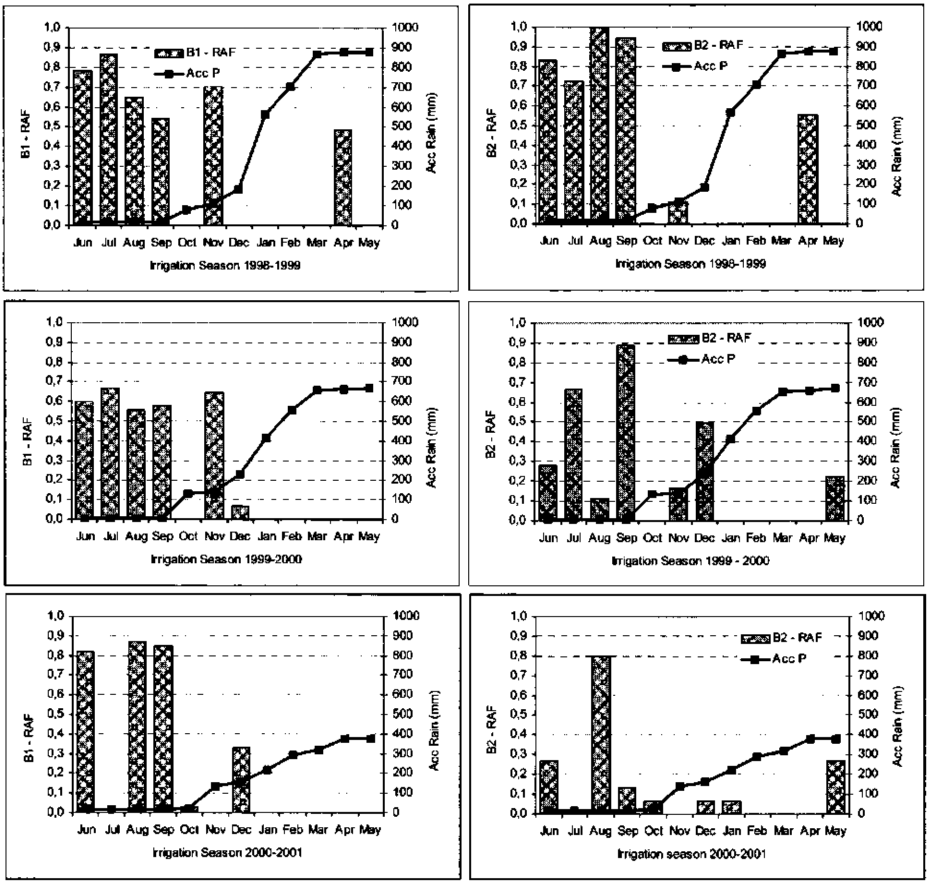

Figure 8.8 RAF per irrigation season in relation to accumulate rain for the two RS branches

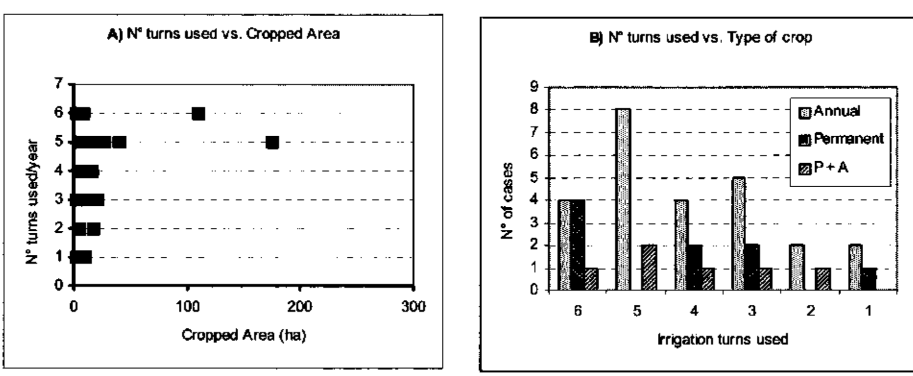

Figure 8.9 Relationship of irrigation turns, cropped area (A) and type of crops (B).

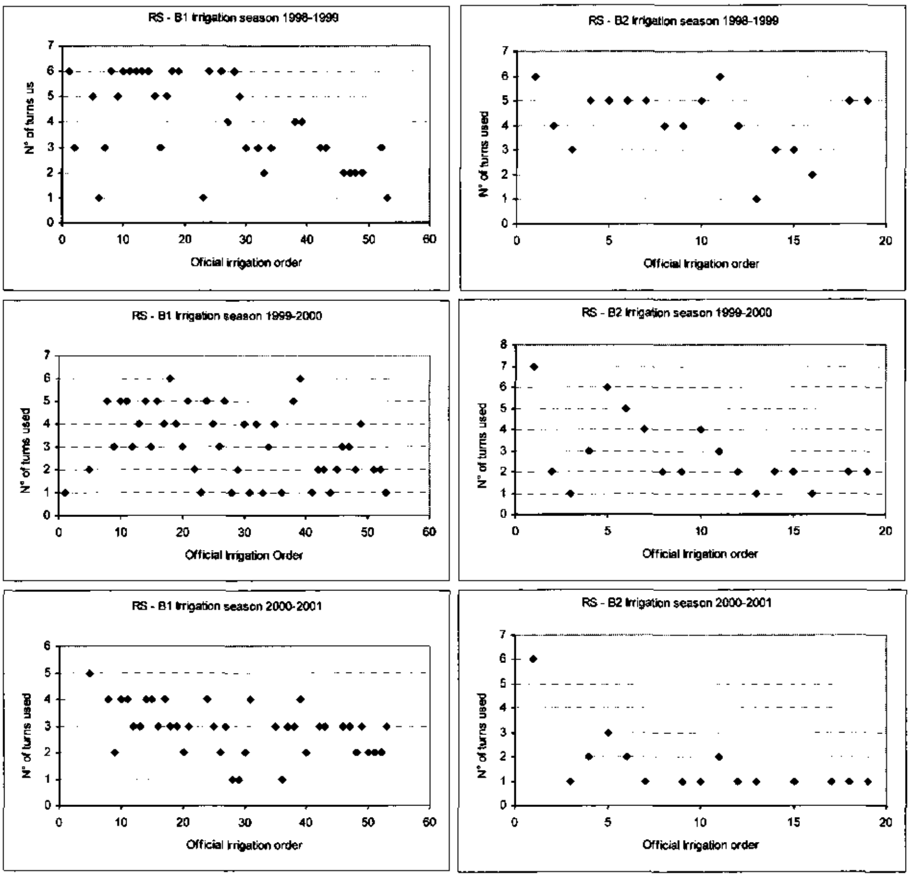

Figure 8.10 Relationship of irrigation turns used and irrigation order

Table 8.15 Mean irrigation time and F- TAR in RS tertiary unit in 1998/99

		Irrigation Turns						Annual
		1	2	3	4	5	6	Mean
Permanent Water Rights								
B1	Mean irrigation time (hr/ha)	1,6	1,9	2,4	2,1	2,0	1,9	1,8
	F-TAR	1,9	2,3	2,9	2,5	2,3	2,2	2,1
B2	Mean irrigation time (hr/ha)	1,4	1,7	1,4	1,4	2,0	1,3	1,5
	F-TAR	1,6	2,1	1,7	1,7	2,4	1,6	1,8
RS	Mean irrigation time (hr/ha)	1,5	1,8	1,7	1,7	2,0	1,6	1,6
	F-TAR	1,8	2,2	2,1	2,0	2,3	1,9	1,9
Pretas								
B1	Mean irrigation time (hr/ha)	1,6	1,9	1,4	1,5	1,4	2,2	1,7
	F-TAR	2,0	2,2	1,6	1,8	1,7	2,7	2,0
B2	Mean irrigation time (hr/ha)	1,0		1,2	2,4			1,5
	F-TAR	1,2		1,4	2,9			1,8
RS	Mean Irrigation time (hr/ha)	1,5	1,9	1,3	1,7	1,4	2,2	1,7
	F-TAR	1,8	2,2	1,6	2,0	1,7	2,7	2,0

(1) Due the low number of cases values are highly influenced by an extreme value of 5, 0 hr/ha in RS-B1 and 5, 5 hr/ha in RS-B2.

This shows that mean irrigation time was on average double the official time of 50 min/ha, overall there were no differences between branches and between farmers with permanent water rights and PRETAs.

Results show that in the 6 irrigation turns of the growing season 1998/1999 most farmers used more time that they were allowed to under their right in both RS branches (Figure 8.11). As discussed under section 8.3.4 this is possible by the combined effects of different factors such as delivery time to the *comunero* and farms based on Total Permanente Righted Area and actual cropped area lower than the maximum (discussed in section 8.3.4), and farmers' irrigation strategies (section 8.4.1)

Time compensation to tail users of B1- RS branch due their lower discharges (section 8.3.5) was detected slightly in the studied year as can be seen from Figure 8.12A. Although the regression line shows decreasing irrigation duration towards the head of the branch data dispersion is rather high and its correlation really low which prove that position along the water course only explain a very low percentage of data variability. In B2 – RS branch (Figure 8.12B) the tendency is slightly positive (higher delivery duration to high irrigation order) but again data dispersion is very high.

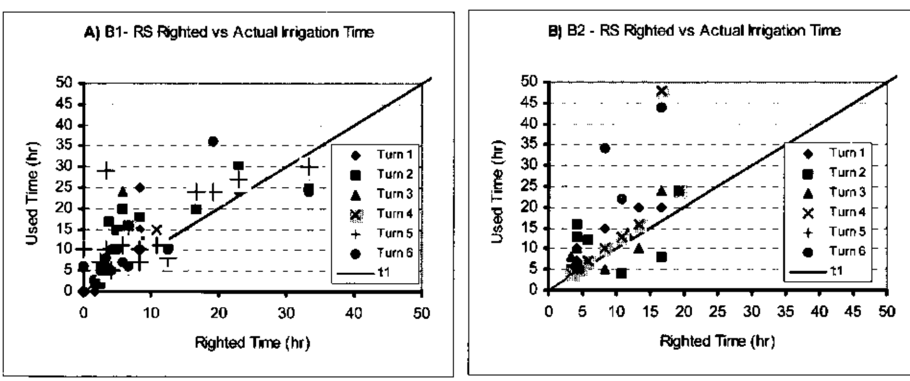

Figure 8.11 Used time per holding in relation to official times (A) B1-RS (B) B2 – RS

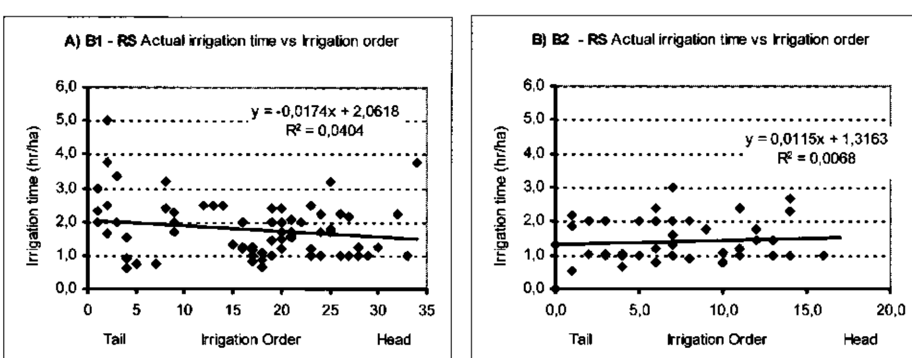

Figure 8.12 Relationship between delivered time (hr) and irrigation order

8.4.4. Water Use at Farm Level

Table 8.16 presents the mean irrigation delivery time per unit area during the agricultural year 1998/1999[8.10].

Table 8.16 Irrigation time and mean irrigation depth in RS (growing year 1998/1999).

	Irrigation Turns							Mean Water use (mm)
	1	2	3	4	5	6	Mean	
Permanent Water Rights								
Mean irrigation depth (mm)	248	307	282	262	274	248	291	908
Farm WDR	2,3	2,6	2,6	2,4	2,5	1,9	2,7	0,92
PRETAs								
Mean Irrigation depth (mm)	266	327	234	292	251	388	292	965
Farm WDR	2,4	2,5	2,1	2,7	2,3	2,8	2,7	0,97

Mean irrigation depth per turn was almost triple the official gross irrigation gift in both permanent and PRETAs righted holdings, but use of fewer irrigation turns than available meant that total amount of water used per year remained with the allocated amount.

Analysis of water use of individual parcels (Figure 8.13) confirmed the suspected high variation and did not detect any significant difference among registered holding size in both RS branches (Figure 8.13 A and B) nor among irrigation order (Figure 8.13 C and D).

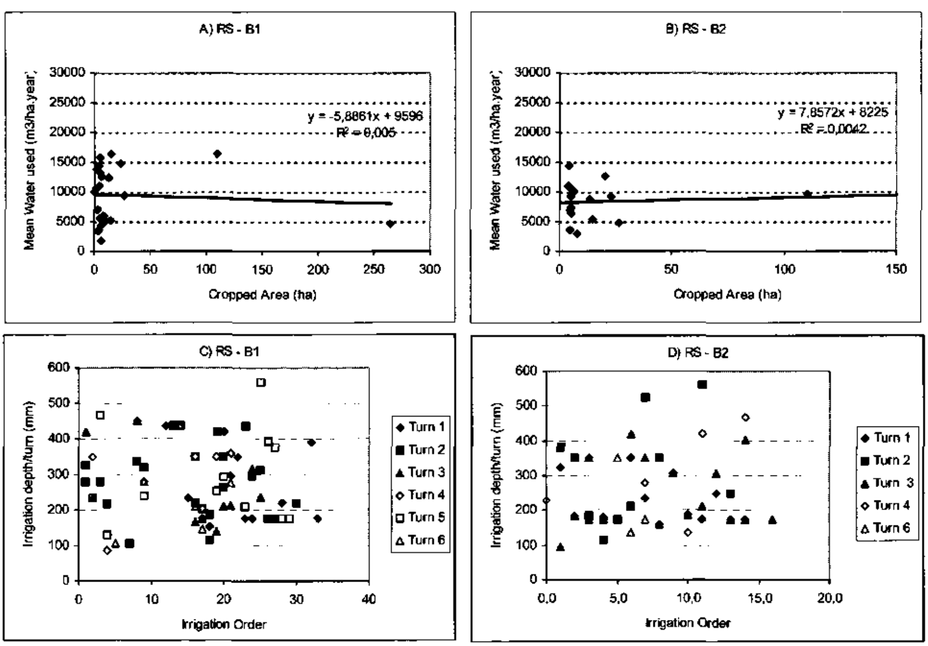

Figure 8.13 Relationship between cropped area and annual water use

The wide spread of water use in holdings under 25 ha could be explained by the normally not officially registered practice of many small farmers to spread irrigation water over the no-water righted area of their holding, to increase forage production of the natural vegetation for their animal and garden production but it cannot be empirically documented during the field research. The wide spread of irrigation depth in relation to irrigation order and irrigation turns could be explained by the variability of delivery discharge and delivery duration, but it would be also affected but non-registered irrigation of areas of natural vegetation.

8.4.5 Application Practices

Field application practices were surveyed through structured interviews and direct observation (at least 20 different farms were visited). Basin irrigation is used for all farmers at pre-seeding irrigations and for most of them after seeding. A few farmers cropping vegetables or row crops change to furrow irrigation, but due the uneven land surface in most cases water flows to fill the end of the downstream furrow before reaching the end of upstream furrow, so the application retains the main characteristic of basin irrigation.

Most farmers use traditional parallel *bordos* to control water application (only 2 small farmers out of 59 cases did not use them). The distance between *bordos* was between 25 and 50 m in 59 % of cases, while 28% construct them closer and 13% use distances greater than 50 m. Most farmers (85%) also use *trabas* to decrease water flow velocity and increase infiltration opportunity time: 25 to 50 m is the most common spacing (40%) but in RS the number of farmers who used spacing greater than 50 m increased to 35%. This group of farmers argue that there is no reason to put *trabas* closer because they get a uniform water application and save work. The area however is not flatter than other studied areas, RS's farmers have no less resources than other farmers therefore in my opinion is the large diverted water flows that make it possible to irrigate larger irrigation units than in other areas.

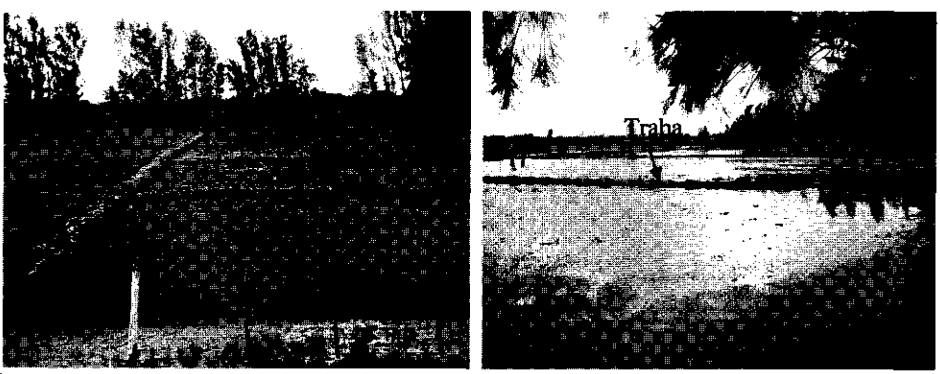

Figure 8.14 Typical basin irrigation in RS

8.5 Conclusions

Findings in RS show clearly that users have capabilities to reshape official irrigation schedules to make water distribution more flexible and able to suit their real needs. Also the data presented demonstrate the evolutionary and contested process of water allocation in the RS command area.

Official information, representing the situation at the end of PRD intervention (1968-1973) indicates that 99% of the water righted holdings are less than 50 ha. This confirms the effectiveness of government intervention to spread irrigation benefits over a large number of beneficiaries by limiting the maximum area of water rights. The continued presence of one farm with 98% of its 108 ha with water rights also illustrates the other component of former policies in terms of water allocation, allowance for the prior appropriation principle. The mosaic of irrigated and non-irrigated areas resulting from the above policies is also clear in the RS area, with holdings with permanent waters representing only 63% of its gross command area overall, but ranging from 39% for holdings under 5 ha to 75% for holdings in the 10 to 25 ha range.

The research shows the dynamic process of water re-allocation implemented since the 1980's with PRETAs that have grown to represent 30% of the RS Total Water Righted Area in 2000/2001.

However, it also shows an active process of concentration of water and land as a consequence of extensive abandonment of agricultural activities by small farmers negatively affected by neo-liberal policies and lack of official support, and not from any struggle around water. This still remains hidden by the out-of-date official information.

The SARCCs role in water distribution is relevant, unlike in the modern tertiary units. As elsewhere, the RS-SARCC is organized around a unique effective position, the *administrador*. The determining role of this farmer leader, with high power but certainly accountable to users is similar to the institution constructed around the private *acequias* and extended to public systems in the initial stage of irrigation development in this area. This institution has been effective under local conditions for implementing a flexible water distribution and for managing local conflicts among users. However it appeared very conservative, appearing always to use water as a substitute for other resources that could help to improve water course operation and/or solve endemic problems.

Farmers' irrigation practices present contradictory features from the water exploitation perspective. Their irrigation strategies were mainly based on high irrigation for pre-seeding and few applications during crop growth (on average 4 turns were used in 1998/99 and 3 in 1999/00 and 2000/01). These resembled former practices and are more close to the protective irrigation approach of the initial stages of the system that looked for a maximization of the social and productive returns per unit of water applied rather than to productive irrigation advocated by the truncated PRD intervention.

However, during water application, water is not treated as a scarce resource and, as elsewhere is a factor to minimise conflict and a substitute for other less available resources (including capital for land levelling, manpower for a better control of water application, and capital for infrastructural change to control endemic reduction of discharges at the tail of the water course). This results in a mean irrigation depth of 291 mm/turn, 2,7 times greater than the official 90 mm/turn). This means there is no reduction of water use per unit of area (WDR = 0,92) despite using less than half of the available irrigation turns. This large irrigation depth resulted from delivery duration and delivered discharges that were in average 1,8 to 2 times higher than officially scheduled.

These greater discharges are technically possible because old water courses (*comuneros* and even secondary canals) have higher carrying capacities that the required one, are operationally acceptable because again water substitutes for resources otherwise needed for better control and are politically supported by their functionality to a key agency objective of avoiding users' complaints.

Lengthened delivery duration is possible because within the *comunero* there are available irrigation times (water) from abandoned parcels, and because the few applications used in farmers' irrigation strategies give them room to concentrate water on smaller areas in each turn or use water not taken by their neighbours also irrigating smaller plots. It is also bureaucratically acceptable because the internal time compensation meant that the *comunero* Time Delivery Ratio exceeded 1,0 only in few cases. When this happens it is made possible by the availability of water upstream and the serviceable attitude of field agency official convinced of the institutional objective to serve farmer preferences and minimize users' complaints.

There are no substantial differences in irrigation practice and water use between different types of farmers, different positions along the water course (head and tail) and type of water rights in this sense is clear that PRETAs did not lead to a better use of water.

Chapter 9

SMFN TERTIARY UNIT: ENTREPRENEURIAL WATER USE IN AN UNMODERNISED UNIT

The SMFN is a rotational unit located just west of Loreto town in the southern extreme of the PRD area watered by a *comunero* that splits in two branches. It is served from the unmodernised part of San Martin secondary canal. Although it is physically at the tail of the San Martín secondary canal, the SMFN *comunero*, an old earthen water course, takes water from the secondary canal 14 km upstream of its command area. The system layout and internal layout of the unit is shown in Figure 9.1.

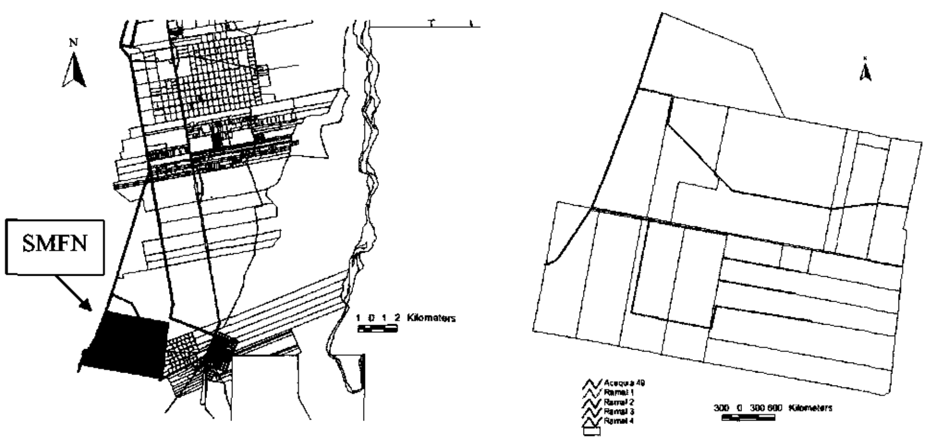

Figure 9.1 General system location and watercourse layout of SMFN tertiary unit.

9.1. Agrarian Structure and Irrigation Water Allocation

9.1.1 The Official World

Data presented in Table 9.1 indicates that the official gross command area of the SMFN tertiary unit studied here is 2.433 ha[9.1] with only 18 holdings (one is without a permanent water right). The traditional-mosaic pattern of irrigated and un-irrigated areas of the PRD remains. The 17 water-righted holdings covering 85% of the gross area have water rights for only 755 ha, that is 31% of the command area.

What makes SMFM distinct from the other case study areas is the polarization in land and water access. The eleven water-righted holdings smaller than 50 ha account for only 23% of the whole water righted area while 3 large holdings with water righted areas of 100, 150 and 170 ha hold 56% of the water-righted area. This demonstrates how water was allocated in this area prior to the PRD intervention and therefore the prior appropriation principle

[9.1] Actually the official area is 4.108 ha, if the gross area of the two most westerm holdings are included. However because parts of these holdings are not irrigated due to their position relative to the irrigation network, the study area is adjusted to include only their area with the possiblity of irrigation from the SMFN watercourse, which are 170 and 32 hectares.

predominated over the political criteria of spreading irrigation to the greatest number of beneficiaries[9.2].

Table 9.1 N° of holdings, gross and permanent water righted area in SMFN (source UER-INTA data base, 1998)

	Holdings		Gross Area		Permanent Water Righted Area			
ALL HOLDINGS	N°	%	Ha	%	ha	%$^{(1)}$	%WR$^{(2)}$	Mean
Without Water Rights	1	6	32	15	0			32
With Water Rights	17	94	2401	85	755		31	44
	18	100	**2433**	**100**	755			
WATER RIGHTED HOLDINGS	Holdings		Gross Area		Permanent Water Righted Area			
	N°	%	ha	%	ha	%$^{(1)}$	%WR$^{(2)}$	Mean
<5	0	0	0	0	0	0		
5 to 10	4	24	386	16	26	3	7	6
10 to 25	5	28	467	19	92	12	20	18
25 to 50	2	12	314	13	63	8	20	31
50 to 100	3	18	470	20	155	21	33	52
100 to 500	3	18	765	32	420	56	55	140
	17	**100**	**2401**	**100**	**755**	**100**	**31**	**31 (44)$^{(3)}$**

$^{(1)}$% of the total water righted area $^{(2)}$ % of the gross area of the class $^{(3)}$ Weighted mean by the number in each class.

One important point not shown in Table 9.1 is that the number farmers (10) was lower than the number of holdings (17); 2 owners had more than one holding (4 and 5) in the era of the PRD intervention (1973).

Table 9.2 shows the dynamic evolution of areas under PRETAS in the three consecutive years of this study. PRETAS in the SMFN tertiary unit increased to 26% of the total righted area in 2000/01 (and had reached almost 40% of the total righted area by 2003/04).

Table 9.2 Evolution of PRETAs and Total Water Righted Area (TWRA) in SMFN

	1998 -1999				1999 -2000				2000 -2001			
	PRETAS			TWRA	PRETAS			TWRA	PRETAS			TWRA
	N°	ha	%$^{(1)}$	(ha)	N°	ha	%$^{(1)}$	(ha)	N°	ha	%$^{(1)}$	ha
<=5	1	5	100	5	1	5	100	5	1	5	100	5
5 to10				26				26				26
10 to 25				92				92				92
25 to 50				63	1	50	44	113				63
50 to 100	1	50	24	230				155	1	60	28	215
100 to 500	1	120	22	570				420	2	200	32	620
Total	**3**	**170**	**19**	**985**	**2**	**55**	**7**	**810**	**4**	**265**	**26**	**1020**

$^{(1)}$Percentage of the total righted area; TWRA = Total Water Righted Area (Permanent + PRETAs)

[9.2] The SMFN tertiary unit was part of the irrigated area developed around Loreto town in former times. The construction of the San Martín canal at the beginning of 20th century had the main objective to take water to that city, after destruction of its own main canal by a Rio Dulce flood (Chapter 2). Nevertheless only one farm is farmed by the heirs of a farmer of that time. Excluding this family, the average residence time of others as water users was only 12 years at the time of study.

Use of PRETAs in all cases, for increasing cropped area within farmers'own holdings should be seen as the logical consequence of the low water-righted area, and the presence of entrepreneur farmers.

Figure 9.2 shows the different type of water rights with each holding in the SMFN tertiary unit.

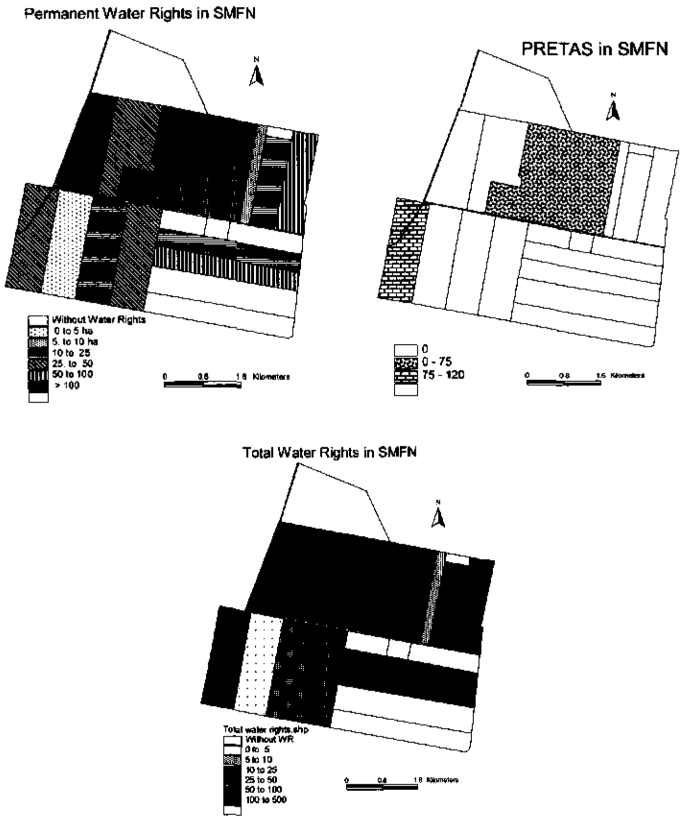

Figure 9.2 Water rights by holding in the SMFN tertiary unit, 1998/99 (own research).

9.1.2. The Real World

Differences between the official and real water allocation were smaller in SMFN than in previous cases. Only one holding was found abandoned, in agreement with official information, and the number of actual farmers (9) was almost equal to the number of registered owners (10) of the 17 active holdings (Table 9.3).

While there is diversity in type of farmers, there has been concentration of land and water in this area created by large entrepreneur farmers with diversified production systems. There were no farmers in classes smaller than 25 ha[9.3] and only one remained in the 25-50 ha class.

[9.3] The special case of the one farmer in the class smaller than 5 ha, is discussed in section 8.2.

Table 9.3 real agrarian structures (based on farmers) in SMFN tertiary unit - 1998-1999 agricultural year – (Source: own research).

Economically Active Plots Size (ha)	Total WR Area[1] N°	%	ha	%	Cropped Area N°	%	Ha	%
0 to 5	1	11	5	1	1[2]	11	5	0
5 to 10						0		0
10 to 25						0		0
25 to 50	1	11	50	5	1	11	42	3 (4)
50 to 100	3	33	222	22	2[2]	22	125	10 (13)
100 to 500	4	44	715	72	5	56	800 (1060)[3]	86 (82)
Total	**9**	**100**	**993**	**100**	**9**	**100**	**972 (1232)**	**100**

[1] Permanent + PRETAs Water Rights [2] they did not appear in Agency's irrigation reports of that year as using irrigation water [3] 260 ha are cropped twice a year

Cropped area is now very close to total water righted area (unlike the other cases), and around a quarter of the area is cropped twice a year.

9.1.3. Production Systems and Cropping Patterns

All farmers in this area belong to the Diversified Entrepreneur type defined by Radrizzani, (2000) (see Chapter 4) – these have medium to large farms, with diversified production systems including arable cropping, livestock production or both. Most SMFN's farmers belong to the last sub-type, with livestock predominating over arable activities at least in recent years. All have their own machinery including implements for forage cutting and bale production. All have from 2 to 6 permanent labourers and hire other for temporary works, mainly for vegetable harvesting.

This can be partly explained by the water allocation: as discussed only 31% of the area has permanent water rights. Most of the non- irrigated areas were under rainfed pasture at this time but they could increase their productivity considerably under irrigation. This also explains why the area under PRETAS has grown. In SMFN, unlike smallholder farmers in the other cases, this group of farmers is likely going to increase their water demand in the coming years, as there is also the area available to apply this increased demand.

Table 9.4 presents the cropping pattern in the 3 agricultural years studied. Twelve crops are found within the active farms of SMFN tertiary unit, and some of them have been cropped only in one year. These features indicate how diversified the cropping pattern is with this type of farmers, and at the same time how responsive to market opportunities. Also, crops used to support livestock cover 53% of the total cropped area - alfalfa and pastures (459 ha in the last year), sorghum that is 100% cultivated for animal production (40 ha), and maize used for both grain and animal production (105 ha), The real production profile of SMFN tertiary is confirmed by the existence of 1600-1700 cattle in the area (interviews and UER information).

9.2. Institutional Arrangements and Operation of Water Distribution at *Comunero* Levels

9.2.1 Institutions and Organization

As in all the earlier cases, water distribution in SMFN tertiary unit is entirely under the responsibility of a SARCC but just as in RS, here it also more relevant than in modern tertiary units. The *tomero* role is here certainly restricted to control of gate openings, and, since he has to close the head gate that is far away from the SMFN area, it is very unusual to see him in the area.

Table 9.4 Cropping pattern in SMFN tertiary unit

Crop	98-99	99-00	00-01
Alfalfa	332	207	283
Small pumpkin	20		
Sweet potato		120	310
Onions	30		
Poplar	60	15	15
Maize		20	105
Potato	140		14
Pastures	198	180	176
Dry Bean	187		
Soybean	150	50	50
Sorghum	15	40	40
Wheat	100	80	130
TOTAL	**1232**[(1)]	**712**	**1123**[(1)]

[(1)] 260 and 130 hectares are cropped two times in the year.

As in the other cases, the SMFN-SARCC, constituted only by an *administrador*[9.4] confirms that in spite of bureaucratic regulations, both modern and old *comuneros* returned to the users' built institutions for practical reasons. However, unlike other cases there is *celador*. This is also a well-accepted position that emerged in the times of private *acequias* to relieve the *acequia*'s owners from taking daily control of water distribution tasks, and later evolved to become the only salaried position in the SARCCs. As another example of heterogeneities within PRD, the *celador* has virtually disappeared in most areas. The exception in San Martín network has been variously explained by the relatively lower water availability in San Martin district, a major imposition of former district officials, and/or just a simple stronger fondness for tradition.

However, in the particular case of SMFN, which is a tertiary unit without water scarcity and made up of a homogeneous small group of user that are self-defined as a group of friends and have regular meeting, there appear to be different reasons to appoint a *celador* that are directly related with their production style. With only one exception, this group does not live on their farms, has other business, and in some cases have professional managers. They take main management decisions but leave daily operations in charge of *capataces* (foremen). Under this farming style, daily water distribution needs to be entrusted to somebody; therefore appointment of a *celador* is functional to the farming style and is not necessarily related to water conditions or organizational needs. The *celador* then assumes operational tasks, while other management decisions are taken by the *administrador*. The amount paid to the *celador* by each user was A$ 0,4/ha (U$S 0,13/ha)[9.5] on each turn used.

The SMFN's SARCC *administrador* was president of the Water User Association (APAZ IV), in charge of San Martin district operation from 1995 to 1998, and one of the proponents of transference of responsibility to users in that period. However, his internal power at the tertiary unit seems to be more balanced by other users than in RS - the other old tertiary unit

[9.4] In this case there is not doubt, as all nine farmers answered that the other positions has not been elected.

[9.5] With 993 ha water righted area the payment received by the *celador* per turn is around U$S 130.

case where the SARCC role is relevant and active (Chapter 7). A higher number of annual meetings (ranging from 2 to 5) confirmed by interviews suggest a more participative way of taking decisions than in other areas. Interviewees also agreed with the *administrador* statement that most decisions are taken by consensus and in the very few cases when that is impossible, they follow strictly official rules. The importance of PRETAS in this area also gives an additional negotiating and operation role at higher levels in the system. It is also clear that both individual users and the group have a higher lobbying capacity. When interviewed, 5 out of 6 stated that, when confronted with any irrigation problem they notify the *administrador* but also go directly to the *tomero*, District Office and even to UER main office.

9.2.2 Collective Actions – Maintenance

Only one of the nine farmers preferred *reparto* as a maintenance method. Works are done by *administración* once a year: tractors and labourers are hired and cost shared in proportion to water righted areas. The amount paid in 1998-99 agricultural year was A$5/ha, which is 50 % of the annual water fees. This can be higher if specific works are decided, such as structure repair. In such a case the cost shared by farmers depends on negotiation with the agency and work urgencies but the amount could be as much as or even more than the annual water fees.

Field observations made clear that the higher resource mobilization from this category of farmers gave better maintenance. Maintenance of both watercourses and control structures has been improved in recent years, and also internal infrastructure is much better in most SMFN farms with respect to other areas. At least three of the more successful farmers have even built permanent internal control structures (Figure 9.3).

Figure 9.3 Permanent control structures in SMFN farms.

9.3. IRRIGATION PRACTICES AT *COMUNERO* LEVEL

9.3.1 Water Delivery Order

In SMFN it became clear that although all users recognize the existence of an official order, the real order is even more flexible than in RS. It clearly apart from the official procedure and it is capable of following more closely the needs of the diversified production systems of farmers. Figure 9.4 illustrates the difference between official and real irrigation order for 5 irrigation turns during the 1998-1999 agricultural year.

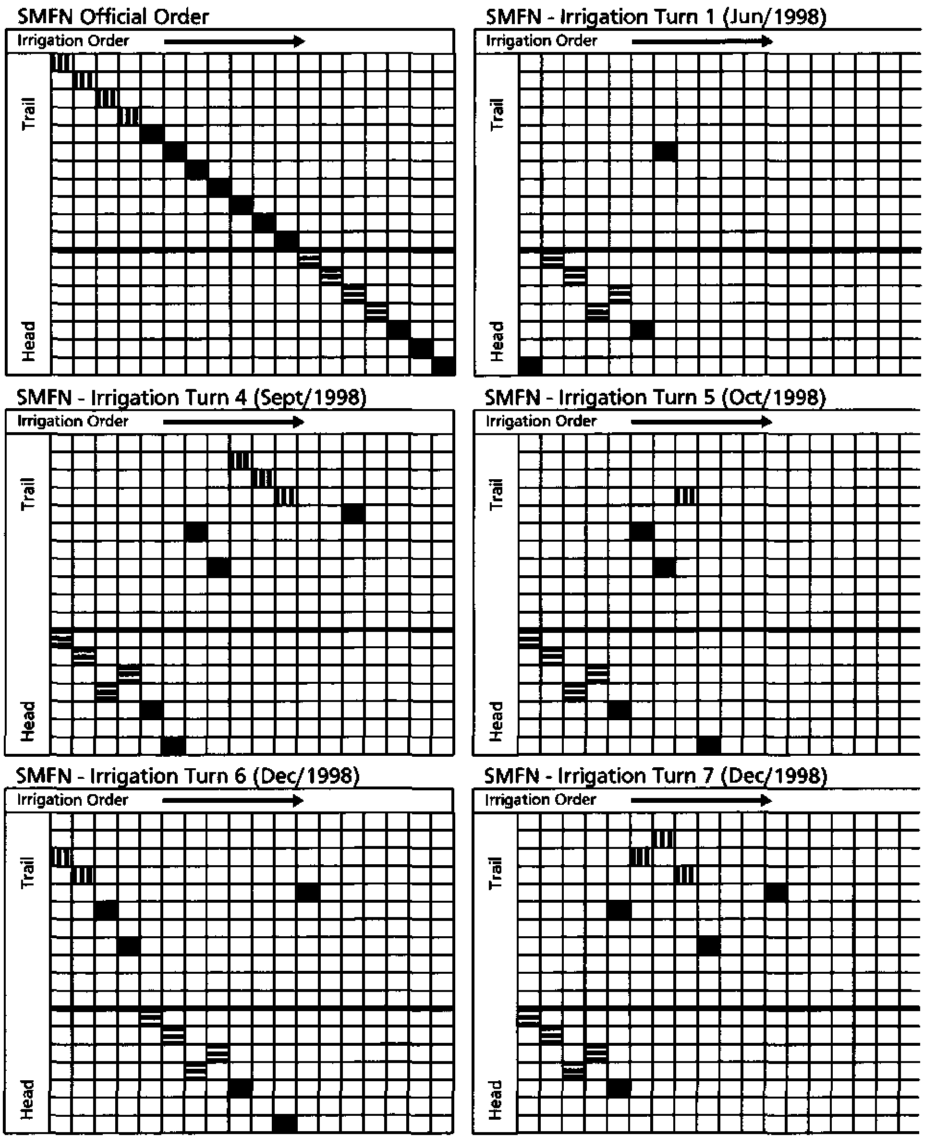

Figure 9.4 Comparison of official and actual irrigation order in RS- Branch 2. 1998/99 (■ ■ same owner, —— change of water course branch)

It is clear from the figure that two types of change are frequent with respect to the official order. The first refers to branch order: in contradiction to official order most of the time the upstream branch irrigates first, rather than the downstream branch that should start each irrigation turn. The second refers to the internal order within each branch: while the official order is generally followed starting at the most downstream farm, there are changes depending on arrangements between users.

9.3.2 Irrigation Turns

The number of turns taken in the SMFN *comunero* is larger than the previous cases, but still less than the maximum officially available number, as shown in Table 9.5. This suggests a more intensive use of irrigation facilities than in previous cases. The annual use pattern is similar to most areas. Water use is concentrated in winter and spring (dry season), decreasing in the rainy season and re-starting at the end of autumn just before the shutdown period at the beginning of a new dry season. It should be noted that on two occasions (December, 1998 and April 2001), two irrigation turns were reported in the same months. That is possible when turns duration are short because few farmers take water and there is also enough flexibility in management of the secondary canal.

Table 9.5 N° turns per year and initial month of irrigation turns in SMFN tertiary unit.

Agricultural Year	N°Turns	Initial and Subsequent Months of Irrigation Turns									
		1	2	3	4	5	6	7	8	9	10
98-99	8	Jun	Jul	Aug	Sept	Oct	Dec	Dec	Mar		
99-00	8	Jul	Aug	Sept	Oct	Nov	Dec	Mar	Apr		
00-01	10	Jun	Jul	Aug	Oct	Nov	Dec	Jan	Mar	Apr	Apr

The number of annual irrigation turns used gives the first indication that also in this area; users have re-constructed official delivery schedules to suit their own irrigation practices, as explained in more detail below.

9.3.3 Delivery Frequency

Intervals between consecutive irrigation turns are presented in Table 9.6. The mean interval between irrigation was rather similar to the official frequency in 1999-2000 and 2000-2001 years and slightly longer in 1998-1999. However there are great variations within agricultural years with intervals from as short as 20 days (March-April 2000) to as long as 44 days (Oct-Nov, 1999). This shows again that the real delivery schedule is much more flexible than the official one, also because there were no complaints from farmers about irrigation frequency.

Table 9.6 Intervals (days) between consecutive irrigation turns in SMFN tertiary unit.

Agricultural Year 1998 – 1999							
Jun-Jul	Jul-Aug	Aug-Sept	Sept-Oct	Dec-Dec			**Mean**
27	38	31	33	22			**31**
Agricultural Year 1999 – 2000							
Aug-Sept	Sept – Oct	Oct-Nov	Nov-Dec	Mar-Apr			**Mean**
30	31	44	22	20			**29**
Agricultural Year 2000 – 2001							
Jun-Jul	Jul-Aug	Oct-Nov	Nov-Dec	Dec-Jan	Mar-Apr	Apr-Apr	**Mean**
33	24	27	23	36	26	23	**27**

9.3.4 Delivery Duration

Delivery duration is the second variable component of water use that users can manage with the objective to get more water, or simply try to match it with their irrigation practices as shaped by their own resource mobilization capacity. As in previous cases, actual water delivery durations to the *comunero* were researched and evaluated against maximum allowable times using four possible bases for its calculation: Permanent Water Rights (PWR), expressing design conditions; Total Water Righted Area (TWRA) adding PRETAs to permanent rights which should represent maximum bureaucratically allowable delivery time; water righted area of only active holdings (WRAP) as a compromise between the previous and following criteria; and considering actual cropped areas (ACA) which should be the maximum time allowable in terms of modern serviced-oriented irrigation system management. This is shown in Table 9.7.

The maximum duration times on the PWR criteria shown in Table 9.7 makes it clear that the SMFN tertiary unit was defined as a rotational unit, since even when the whole area was cultivated its roster could be completed in 26 days - 2 days less than the official delivery frequency. It is also clear that with PRETAs, maximum time exceeded official time in 2 out of the 3 study years (34 and 35 days for 1998/99 and 2000/01 agricultural years respectively). This would imply use of two *caudales* at least during part of the turns if the whole area would be cultivated. Finally if only the water righted area of active holdings is considered, the time required would be close to the official frequency but still the roster could not be finished within the official frequency in case the whole area was cultivated.

Table 9.7 Maximum time (days) required to complete SMFN roster considering PRETAs.

PWR	Based on TWRA[1]			Based on WRAP[1]			Based on ACA[1]		
	98-99	99-00	00/01	98-99	99-00	00-01	98-99	99-00	00-01
Days	days	days	days	days	days	days	days	days	days
26	34	28	35	32	25	32	34	25	34

(1) Permanent + PRETAs

The actual annual time used is compared with maximum times in Table 9.8. It can be seen that, as in previous cases, average annual Time Delivery Ratio ranges from 41% to no more than 45% even taking actual cropped area as a base for calculation of maximum available time. As in other areas a lower land use intensity than assumed at the design stage, and farmers irrigation strategies that also include fewer irrigation events than planned, determine this low TDR at *comunero* level.

Table 9.8, N° of turns-year, maximum and real annual delivery time of SMFN tertiary unit.

	Maximum time based on			Actually	C – TDR		
	TWRA	WRAP	ACA	used time	%	%	%
N° Turns	days	days	days	days	TWRA	WRAP	ACA
Agricultural Year 1998 – 1999							
8	376	354	371	156	41	44	42
Agricultural Year 1999 – 2000							
8	309	271	272	130	42	48	46
Agricultural Year 2000 - 2001							
10	390	351	379	153	39	43	40
Mean 9	358	325	341	146	41	45	43

Disaggregating annual Time Delivery Ratio into individual turns, (see Figure 9.5) shows that, unlike other areas, C-TDR does not exceed 1 in relation to WRAP and ACA even in months of more intensive irrigation use. This demonstrates that in SMFN, as is believed for the whole San Martin command area, there is a better control over delivery times. Although there is no regular yearly pattern and irrigation water use concentrates during late winter and spring months as in other areas, there is in this case a more intensive use of irrigation. The lower C-

TDR at the end of the study period could be explained by an evolution of land use from agriculture to pasture.

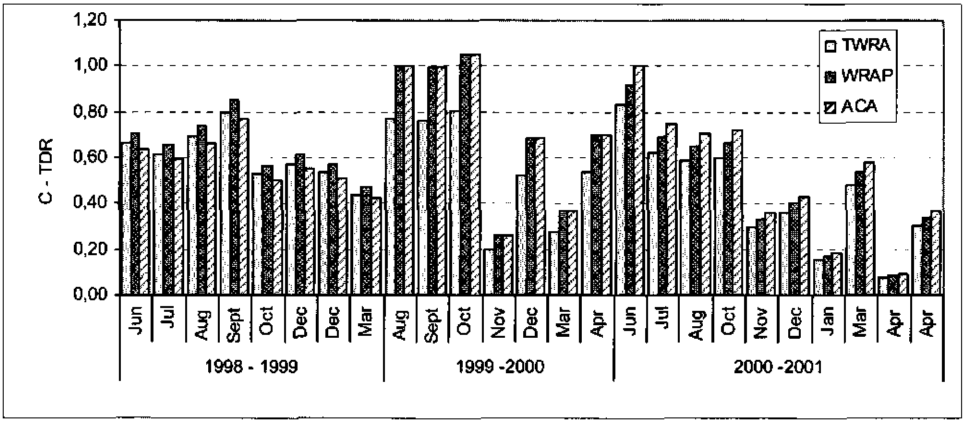

Figure 9.5 Variation of TDR in turns in the SMFN tertiary unit, according to TWRA, WRAP and ACA, 1998/99-2000/01

9.3.5 Delivery Discharges

Delivery discharges, the third key variable component of water use, were also researched in SMFN. This study was based on official information registered by the *tomero*¨ using their empirical unit, the *caudal* and an empirical relationship (summarized in Table 9.9) between it and direct flow measurements at the head of the *comunero*. Due to the long distance between *comunero* gate operated by *tomero* and the command area (14 km), direct measurement had to be done in both places in order to establish a relationship between registered discharge at the head and water actually reaching the command area. Simultaneous measurements at both places yielded consistent results (with 82% conveyance efficiency). Therefore the established relationship of Table 9.9 was considered sufficiently accurate and stable for the purpose of this research.

Table 9.9 SMFN's discharges reaching SMFN command area reported as one *caudal* by *tomero.*

Caudal reported	N° Measurements	Mean Discharge (l/s)	Limits 95% confidence interval (l/s) 95% max	95% min	Variation Coefficient (%)
1	20	577	636	517	24

As can be seen, average discharge for the SMFN tertiary unit are higher than in previous tertiary units (139%, 44% and 18% higher than mean discharge in JS, TTS and RS *comuneros*) although their mean variability is rather similar[9.6].

All users categorized stream flows as sufficient: 4 out of the 9 farmers stated that discharges varied between and within turns, considering use by upstream users as the main reason for

[9.6] Mean discharge at the head was 695 l/s and its CV only 11%. This good control of water level in the parent canals was attributed by a hydraulic jump located very close downstream to sluice gate offtake. Losses on the way to the SMFN command area not only reduced the discharge but also increased variability. It has to be mentioned that few people live along the 14 km path of the water course and it is mainly an excavated canal. Therefore use of water is restricted to drinking water of that low population and their few animals.

that variation. The *administrador* mentioned that when there is an excess of water a second farmers is allowed to take water, or the water surplus is delivered to many small farmers to refill their small reservoirs. Water flow to this group of small farmers is normally registered in daily reports, but use of water simultaneously by two farms for irrigation purposes is not - although it could be directly observed on two occasions during the field work. On those two occasions registered farms received very high discharges 596 and 761 l/s while discharges to unregistered farms were only 178 and 167 l/s (23 and 18% of the discharge arriving at the command area).

9.3.6 *Water Use at Comunero Level*

According to collected information, the mean annual gross irrigation water used in SMFN tertiary unit was 803, 936 and 852 mm/year in 1998/99 -2000/01 respectively (Figure 9.6 A) ranging with a 95% of probability from 1032 mm/year in 1999-2000 to 720 mm/year in 1998-99. Taking maximum gross irrigation depth allocated (990 mm/year) as the intended delivery water, the above data yields an Annual Water Delivery Ratios (WDR) of 0,81, 0,95 and 0,86 for SMFN *comunero*. These values are closer to the annual allocated water than the previous case studies.

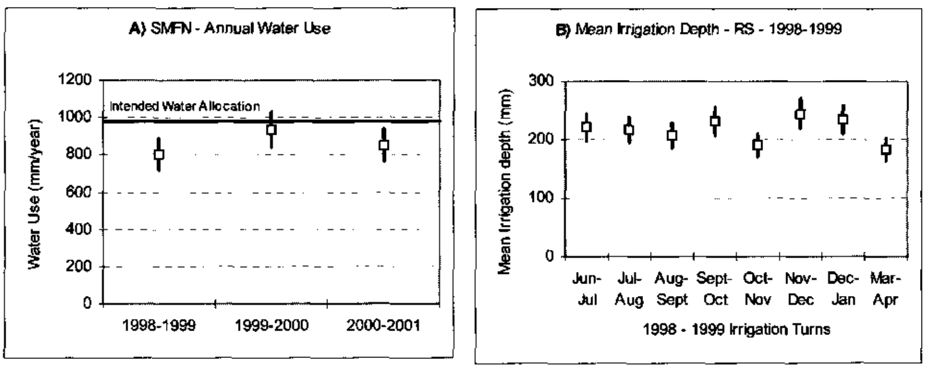

Figure 9.6 Mean and 95% confidence interval for annual water use and mean irrigation depth of each 1998/99 irrigation turn.

Although these figures shows that annual use of water was below the allocated amount, the mean irrigation depth per turn in 1998/99 (Figure 9.6 B) was 216 mm, ranging from 244 mm (Sept-Oct turn) to 183 mm (Mar-April). These are 2,4, 2,7 and 2 times greater than the design gross irrigation depth (90 mm).

9.4 IRRIGATION PRACTICES AT FARM LEVEL

9.4.1. Irrigation Strategies

Irrigation strategies and planned irrigation application by farmers for their different crops were researched through structured interviews (all SMFN's farmers were interviewed) and information cross-checked with the irrigation register (*boletas de riego*). Results are summarized in Table 9.10.

Table 9.10 Farmers' irrigation strategies for the predominant crops in SMFN tertiary unit.

Crop	Pre-seeding irrigation	Irrigation after seeding	Farmers Interviewed	Real Activity
Alfalfa	Always = March/April	5 times (Apr –Sept)	4/9	2/4
	Always – March/April	4 times (Apr- Sept)	3/9	2/4
	Always – March/April	Others	2/9	
Pastures	Always - March/April	2 times	4/4	2/2
Soybean	Always – Oct/Nov	1 time (flowering)	3/3	2/2
Wheat	Always – April	2 times	1/1	1/1
Sorghum	Always – Nov-Dec	Not irrigated	2/4	½
	Always – Nov - Dec	1 time	2/4	1/2
Potato/Onion	Always - April	2 to 4 irrigation	3/3	3/3
Sweet Potato	Always - August	Not irrigated	3/3	2/2

Despite the different production systems in SMFN tertiary unit with respect to other areas, farmers' irrigation strategies in most crops were similar. Use of more turns - 8 or even 10 in 2000-2001- resulted from their practice of making blocks of crops with different sowing dates.

9.4.2 Irrigation Turns

The number of irrigation turns used per year by each active holding was different every year. Few of them used the total number of turns and there was no clear pattern of use as can be seen from Table 9.11.

Table 9.11 N° of holdings using different numbers of irrigation turns.

	N° of irrigation turns used									
	1	2	3	4	5	6	7	8	9	10
1998 -1999	1	1	0	2	3	1	2	3		
1999 - 2000	3	0	0	6	5	1				
2000 – 2001	3	3	1	2	3			1	1	1
Mean	2,6	1,3	0,3	3,3	3,6	0,6	0,6	1,3	0,3	0,3

No regular pattern could be observed between the Relative Active Farms (RAF) (N° of farms irrigating at specific turn/Total number of active holdings) in each turn (Figure 9.7). However values are higher than in other studied cases – the product of the more diversified cropping pattern in SMFN and the place at intervals of crop seeding due the large area of cropped plots.

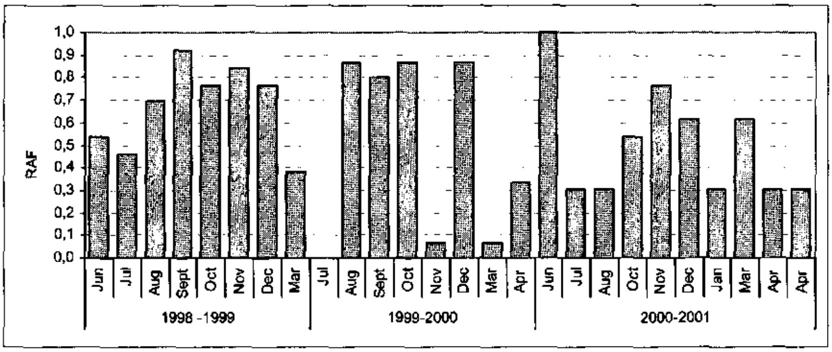

Figure 9.7 Variation of RAF along turn and years

Figure 9.8 relates RAF with accumulated rainfall. Obviously there is a high activity during the dry season but it also clear that farmer adapt their irrigation practices more to their own needs and system operation than to climatic variables. In 1999 – 2000 when the canals became operational late after May, most farming used the first three available turns. However in 1998/99 there was a more homogeneous use of irrigation turns. In the last year all active holdings irrigated in the first irrigation turn and made a low use of the two following turns. Failure of the canal in November 1999 increased activity in December of that year: low rainfall in December 2000 extended irrigation to January 2001.

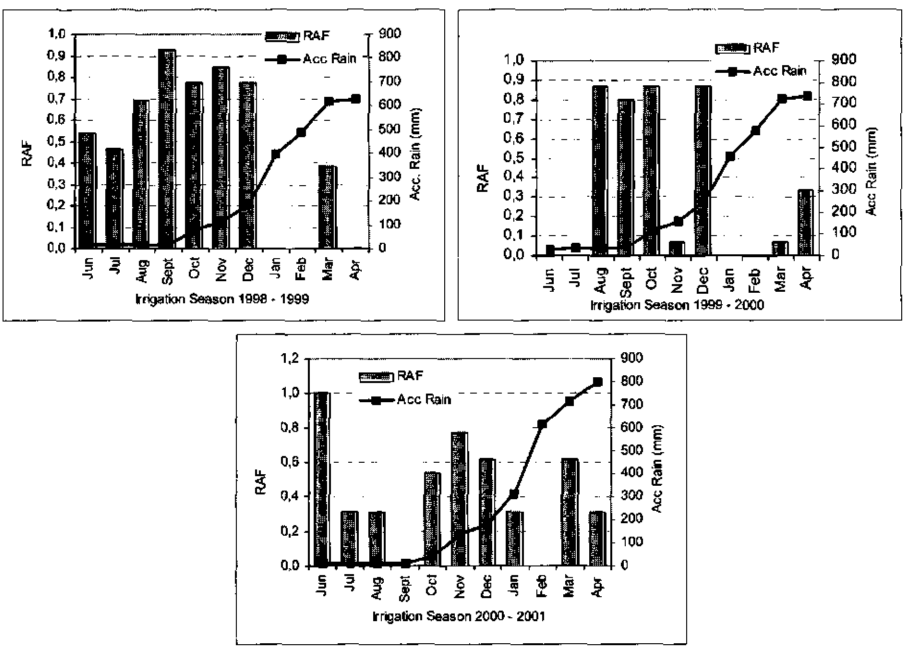

Figure 9.8 Relation of relative use of irrigation turns with accumulate rainfall.

In relation to internal farm irrigation practices, the low number of farms makes specific conclusions difficult. However farmers with a more diversified cropping pattern and/or more intensive land use of lands (two crops per year on at least part of their farms) used 6 turns as minimum. There was a positive relation between number of irrigation used and cropped area (Figure 9.9), although the correlation was low.

9.4.3. Time per Farm

Unlike other tertiary units, in SMFN water is not delivered until finished (This is also true for the whole area under control of San Martín District). The official discourse is in this case that delivery time is restricted to official time (although not explicitly stated, official time is calculated based on TWRA independent of cropped area).

Figure 9.10 shows the time delivery ratio for different farms. It appears that time used is closer to official time than in previous cases suggesting a better match between discourse and practice. However, some farmers are still able to extend their irrigation time even to double their allocated time. Farmers cropping more than 1 holding (F1, F5 and F6) used in some cases more hours in some of their holdings but compensated with less time in others. Cases are too few to be conclusive, but there are indications that those with more righted and/or cropped area cross the line of authorized times less than those with smaller areas and consequently smaller times

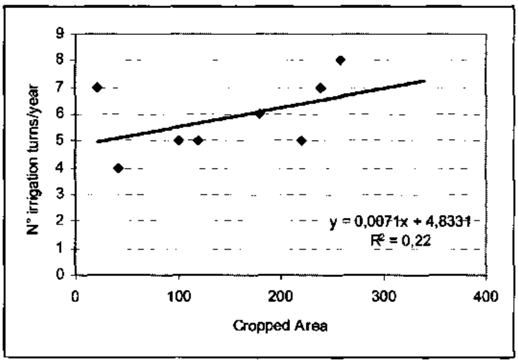

Figure 9.9 Relationship between the numbers of turns used and cropped area in the 1998-1999 Growing.

.Mean irrigation time and Farm Time Delivery Ratio (F-TDR) were calculated based on individual registers and are presented in Table 9.12. Mean time per unit of irrigated area is in this case clearly lower than in the other sampled areas. This confirms the more strict attachment to time rules in San Martin district. Similar values of F-TDR calculated from TWRA and ACA result from the fact that almost the whole water-righted area is being cropped.

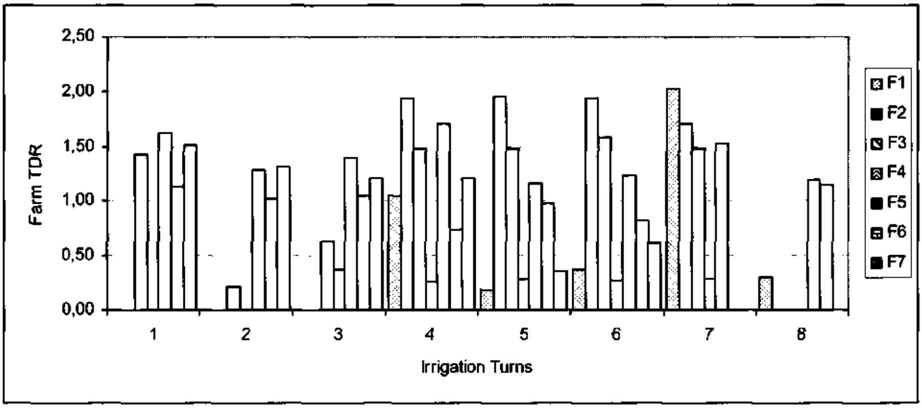

Figure 9.10 Farm delivery times in SMFN tertiary unit, 1998-1999 agricultural year.

Table 9.12 Mean irrigation time and F-TDR in SMFN tertiary unit (1998-1999).

	Irrigation Turns								Annual
	1	2	3	4	5	6	7	8	Mean
Mean irrigation time (hr/ha)	1,3	1,1	1,2	1,2	1,2	1,4	1,2	1,0	1,2
F-TDR $_{(TWRA)}$	1,5	1,4	1,4	1,4	1,5	1,7	1,5	1,2	1,5
F- TDR $_{(CA)}$	1,5	1,4	1,4	1,6	1,5	1,7	1,5	1,2	1,5

9.4.4 Water use at farm level

As in previous cases, water use at farm level was calculated based on delivery times to each farm and mean discharges measured at the head of *comuneros* (Table 9.13). In spite of the low F-TDR, discharge 2 to 3 times greater that the official flow increased mean irrigation depth to make it on average 2,9 greater than the official gross irrigation depth, and put it close to that applied in other areas.

Table 9.13 Mean irrigation time and irrigation depth in SMFN tertiary unit (1998-1999)

	Irrigation Turns									Mean Water use
	1	2	3	4	5	6	7	8	Mean	(mm)
Mean irrigation depth (mm)	252	219	189	208	247	287	173	152	257	803
Farm WDR	2,8	2,4	2,1	2,3	2,7	3,2	1,9	1,7	2,9	0,8

Both irrigation time and mean water used per unit of irrigated area decreased with cropped area, as shown in Figure 9.11 This could be related with greater control of water during the application phase that was clearly observed in the three most important farms in this area.

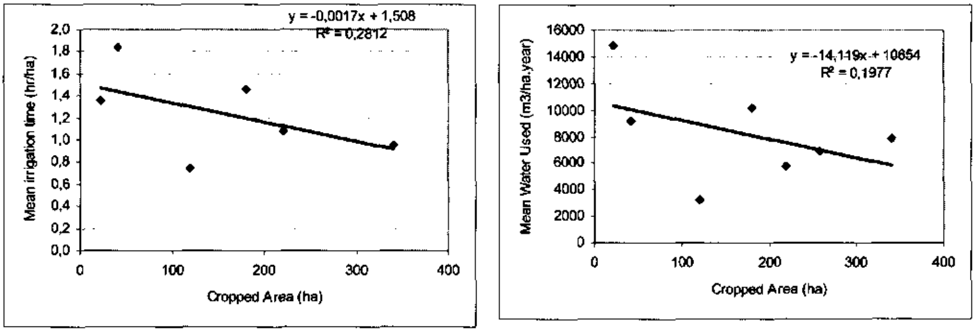

Figure 9.11 Relationship of mean irrigation depth and annual water use with cropped area in SMFN tertiary unit (1998-1999).

9.4.5 Application Practices

Normal application practices were surveyed through structured interviews and direct observation (all farms were visited at least once). All farmers used basin irrigation in pre-seeding and followed irrigation recommendations with one exception. In vegetable crops a kind of checked furrow is the main method declared by farmers. However due the uneven land surface in most cases water flows to fill the end of the downstream furrow before reaching the end of upstream furrow, so the application retains the main characteristic of basin irrigation.

All farmers use *bordos* to control water application. Four farmers use the traditional design of parallel *bordos* while 3 (the largest) use contour *bordos* (Figure 9.12) achieving a better control and a more even application of water[9.7]. Those using the traditional design, estimate 15 m as the mean distance between their mechanically constructed *bordos* and *trabas*. This gives a denser network of earth ridges than in other areas, requires a high resource mobilization but lead to better water control and higher uniformity. In other sample of the resources of the SMFN's farmer type, the three farmers that use contour *bordos*, have constructed permanent diversion structure (on/off control) at crucial diversion points of their farms and use portable checks to control water at irrigation ditches.

[9.7] Irrigation time per ha of one of the farmers using contour *bordos* was 1 hr/ha, the lowest in the area. However delivery time for the other two using this type of desing was still 1,4 and 1,6 hr/ha proving that also at farm level, a better physical control of water is a necessary but not sufficient condition for a good water management. The delivery time to each irrigation unit, the human controlled component of water application was responsible in this case of the rather high irrigation gift applied.

Figure 9.12 View of a plot irrigated using contour *bordos* in SMFN

9.5 Conclusions

The SMFN is an old tertiary unit in terms of infrastructure but is under the official delivery schedule and irrigation practices adopted during the PRD intervention. This study showed that it functions more closely than others in some aspect to official criteria. Yet still users were able to reshape many aspects of water delivery to make it more flexible and highly responsive to their demand.

The percentage area with permanent water rights is similar to that of previous case studies but unlike them only 10 farmers hold it. Although not researched in detail, the only possible explanation of this distribution is that SMFN area belonged to the historical irrigated area around Loreto village that motivated construction of San Martin canal in 1912. Application of the prior appropriation principle, one of the two criteria adopted during PRD intervention to redefine water allocation, validated this situation. However the mosaic pattern of irrigated and non-irrigated areas is still present, since in spite of the large area under permanent water rights, this actually only covers 37% of the gross command area of SMFN *comunero.* This fact, complemented by the diversified entrepreneurial production systems with high capacity to respond to market incentives, has made the use of PRETAs a frequent tool to respond to market demand and support steady growth of the irrigated area.

SMFN's SARCC does not conform to official rules at least in relation to appointed positions. Here as in other areas only the *administrador* is a functioning position. However unlike other area, a *celador* has been appointed here and he is in charge of daily operation tasks that the *administrador* executes in RS and the *tomero-administrador jointly* execute in JS and B1-TTS. The appointment of a *celador* did not correspond to a need to control water distribution bur rather is a reproduction at *comunero* level of the production styles of most SMFN' farmers who keep management decisions but delegate daily tasks. The small size of the user group, their homogeneity in term of production systems and capacity for resources mobilization in conjunction with relative high water availability explain the collaborative behaviour of users and the smooth functioning without conflicts in water distribution.

Average annual water used ranges between 80 and 90% of the volume allocated and, unlike other areas, cropped areas remained close to water righted area: the irrigation strategies adopted in both arable and pasture production were determining factors in this case.

In spite of being one of the *comuneros* at the tail of San Martín secondary canal, SMFN had discharges delivered during the research period that were 1.9 times greater than the official planned discharge.

As their colleagues in other areas, the users of SMFN were able to reshape official delivery schedules according to their preferences as follows:

- the official farm irrigation order was mostly the exception rather than the rule in almost all the 20 irrigation turns analyzed;

- the delivery duration varied between irrigation turns and farms, but in most cases it was 20- 70% greater than the official duration, yielding a mean annual delivery time that was 1,5 higher than the official duration, but was certainly the lowest among the study areas.

Despite low delivery times, due to the high discharge the mean irrigation depth per turn was 257 mm, the lowest in this study, but still similar to those applied in other areas and almost triple the official gross irrigation depth.

Basin irrigation is also the most used water application practices of the SMFN tertiary unit but there is a better physical control of water, through making smaller distances between *bordos* and *trabas*, incorporating new technologies (contour *bordos*) and in some cases constructing permanent diversion structures at strategic points in their farms.

All the above elements result from the higher resource availability of farmers of this area (in income, equipment and information). However, they did not result in lower irrigation depth because the water level in respect of *bordo* height continues to be the threshold for the decision to cease irrigation and pass water to downstream irrigation unit.

As in other areas, farmers' irrigation practices such as use of basin irrigation for water application, large irrigation gift per turn and flexibility of delivery duration were functional to buffer large discharge variation and high irregularity in the frequency of irrigation turns resulting from technical limitations of agency operation practices - that would affect seriously farmers' irrigation performance if modern irrigation practices would have been applied.

Regarding the main hypothesis of this study (see Chapter 1) the case study shows how increasingly areas with PRETAS are emerging at the tail end of the system; how field actors (field agency officials and farmers) have adapted "modern" design conditions to their historical practices rather than in the other way around and proved in some sense that this room t manoevre is greater in the unmodernised areas.

Chapter 10

ASSESSING OUTPUTS AT TERTIARY LEVEL

In Chapter 5 it was shown that at secondary level PRD is a well watered system with annual irrigation water use that is doubling annual irrigation requirements and with an uneven monthly water use. This suggests adaptive changes in the management of the main system that responds to users' demands since it is far from technical expectations based on the official fixed rotational water delivery schedule.

This chapter makes a comparative analysis of the 4 studied "tertiary units", looking for conclusions about the initial hypothesis of this study - that the five basic attributes used to select them: infrastructure, Agrarian Structure, Water Availability, Presence of PRETAs and type of Water Delivery Schedule (Section 1.8.1) - affect their performance. Within the general framework of the research it also explores how much farmers' irrigation practices at farm level condition water management in tertiary and main systems and therefore their performance.

10.1. Linking Water Use with Conditions of Possibilities

Table 10.1 summarizes the main characteristics of the sampled areas and research results in relation to water use and irrigation practices. As can be seen from the first part of the table related to agrarian structure and production systems, the cases do represent different conditions and realities found in PRD[10.1]

JS and B1-TTS were conformed by smallholders farmers although with differences in initial conditions and cropping patterns (traditional cotton-alfalfa sequence in JS, vegetable in B1-TTS), and show clear feature of economic recession. In both cases cropped areas decrease to 0,57 of the water righted area (permanent + PRETAs). However, while in JS there has been a high desertion of farmers (active farmers represent only 40% of registered plots) in B1-TTS most farmers remain active (averaging 0.9 farmers per plot) but reduced their cropped area from 25 has (remember it is the area of re-settlement of small holdings farmers within PRD project) to 10 has[10.2].

RS and SMFN tertiary units, the two old tertiary units, are highly active and show completely different behaviour with respect to previous cases, and also differences between them basically relate to different initial agrarian structure and production systems.

In RS, where the original agrarian structure included a mix of a many small farmers and few large farmers, there has been an important process of land and water concentration caused by the different economic realities of both type of farmers, and the presence of important areas of suitable lands without water rights within the command area.

[10.1] Although the number of samples area small, they actually represent the most important situations within the PRD.

[10.2] Farmers settled in 25 has parcels in this area were originally smallholder farmers in other areas. Under negative economic conditions and desertion of government support, it seems that they returned to crops similar to those areas they used to cultivate in their places of origin. This supports the idea that their economic status could not be sustainably improved due the early truncation of the re-settlement component of PRD project.

Table 10.1 Summary conditions in sampled "tertiary units" in 1998-1999 growing year

	"Tertiary Unit"			
	JS	**B1-TTS**	**RS**	**SMFN**
	AGRARIAN STRUCTURE			
Water righted area (Permanent + PRETAs)	749	780	1086	993
Cropped Area (ha)	430	441	914	1232
N° Active farmers	37	31	34	9
N° active farmers/registered plots	0,4	0,9	0,4	0,9
Mean size EAP (ha)	12	10	27	154
Homogeneity	High	High	low	high
PRETAs/Cropped area (%)	9	16	31	17
Predominant Production System	Smallholding	Smallholding	Small to Large	Large
Cropping intensity (cropped area/registered area)	0,57	0,57	0,84	1,24
Predominant crops	Cotton-alfalfa	Carrots-Onions	Soybean-Alfalfa	Alfalfa-pasture
	IRRIGATION OPERATION CONDITIONS			
Infrastructure	Modern – lined	Modern – earthen	Old - earthen	Old-earthen
Maintenance conditions	Very poor	Very poor	good	Very good
SARCC role	Low	Low	High	High
"*Tomero*" role	High	High	Low	Low
	WATER USE			
Use of irrigation facilities (N° turns/year)	2 to 2,5	2,3	3	3,4
Irrigation turns frequency (days)	30	Arranged Rotation	37	29
Irrigation order	Official	Arranged Rotation	Official - Flexible	Flexible – Official
Mean delivery duration (hr/ha)	2,7	3,3	1,7	1,2
Mean Discharges (l/s)	241	278	487	577
Mean water apply per irrigation event (mm)	230	327	291	257
Mean annual water apply (mm/year)	549	862	908	803
Application Method	Basin	Basin – Furrow	Basin	Basin
Distance between "bordos"	25 50	20 – 30	25-50	15-20 (contours)
Distance between "trabas"	> 50	>50	25 – 50	15 - 20
N° of irrigators	<=2	<=2	<=2	2

While small farmers like those in JS abandon farming activities, medium and large farmers enlarge their cropped areas. Signs of this process are clear in Table 10.1, where RS shows a relatively high land use intensity in terms of the PRD, 0,87 but the number of active farmers average only 0.4 per registered holdings, and gradually and large entrepreneur farmers are taking the place of traditional smallholdings and becoming dominant. Proof of this is the fact that the mean area of EAP has increased from 10 ha at the beginning of the PRD to 27 ha in 1998-1999 (possibly it is even larger nowadays), PRETAs account for 31% of the cropped area, and cropping patterns based on extensive crops and alfalfa have become more dynamic and highly market oriented.

SMFN shows a complete different agrarian structure, with only 9 to 10 farmers with a mean area of 151 has. Almost all plots are active (0,9) and land use intensity is the highest of the four cases - 1,24 - and very high for PRD considering that there is only a small area of vegetable crops. PRETAs, which account for 17% have been used mainly by existing farmers to increase the cropped areas within their own farms. These large entrepreneur farmers are very responsive to market opportunities, changing crops even from extensive crops to vegetables. However the foundation of the main business of this group is related to cattle rising, and for that reason alfalfa and pastures are the dominant irrigated crops in the most recent seasons.

Paradoxically JS and B1-TTS are the modernized areas in terms of irrigation infrastructure that even reached farm level in the case of B1-TTS (see Chapter 6 and 7). However their functioning is far from design conditions, due to the poor maintenance that greatly reflects the economic recession in the production systems predominant in both areas. In JS with the best irrigation infrastructure, weed growth is almost unchecked, and most sluice gates are destroyed and work as on/off gates. A similar situation is found in B1-TTS. By contrast conditions are better in RS with old structures fairly well maintained and they improve considerably in SMFN where *comunero's* gates have been improved by farmers, maintenance of watercourses is good and some farmers have also built permanent diversion structures within their farms (Chapter 9).

High variations are also found between the study areas in most of the elements shaping make water distribution.

The average number of turns per year used in the 3 year study period increased from 2,3 in JS and B1-TTS to 3,4 SMFN: these are very few for a "modern" systems designed to offer 11 irrigation turns/year. As discussed in Chapters 6 to 9, this low use of irrigation turns per farm is highly related with traditional farmers' irrigation practices rather than restrictions in water supply by the main system.

If the real frequency of irrigation turns would be used as indicators of reliability of irrigation deliver, they PRD would score a low value for such indicator. Only in SMFN was the mean frequency of irrigation turns close to the 28 days official interval. It was longer and its variability higher in JS and RS, although this data is mainly anecdotal since farmers used few turns, and only from July to October could a series of consecutive effective turns be found.

Delivery order is another variable managed in different ways across the study areas. While the official order is normally followed in the short *comuneros* of JS with a strong *tomero's* role, order is frequently changed by the *administrador* in RS despite the large number of farmers involved. In SMFN, the low number and homogeneity of farmers make arrangement needed easier than in the previous case. B1-TTS is under official arranged rotation highly controlled again by the tomero and shows a rather chaotic order with water flowing from the head to the tail and vice versa.

Delivery duration is, together with delivery discharge, one of the parameters of the water distribution with higher variation between the areas studied. Mean delivery duration decreased from 3,3 hr/ha for B1-TTS to 1,2 hr/ha in SMFN sampled unit with values for JS (2,7 hr/ha) and RS (1,7 hr/ha) in between. These delivery durations are 1,5 to 4,1 times greater than the official of 50 min/ha (0,8 hr/ha), and are practically possible because not all the water righted area is irrigated each turn.

As regards discharges, contradicting local belief that assigned *tomeros*[10.3] have a high capacity to deliver official discharges, field measurements showed a great variation of discharge between studied units, among turns and even during the same turn. Although all are officially reported as 1 *caudal* there is a marked difference in mean delivery discharge, especially among modernized and "old" units. It is below the official 300 l/s (241 and 278 l/s) in modern units and far above it (487 and 577 l/s) in "old" tertiary units proving that modernization really was able to control water flows close to designed discharges.

However despite the strong control effect over delivery discharges of modernization initiatives and the high heterogeneity in other factors, mean application depth per irrigation event is fairly homogeneous –with the exception of B1-TTS. This homogeneity results from the fact that flexibility in delivery duration compensates for the large differences in discharges.

Nevertheless to say that rather homogeneous irrigation depths are applied in practice is not to say that results they are close to technical expectation. The mean irrigation gift, 260 or 275 mm (depending if B1-TTS is included or not in calculations) is 2,8 to 3 times greater than the official 90 mm technically calculated at system design stage (based on mean moisture storage capacity of soils and a classic irrigation threshold of 50% of available soil moisture). It is however close to users' preferences and their practical possibilities with the technology applied, and their particular approach to irrigation management highly rooted in protective irrigation.

As has been shown, basin irrigation is the main application method of all type of farmers and type of water right. Earth ridges - *bordos* and *trabas* – delimit irrigation units (basin) of different size depending on topographic features and farmers' resources, but application practices are the same for all type of farmers. Basins are filled in upstream – downstream direction by opening their downstream ridges when water is close to the top of them. Because the height of *bordos* and *trabas* is fairly homogeneous in the different areas, the time required to fill each unit changes with delivery discharge. However, irrigation depth results are rather homogeneous in different areas because it is the height of *trabas* and *bordos* in this order that determine this, and not delivery duration and discharges.

The above findings prove that, as supported throughout this thesis, that the responsive attitude of the Agency has not been a reflexive decision in terms of service provision, but a pragmatic practice. It is argued here that the similar irrigation depth applied by balancing low discharge with longer duration is highly determined by farmers' application practices and the

[10.3] Actually "*tomeros*" and users manage by trial and error to find a discharge that is a compromise between systems supply possibilities and users demand requirements and avoid conflicts between them. This discharge is defined as the "caudal" for that specific area and the assumption of its homogeneity in space and its association to official 300 l/s is just part of the discourse, but irrelevant for both actors at the frontline.

similar evaluation of an irrigation event as good or bad irrespective of farmers type, and not a rational operative decision taken at system or lower agency levels.

There are differences in annual volume of water used among tertiary units, with the lowest values in JS and the highest in SMFN. These differences, in spite of the similar irrigation gift, result from the different number of turns used per year consequent mainly to differences in land use intensity, and not from large differences in irrigation scheduling or water availability which is in all cases are similar and high.

10.2 Water Supply and Irrigation Adequacy

10.2.1 Annual Data

Figure 10.1 presents annual RWS and RIS for comparative purpose among tertiary units (A and C) and for comparison with their values at the parent canals (B and D).

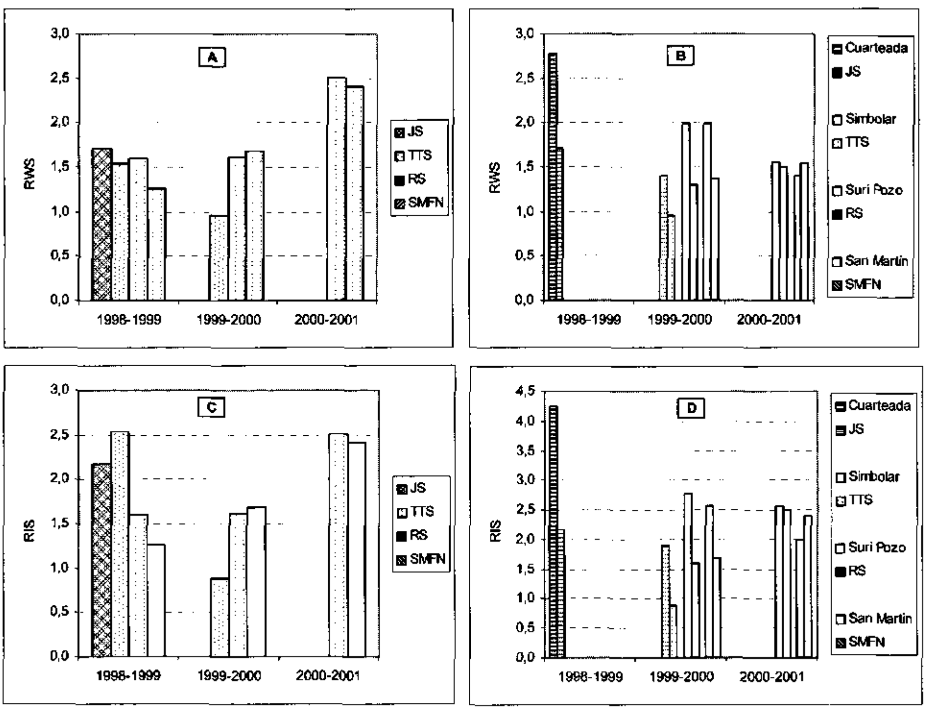

Figure 10.1 Annual RWS and RIS for studied tertiary units (A and C) and its comparison with parent canals (B and D).

Although the short and incomplete set of reliable information does not show a regular pattern and do not allow real conclusive discussion, they give an image of the differences among different areas. They show that - as in almost all study aspects of water management in PRD - there is a high variability in the results as it was already shown for secondary canals in Chapter 5.

They also suggest that modernization (JS and TTS) would have not led to a better use of water or to a more stable inter-annual water delivery, since the highest RIS in 1998-1999 was found in "modern" units (JS and B1-TTS).

There is no pattern to relate water use in tertiary water courses with their location along or water availability in their parent canals. RIS for RS and SMFN increased from 1999-2000 to 2000-2001 seasons while it decreased for their parent canals, Suri Pozo and San Martin. The 1999-2000 RIS for B1-TTS, although it is a tertiary water course close to the head of its supplier, is lower than for Simbolar Secondary. The "old" units RS and SMFN, tail *comuneros* of their respective secondary canals, have low RIS in 1999-2000 season but similar or higher RIS in the 2000-2001 season than their parent water courses.

10.2.2 Monthly Data

In a similar way as for secondary canals, monthly RWS and RIS were calculated for a more precise study of the irrigation practices in tertiary units (Figure 10.2). In agreement with results at higher level they reflect the uneven use of water during the year, with high water and irrigation supply in the last half of the dry season.

Cropping pattern discussed in Chapter 6 to 9 (that include heavy pre-seeding irrigation and few applications during the growing seasons of most crops) are highly reflected in the monthly distribution of both RWS and RIS.

The more even results for JS are consequences of the presence of alfalfa (irrigated almost every month during winter) as a second crop after cotton in that area. The practice of applying two pre-seeding irrigation by RS's farmers are also evident in the high use of irrigation water from June to August in this area. The diversified cropping pattern in SMFN is also clear while the low use of irrigation during the 1999-2000 season masks the water use pattern in B1-TTS dominated by winter vegetables in the last 3 seasons.

Under the responsive management of the main system by the agency this pattern is also transmitted to the secondary canals, (see Chapter 5), confirming in the PRD case the high influence of farmers' practice over management decision at upper levels of the system.

10.3 CONCLUSIONS

Comparative analysis of the 4 sampled tertiary units allows show that:

Modern irrigation infrastructure, high water availability and responsive management of the main system to users needs have not been sufficient to guarantee economic development, and/or simply overcome negative effects of open market policies for small farmers.

Despite modern irrigation facilities, including the Rio Hondo reservoir, assuring a monthly irrigation water supply, farmers do not use more than 30% of the available irrigation turns.

There is a high lack of uniformity in most parameters of water distribution: frequency of irrigation turns is highly different from the official; irrigation order is frequently changed within the tertiary units especially by *administradores;* while there are variation to the order of 2,8 and 2,3 magnitude in delivery duration and delivery discharges among sampled areas.

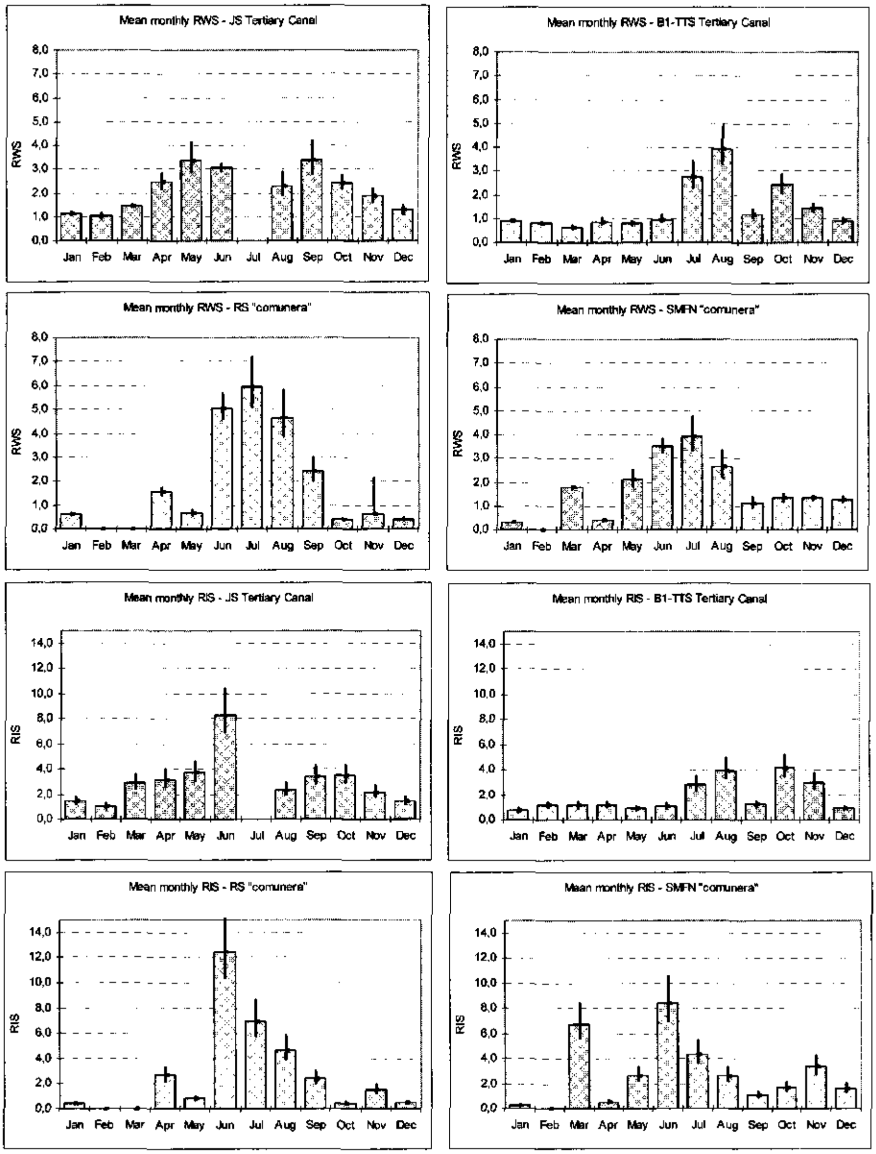

Figure 10.2 Mean monthly RWS and RIS for studied tertiary units in PRD.

Mean irrigation depth per irrigation event (275 mm) is 3 times greater than the designed, and are possible to apply by a high compensation of delivery duration and discharge, and irrigation areas per turn that are smaller than the water righted area.

Due the low number of irrigations during the year, the annual use of water remained below the water-righted volume, despite the heavy individual applications.

According to RWS and RIS performance indicators, there are differences between tertiary units with respect to water supply, but all of them are, on an annual base well- wetted -

irrespective of infrastructure, production systems, predominant crops and homogeneity of users.

Monthly water supply (RWS) and monthly irrigation water adequacy (RIS) show the same pattern than in secondary canals (Chapter 5), with very high values from July to November when predominate the heavy pre-seeding irrigation practiced by farmers and very low values indicating under-irrigation in the rainy season (November March) the growing period of most crops. This highly supports the statement of Chapter 5 that irrigation practices have made the PRD a wet system in a dry area with dry crops in the wet season.

Despite the modernization introduced by PRD intervention at system level, it is the traditional on-farm practices developed under unregulated river flow and protective irrigation that determine the pattern of water use and the main component of system performance.

Chapter 11

ALTERNATIVE APPROACHES TO PERFORMANCE ASSESSMENT

In Chapters and 5 and 10 different performance indicators were used to assess outputs of irrigation practices in PRD. However, in selection and interpretation of results I tried to avoid a pure engineering vision, using other researched information about socioeconomic context, production systems, and farmers' irrigation practices. I have even introduced the local practice of pre-seeding irrigation in calculation of main indicators.

Nevertheless, as clear in the definition of indicators and calculation procedures, the engineering vision persists and predominates in the estimation of water requirements, which definitely assumes that achieving the full irrigation strategy is the objective to be reached. This is not to say that I renounce the use of the engineering vision as an important component in design of interventions to improve water management. Rather I emphasise, - as has been clearly defined by Small and Svendsen (1990), Murray-Rust and Snellen (1993), Bird and Gillott (1992), Jurriens (1996), Renault and Vehmeyer (1999) Bos et al. (2005) - the objective of performance assessments and use of performance indicators and standards or target depends highly on the vision and interest adopted.

For the above reasons a complete evaluation of irrigation practices in PRD would be incomplete if the assessments by those who have been the main actors in the last 30 years remained unknown. Few attempts have been made to study performance from farmers' perspectives (see section 1.5.3.) and even less from perspective of a "real" irrigation agencies since most performance assessment assign to them a professional rationality derived from the engineering vision.

11.1 AGENCY VISIONS

For almost 20 years, A&EE collected information about discharge of main canal, cropped and harvested areas and crop yields that was annually internally reported. Under UER administration, collection of canal discharge data was extended to secondary canals: information was periodically checked but cropping pattern has not been systematically collected and processed. However as Burt and Styles, 1999 stressed for most irrigation agencies, these have been routine activities only for statistical purpose without any practical implication on decision process about water distribution.

There is no evidence of any formal performance assessment by any of the organizations that have been in charge of PRD administration, including the former DPR that operated the systems in the 1950's, the A&EE responsible from the 1970's to the 1990's and UER in the last 10 years. None of them have collected and processed information for operational purposes or explicitly defined objectives, targets or intended values in the way they are treated in international literature.

However convinced that there should be some type of performance assessment, I undertook many interviews at different agency levels, looking for any informal or implicit way of performance assessment. Interviewees included the bosses of the agency (*intendente*), past and present heads of district offices, field officials at district offices and *tomeros* from different areas of the system (including of course those from the studied tertiary units).[11.1]

Almost the unique and common "performance indicator" for all administration and at all levels of the Agency, has been the number of users complaints, as frequently mentioned in this thesis. Keeping this pragmatic indicator low was the positive and unanimous answer for all administrative level to the now well known questions: "Am I doing the right things?" and "am I doing the things right?" which according to Murray-rust and Snellen, 1993 any modern operation unit with a service oriented approach has to deal with. According to results shown in this thesis, at least since construction of Rio Hondo reservoir, use of this criterion of low complaints has been very effective for being responsive to farmers' demands. In practice this meant, apart from the official rotational water delivery schedule, keeping water supply per irrigation event close to customer wishes but high in relation to theoretical requirements.

Beside this common indicator for systems operation, each *intendente* had their own objectives and assessed the Agency performance based on their specific visions or personal profiles.

The "bureaucrat", in charge during the period of A&EE as a strong agency, constructed a world of perfect technical reports full of numbers and statistical information, and offered a strong public position but was almost completely under the control of the real operational practices downstream the Matriz canal.

The "pragmatist", acting in the last A&EE period and first period of UER administration, with experience at district offices and with an assumed "service" discourse, over-trusted the experience and negotiation capacity of *tomeros* and other field officials for running the systems. In his second period as *intendente* he promoted user participation and made it effective,- mainly through organizing WUAs under control of large users,- and made the first step to improve communications within agency field officials to support flexibility in water delivery.

The "engineer" made efforts to incorporate new technology in systems operation that was coherent with his technocratic and positivist discourse, that the Agency should lead a process for improving water management to solve "underperformance" of the system. However, convinced that the main problems were at farm level and not at Agency level, he proposed technical approaches to control water delivery at farm level. However his technical profile and low political support in times of local political fighting to re-assume political control over water distribution meant he had no political force to implement them.

Appointment of a "politician *intendente*" was a logical consequence of the renewed times when officials where highly dependent on local political power. He offered an efficient administration, improved administrative procedure and communication capacity of the agency for working in real time. But the objective of this improvement was not to make the system more flexible to cover water demand. The objective was to have better control over users and manage the irrigation systems based on administrative issues, basically collection of water fees rather than water use.

[11.1] Six of the 8 *intendentes* from the 60s, 5 chief and 2 *capataces* of district offices and 11 *tomeros* were interviewed

In the interviews, beside the common discourse of the low numbers of users' complaints during their administration, all respondents highlighted relevant aspects from their vision. The "bureaucrat" stressed the order of his management, the close control of reservoir water use, and consultation of users in time of water crisis to reach a consensus about strategies to be followed. The "pragmatist" stressed the increased participation of WUAs and their contribution to overcome rigid bureaucratic rules that prevented the agency from increasing the capacity required for improving system response to farmers demands. The "engineer" emphasized the re-assumed role of the agency over water use issues and a better power balance with WAUs. Finally the" politician" considered successful their administration due the "*low cost of one of the best irrigation service in the country with a low number of employees*", the free water for small farmers at the beginning of his period and the application of the principle "no payment no water" when the provincial government reduced funds and ordered him to collect water fees.

The fact that keeping users' complaints low has been the main objective of administrators with different visions and political contexts does not mean it is a unifying reason but that it has been functional to all visions. For the "bureaucrat" users' complaints would put some shadow over his "excellent" administration and could be dangerous for his position in time of populist national governments. For the "pragmatist" they would lead to conflict situations. For the "engineer" and "politician" acting in the last period under highly politicized contexts, complaints would threaten his position directly, since they would be quickly removed under any public conflict, especially if powerful support from the provincial government were involved.

Officials at district offices and "*tomeros*" also stressed the importance of low number of users' complaints in their areas, their good and cooperative relationship with all users and their response to water users' demand. At this level, pragmatic management of the daily situation highly predominated over technical aspects, and was even part of the discourse of the chiefs of district offices, who in most cases were engineers.

There is no a solid corporate behaviour of the agency as a whole, with the membership commitment to the agency waning from top to bottom. Field workers and even officials at local offices recognized their affiliation to a district rather to the agency. They knew little about realities in other districts; however the shared objective of full coverage of users' demands to avoid complaints gave them a coherent approach to daily tasks, and unified their discourses to outsiders.

Independent of their approach, personal characteristics or position within the organization, all those interviewed assessed Agency performance as good or very good and even excellent. They only considered system performance in their responses, without differentiating any other dimension of performance for the agency. From their expressions it could be concluded that all interviewees managed adequacy, timeliness, and equity as criteria for their assessment.

Interviewees defined supply adequacy as indicating the grade of coverage of users needs', and considered it as the most important criteria to assess performance. They scored the PRD irrigation system high as regards this criterion because, they stated, it always responded and fully covered user needs.

Performance was also considered high as regards timeliness of water delivery not because water always arrived at the time crops or users needed it, but because always an agreement is reached with users.

The system performance was also ranked very high in terms of equity by the interviewees, who correctly distinguished equity from equality. In this case the reason for the high evaluation is that according to most of them, all users receive the amount of water they need because in most areas water is delivered "until finished".

Paradoxically, the former head of the provincial agency, that managed the systems before A&EE, under unregulated flow conditions (in times with large numbers of conflicts with and between users) was the only person interviewed who talked about the accountability of the Agency to farmers. He highlighted this point as the main difference with regard to Agencies that followed his in time. He mentioned frequent meetings with farmers, and public diffusion of annual reports and information on river discharges in times of water crisis (see chapter 2). He contrasted this behaviour with that from other agencies that never made public any information on water delivered to different canals, number of users served or water fees collected. I considered this position paradoxical because he did not recognize that it was in part the high mobilization of farmers about water issues at that time that was the main reason for that attitude of the Agency.

Also paradoxical was the fact that the "politician" *intendente* mentioned that for the first time in the history of PRD the criteria of 'no payment no water" was implemented - when farmers were exonerated from payment of water fees many times for political reasons during PRD history.

There was no mention (as defence, justification or question) of any possible wrong water management at system head, main and secondary canals under agency responsibility. Only the "engineer *intendente*" referred to the low efficiency of the system, but also stressed the high responsibility of the poor water management at farm level. There was no mention of water as a scarce resource, of low productivity of water and, of course, nor to any lack of water resource planning - since for all of them their main task was just to administer a given situation.

Definitely the local agency is far from being a rational agency, such as that promoted and underpinned in most proposals for performance assessment – that would define long and short run objectives, collect information during operation, assess their performance as routine work and correct their working procedures based on theses results. Rather the local agency is a pragmatic organization with an evolutionary path, just like the PRD as a whole, that - without water policy mandates in the last 30 years - has shaped its actions based on its own internal visions, and the claim that their customers could be satisfied until now based on a high amount of available water in relation to demands.

11.2 Users Visions

Performance assessment from users' vision was also researched through structured interviews in the study areas and through a large number of unstructured interviews and talks with users within and outside the studied areas. It is clear that users are not a homogeneous group, with similar interests, resources and vision as has been many times assumed even for large irrigation systems such as PRD (Renault, 1999). In this sense the heterogeneous characteristic of sampled areas gave possibilities to pick out up different visions, but representative farmers of the most identified vision were also interviewed.

First I hurry to express that in global terms most farmers, independent of type and vision considered irrigation performance very acceptable. Eighty eight percent of all interviewee farmers in sampled areas answered that they do not have any irrigation problems. The most frequent reason argued by the few who said they have problems, were of operative type such as frequent canals breaks, water stealing by upstream users, etc. As it can be seen from Figure 11.1, the percentage of farmers answering that they no irrigation problem is very high in all studied areas.

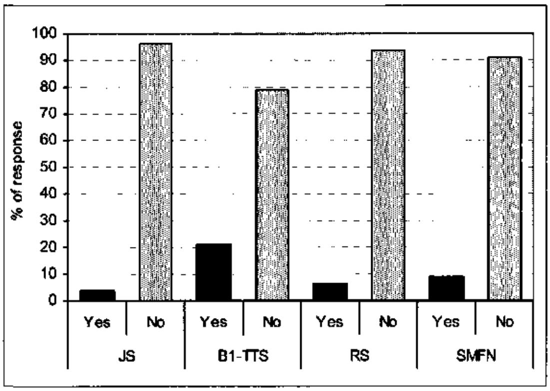

Figure 11.1 Farmers' answers about if they face any irrigation problem.

Asked about adequacy of water supply, it was clear (in agreement with findings of Hoeberichts, 1996 in Pakistan) that PRD farmers perceived this as a relation between numbers of irrigation turns they received and the number they wish to have. Since they are always emphatic that numbers of turns do not limit their irrigation management, they rated a very high system performance in relation to this parameter (Figure 11.2). Only a few of them, mainly the vegetable and alfalfa croppers, mention the inopportune shutdown of the system in May that deprives them of a turn that could be important for their production. However this answer has not been quantitatively surveyed and in practice there has been no official claim from this group of farmers asking for a change.

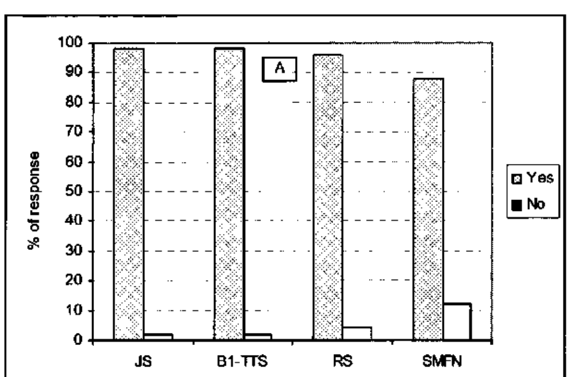

Figure 11.2 Farmer's opinion about appropriateness of N° irrigation turns/year in PRD.

Based on two other questions from the structured interview a second combined indicator was derived, and 6 classes defined (Table 11.1. The first question enquired if farmers found delivery duration sufficient for them (Yes or No) and a second that asked about their evaluation of delivered discharge in three categories (Low, Fair, High)).

Interpretation of delivery duration sufficiency is straightforward: farmers are able of irrigate or not as they want. Classification of delivery discharge is not only a judgment of farmers about the absolute quantity of water they receive but indeed a valuation of their own capacity to manage water at farm level. Therefore when they value discharge as low they are saying that they would like to receive more and that they could manage it.

Table 11.1 Adequacy based on farmers' perception of duration and discharge delivered

Delivery Duration Sufficient	Delivery Discharge	Supply Adequacy
	Low	Very Low (VL)
Not enough	Fair	Low (L)
	High	Moderate Low (ML)
	Low	Moderate Fair (MF)
Enough	Fair	Fair (F)
	High	High (H)

Figure 11.3 shows differences among the studied areas based on the combined indicator. In JS 18% and 42%, and 16% of farmers respectively qualified adequacy as very low, low and moderate low. That means that for 76% of the farmers of this area, water supply would be below their requirements and in particular that 18% of them were able to receive more water and longer time. For the other subgroups, improvement of adequacy would only come from taking longer delivery times since they would not be able to manage higher discharges.

Satisfaction of B1-TTS users is high: more than 80% considered delivery duration enough (remember that the delivery duration in this water course is 3,3 hr/ha, the highest of the 4 studied cases) and delivery discharge fair. Satisfaction is also high in RS but more than 30 % of the farmers recognized that delivery discharges are high which is in agreement with the high mean delivery discharge measured for this water course.

Farmers are evenly divided in SMFN in two groups, although results in this case should be taken only as a guide since the number of interviewee, 9, is very low. It is clear that both groups are satisfied with delivery discharge (the second group more so) but one group still could not irrigate within the available time (remember that this is the area with lower delivery duration of 1,2 hr/ha).

Except for JS answers are rather consistent with the statement of farmers that they no irrigation problems.

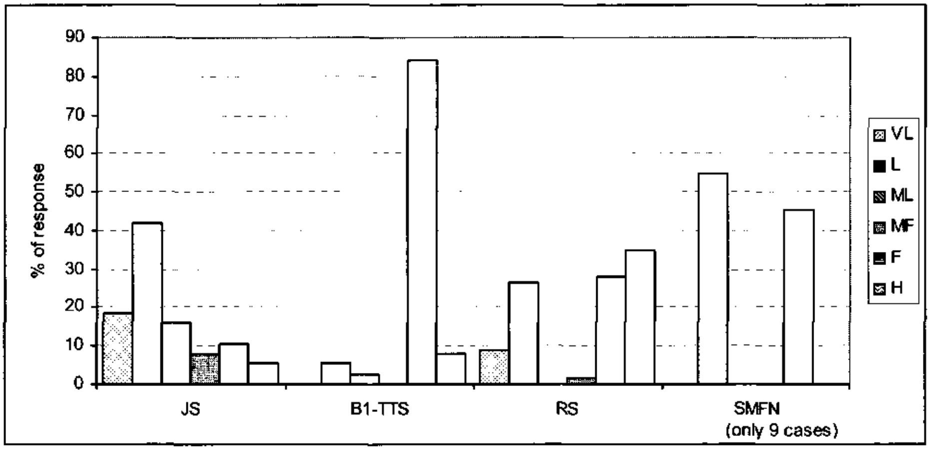

Figure 11.3 Farmers' evaluation of supply adequacy base on a combined indicator linking discharge and delivery duration.

There are no specific indicators about timeliness and predictability. This is not because farmers do not consider them important, but because they value PRD performance high in relation to these two performance parameters (despite the variable delivery frequency which most of the time is longer than the official 28 days). As mentioned in the case studies in Chapters 6 to 9, the predictability is high for farmers because they expect one turn per month and this has happened in the last 30 years ago. Timeliness is also a subjective valuation related to farmers' water management. In this case the high score result was unimportant - due to the "protective" irrigation practiced by most farmers, and because the high irrigation depth applied in each irrigation event gives them possibilities to buffer changes in delivery frequency.

Equity is another performance parameter that did not result as relevant from the farmers' point of view. Hoeberichts, (1996) in her research about water users' perspectives of irrigation performance in Pakistan, considers it a complex parameter because if water is in abundance water users do not concern themselves with equity issues. That seems to be the case in PRD, where: farmers know nothing about other areas and others districts, water supply changes are normally charged to water management upstream from their *comunero* but they have normally equity issues under control within their domain, the *comunero.*

Prior to this research I also agreed with others that the great acceptance of the "caudal" as a discharge unit extended from the belief that water distribution is spatially uniform, in spite of the high variability showed by direct measurements. Research results proved that the general belief of acceptable spatial uniformity would not be only related widespread agreement, but also to the fact, that through time compensation, differences in discharge are highly reduced.

11.3 Assessing the environmental impact of irrigation in PRD.

11.3.1 Within the PRD Command Area

Although the potential negative effects of irrigation on the environment have been known about for many years, the subject has gained interest with the increased societal awareness on environmental issues only in the last decades. Some performance indicators such as the rising level of the water table; and the mean EC have been proposed to assess environmental impact of irrigation (Bos, 1994, Bos et al. 2005). Salinization and water logging and more recently pollution, and irrigation externalities over other water use at basin level, have been the main focus of attention of the international community. However references about these types of performance indicators are much less frequent in the international literature than those related with water use.

The topic has not been extensively and systematically researched during my field work, but some data were collected for a better understanding of field observations. They are presented here not for an exhaustive technical analysis but to show how irrigation practice in a broad sense (including the political process of water allocation) is affecting environmental issues (salinization) and puts conditions over future strategies for water use improvement.

The role of irrigation on salt concentration and salt mobilization in semiarid regions is well documented and cases of salinization of land and water resources has been highly reported (Ghasemi et al 1995, Van Horst, Martinez Beltrán, 1986, Smedema 2000 Smedema and Shiatti, 2002). Land secondary salinization is a traditional process promoted by irrigation through its direct contribution of salts, mobilization of natural salinity and raising water tables to a shallow depth from which by capillary rise of water and salts reaches the rooting zone of crops. River salinization induced by irrigation, due two related process: withdrawal of fresh irrigation water from the river and return of saline drainage water to the river (Smedema, 2000, 2002) is another topic already known for many years. However, these have gained in focus recently due to serious constraints over disposal of saline drainage water to rivers imposed in some places, which require changes in irrigation strategies and a search for alternative salt sinks.

PRD is no exception in relation to secondary salinization, to the extent that it is normally taken as an example of soil degradation by salinity at national level. With very high RIS over a significant important part of the year, recharge of groundwater has been important. Water tables rose at rates ranging from 0,03 to of 0,15 m/year (Prieto, 1990) in the Zone I in the period 1968-1978 until they reached an annual average depth around 2 – 2,20 m depth, when a new output, evapotranspiration, allowed to balance the recharge.

The annual water table remains around 2m at present in the same area as is shown in Figure 11.4 for JS tertiary unit, but it varies during the year following the water supply pattern already shown in Sections 5.5.3 and 10.2.2

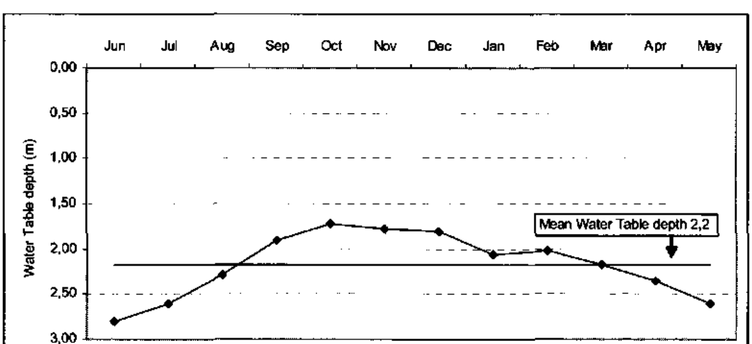

Figure 11.4 Annual variation of Water Table in JS (Observation well S, 3 years mean)

Salt content in irrigation and ground water (Table 11.2) indicates that salinity of ground water is 12 times greater than in irrigation water. As it is well known this is one of the main conditions driving secondary salinization process in PRD[11.2].

Table 11.2 Salinity of irrigation and ground water in JS, (average values of 5 observation well in the period Jun-Sept, 1999).

		Irrigation Water	Water table
SO4	meq/l	1,8	62,4
Cl	meq/l	1,3	37,2
CO3	meq/l	0,0	0,0
HCO3	meq/l	4,9	2,9
Ca	meq/l	3,2	12,7
Mg	meq/l	0,8	6,0
Na	meq/l	4,0	82,5
K	meq/l	0,0	0,0
EC	dS/m 25°C	0,8	9,4
SAR		3,7	31,1

But the objective of this section is not to show that, as in many other irrigated areas, irrigation practices led to a secondary salinization process. It is to highlight that as the product of the water allocation and irrigation practices of water righted farmers secondary salinity is not only affecting irrigated areas. In fact, the large irrigation gifts applied continuously recharge groundwater and leach salts from irrigated soils while natural vegetations (bushes and trees) in non-irrigated plots continually pump water from the water table and accumulate salts in these areas. With the objective to check this hypothesis, parcels with and without irrigation were sampled within the studied areas JS, RS and SMFN and the mean results are presented in Table 11.3 Data confirms an active process of salinization in non-irrigated areas and a good balance in irrigated ones.

Table 11.3 Average soil pH, salinity, sodicity of irrigated and not irrigated parcels in three sampled areas.

		With Irrigation			Without Irrigation			
	N	pH	EC (dS/m)	ESP	n	pH	EC (dS/m)	ESP
JS	8	8,4	1,6	9,2	5	8,3	7,7	24,9
RS	5	8,1	1,0	5,9	6	7,6	16,7	21,3
SMFN	8	8,0	1,0	5,3	5	7,7	25,9	23,1

n = number of sampled cases

The selective and negotiated process of water allocation of the PRD - that has many positive features with respect to reported state intervention in other areas, such as acknowledgement of existing water rights and restriction of maximal individual plot areas - have however had unexpected social and technical consequences:

- From the social point of view, the mosaic pattern of water righted and non-water righted lands imposes on the latter the role of salt sinks and results in a second source

[11.2] Other important component is the minimum to almost null discharge of drainage canal (not shown, but well know in the area) of social differentiation to their owners already excluded from the benefit of irrigation.

- From the water drainage disposal point of view, the "mosaic" pattern of irrigated and non-irrigated lands has solved until now, the problem faced by other areas - of finding a place for salt disposal. However while for San Joaquin valley in California A&EErs and Soppe, 2001 estimate that salt sink areas should be around 10%, for the irrigated area in PRD it could be 200%[11.3], a very high cost for a poor society.

11.3.2. At Basin Level

During the 1990's, the works of Willardson *et al.*, (1994), Keller and Keller, (1995, 1996), and Allen *et al.* (1997) questioned the traditional concept of irrigation efficiency, and the high investment on water conservation programs that misplaced their objectives on "freeing up" water from inefficient irrigation water use.

Based on the basic law of mass conservation and the well known integrity of the water cycle within river basin, they demonstrate that such programs could have negative effects over the water use at basin level since "losses" of one subsystem normally return to the river and form part of the delivered water entering a second systems downstream. This approach has gained supporters, changed the paradigms of international agencies (Perry, 1999) and is at the core of the new global consensus reached towards the end of 20[th] in what Bolding and Wester, 2005 qualify as the third wave of river basin management.

Keller and Keller, (1996), differentiate closed and open basins based on the fact of usable water reaching or not its final sink (sea, salty lake, etc). They demonstrated that in closed river basins, reduction of non-beneficial evaporation is one of the few opportunities to increase water efficiency of the whole system. Allen *et al.* (1997) proposed to change the term efficiency by fractions (differentiating beneficial, not baneful fractions of delivery water) to avoid misunderstanding at regional water management level. They stressed the importance of determining consumed and re-usable fractions, and reduction of the non recoverable consumed fraction as the only way improve water use at regional scale in many cases.

Rio Dulce is an open basin, since much usable water is reaching the final sink of Mar Chiquita, therefore there could be many opportunities to develop new water exploitation. However, the point here is again to focus on the PRD and look in detail of the effect of the "mosaic" pattern created by the water righted process over returns flows and non-beneficial water use.

In this way the hypothesis is that return flow to Rio Dulce river is minimal, due the "non beneficial" use of the non-irrigated lands component of the "mosaic". Although more work is still needed, results of a study of the salt content of Rio Dulce river water made during the research at the entrance and downstream PRD (Table 11.4) would prove a minimum return flow from the system, suggesting that "non beneficial" use could account for a high fraction of diverted irrigation water converting PRD in a "closed" irrigation system.

[11.3] This figure was estimated based on the fact that the non-irrigated area (around 200.000 ha) is two third of the gross command are of PRD (around 350.000 ha) or 200 % of the maximum irrigable area (122.000 ha).

Table 11.4 Salt content (dS/m) variation of Rio Dulce water before and after entering PRD.

Sample Date	Matriz Canal	River downstream
Jan - 1999	0,87	0,92
Jul - 1999	0,78	0,88
Oct - 1999	0,64	0,59
Mar - 2000	0,82	0,85
Jun - 2000	1,02	0,99
Dec - 2000	0,62	0,77
Mar - 2001	0,78	0,88
Jul - 2001	0,83	0,81
Oct - 2001	0,92	0,86

11.4 Conclusions

Alternative assessments of system performance from agency and user perspective revealed their high satisfaction with outputs and different understandings of some of the classic assessment parameters such as adequacy, timeliness and equity.

The last two agencies in charge of main systems operation (A&EE and UER), with almost the same staff but different political conditions, had the number of user complaints as a unique explicit and powerful indicator to internally assess their performance. The objective of keeping this as low as possible led them to be highly responsive to users and to give users a strong opportunity to influence the way water is delivered in the system.

In practice the relatively high water availability in relation to the cropped area has been one of the main factors that allowed the Agencies to achieve its objective of avoid users' complaints in spite of their low technical skills.

As with many other features of PRD operation, incorporation of flexibility in water delivery - a core element of the modern irrigation system operation - was just a logical consequence of the pragmatic management of irrigation issues in the area and not a reflexive decision based on a planned intervention.

Independent of the continuity of the responsive behaviour and use of the same performance indicator by both agencies, there has been some change in agency operation criteria derived from different positions and political contexts, but also from the individual vision of the successive *intendentes*. But definitely all of them add features that enlarged continuously the adaptive capacity of the Agency.

Poorly demand for very precise water delivery by the users, means it cannot be a surprise that most of the improvements incorporated were not technological, and that even some technical tools already in place such as water measuring devices have been systematically ignored during all this years.

High farmers' satisfaction on system performance is highly related to the full coverage of their low water requirements and their preferences in terms of the way water is delivered to their farms. Here a water management rooted in "protective" irrigation principles is practiced even in the case of those production systems that apply modern technology in other component of their irrigated agriculture.

Water in all cases is treated by farmers and agency as a non-scarce resource (indeed it is not scarce under the real situation for these two stakeholders).

Results presented in this chapter and others show that the mosaic pattern of irrigated and non-irrigated lands is the product of negotiated water allocation process that took place at the beginning of PRD. Local irrigation practices are characterized by a few but concentrated heavy water applications, and has produced an active process of secondary salinization. This process affects non-irrigated area within the command area and has direct and indirect social consequences. On the one hand, lands without water rights are gradually deteriorating and decreasing their possibilities of future use, while on the other hand this big salt sink within the PRD command area is many times larger than what should be required, and represents a high cost for the province.

From future interventions and water management at basin level it has to be taken in consideration that PRD is a closed irrigation system in the way used by of Keller and Keller, 1996 for water basins, since non-beneficial use of delivered water within the command area is very high and the return flow of usable water minimum.

Chapter 12

DISCUSSION, CONCLUSIONS AND FUTURE CHALLENGES

Analysis of the evolution of irrigation practice in the Rio Dulce Irrigation Project (PRD) offers examples of many of the issues discussed within the irrigation community from almost all irrigation visions, from the technocratic to constructivist. It reaffirms many but also contradicts some "truths" of the global water consensus and alternative approaches. However, it definitely confirms the contested process of water use, its collective construction by stakeholders, and at the same times its evolutionary characteristic. This confirms that modernization is not always a top-down intervention but can be a collective action of all actors.

This concluding chapter reviews the findings of previous chapters to support the statement of the subtitle of this thesis - that evolution or modernization of irrigation practices in the PRD should continue to be a collective action of all its actors as this have been in the past.

The chapter is divided in four sections: The first summarizes the relevant aspect of construction of the PRD. The second section focuses on the real functionality reached by the contested process of construction of PRD. The third summarizes the performance outputs from different points of view. These sections together inform the fourth section presents some ideas for the agenda for a future and collective modernization of the PRD.

12.1 CONSTRUCTING AND RECONSTRUCTING FUNCTIONALITY

The chapters have shown that the PRD has been in a process of continual adaptive evolution, leaving a diverse set of operational environments. They also showed how, despite elements of poor performance in technical terms, actors have taken informal actions, and promoted and decoded formal interventions to improve or reshape the functionality of the system.

To follow this through, it has been helpful to look at what Chapter 1 described as 'alternative' approaches to performance, that allow social dimensions within the study of functionality, such as those of Perry (1995) and Levine (1980). To summarize these changes, these conclusions return to the framework of Perry.

Perry (1995) considers the three essential elements for a successful irrigation system to be water rights, infrastructure capable of delivering the service implied in water right, and assigned operational responsibility. He classifies as functional those systems where these three elements are matched, and considers functionality a prerequisite to significant improvements of performance by allowing a clear interpretation of performance assessment, a good problem identification and formulation of interventions. However, periods of evolution in a system can also be related with which elements of performance are emphasized in interpretation, problem identification and intervention design.

Following the path of irrigation development in the area in the last 100 years it is clear that Perry's basic components of a functional irrigation systems were socially constructed and re-constructed by the interactions (negotiations, struggles, alliances) of local actors. In these contestations by actors, the roles and focus of their individual and collective actions changed in adaptive ways in response to changes in the political, social and economic contexts.

In this sense roughly three main overlapping periods can be defined in the PRD, based on the predominant process: an initial period dominated by the struggle over water acquisition and consolidation of effective water rights; a second one characterized by the set up of a minimal infrastructure and organization capable to cope with fulfilling water right commitments; and a third period, more deeply researched in this thesis, characterized by adjustment of coping strategies for operation of the irrigation system. In this third phase, the system has apparently reached functionality, based on the pragmatic rules and strategies adopted by the main actors, but with a declining contribution to provincial development.

12.1.1 Water allocation – Water rights

Water allocation and water rights have been recognized as the main political and crucial aspects of collective use of natural resources (Perry 1995, Bruns and Meinzen-Dick, 2000, Boelens and Hoogendam, 2002, Boelens and Zwarteveen, 2005). Evolution of water allocation in the PRD is a clear example of a contested process among stakeholders.

As shown in Chapter 3, the PRD progressively became a large-scale system that was agency-managed until tertiary units, rather than starting out as one. Here, unlike other areas, water allocation has not been a top down component of a strong well-planned intervention that imposed new water rights over existing customary rights. Rather it was an evolutionary and negotiated process that was always active, in which stakeholders appealed to different sources to claim water rights and used different strategies to make them effective, in a sort of legal pluralism and forum shopping (Meinzen-Dick and Bruns, 2000).

The process had users as the main actors in a first stage, when they acquired rights through capital and labour investment, and powerful farmers shared with the provincial government the political control over water resources. They exercised their power to exclude people and dictate water management rules in their own *acequias*.

The state started to take control over water allocation when conflicts between users increased and the available technology seriously limited water exploitation, and took full formal control through two weak state interventions (the Los Quiroga and PRD interventions). These had different approaches to irrigation (protective in the first, productive in the latter), but had a similar political criterion of limiting individual maximum water righted area - in order to spread irrigation benefit over a large number of beneficiaries, open (or force by political means) the recognition of existing rights, and to negotiate the application of the prior appropriation principle. Users continued to be very active in those two periods around water allocation issues, particularly on making them effective.

With formal definition of statutory rights in accordance with existing customary rights (of the water entitlement given water rights for a maximum irrigable area), during the last intervention (the PRD 1968-1973) allocation of the available water seemed to be definitely achieved without winners and losers.

Ninety six per cent of the water-righted holdings were less than 50 ha (the maximum established in both government intervention) proving to some extent the effectiveness of government interventions to reach their objective of spreading irrigation benefits over a large number of beneficiaries. On the other hand, 300 holdings – that concentrated 32% of the water righted area -confirmed the political power of a group of large farmers, derived from former patrons, to force the application of prior appropriation principle and to put their rights outside the acreage restriction imposed by the government on new water rights.

However, alongside these formal outputs of the explicit negotiation among stakeholders, the contested process of water allocation also based on the pragmatism of all actors defined what would be another particular characteristic along the PRD evolution - the "mosaic" pattern of water righted and not water righted lands. This "mosaic" pattern of irrigated and non irrigated areas would come to affect system performance, its environmental impact and future possibilities of evolution while at the same time hiding two basic reasons to keep water allocation under constant negotiation:

- An unsatisfied water demand from a large number of partially righted holdings and from the real losers of the process - the high number of excluded holdings (first by owners of private *acequias*, and later by the provincial government) located within the command area;

- An important amount of water "kidnapped" by the farmers' practices assumed in times of uncertain hydraulic water control, of claiming water rights for an area greater than the cropped in order to counteract the provincial government's objective of reducing the amount of water entitled to formal water rights.

Effectively, with the new infrastructure built to cope with a maximum irrigable area never reached, and operational responsibility under a professional national agency, the system became dysfunctional in the terms of Perry, 1995. Thus the water allocation process was re-opened in the 1980's, driven by a pragmatic and temporary alliance of Agency engineers and partially water-righted large farmers, who proposed and succeeded in the creation of a temporary annual water right, the PRETAs.

The emergence of PRETAs, established a sort of agency-controlled "water banking" that was highly functional to the Agency (source of cash) and to most users, but especially to large, highly market-oriented farmers, enabling them to access to water and follow changing conditions of markets.

This was not the outcome of a neo-liberal discourse or a call to market principles, but rather a technical-pragmatic argument about the need to giving a beneficial use to the large amount of water otherwise annually delivered downstream without any productive use. At the same time PRETAs meshed with political visions and opportunity, since PRETAs helped local politicians avoid a confrontation and political decision they likely would never take, of removing permanent water rights from those who had not used them in the previous 3 years (which is the official rule). PRETAs have only been criticized by permanent right holders in times of water crisis (1988-1989, 2003-2004; 2004-2005), but their holders had enough lobbying capacity to overcome criticisms on these few occasions, and in practice PRETAs work almost as permanent water rights.

Contrary to what should be expected, according to some shared characteristics with tradable water rights proposed by water market supporters (Winpenny, 1994) PRETAs have not led to a better water use overall. (Some large farmers and commercial producers do benefit). By contrast, they have extended the "mosaic" pattern of water righted and non water righted areas rather than resolve this, and resulted in an effective tool to re-concentrate control over water. This is clear from the fact that the area under PRETAs was rather low and constant around 5% of the total righted area initially, but has increased sharply in the last years with improvement of agricultural profitability to reach almost 30% of the righted area. Information surveyed in this study also proves that a not officially registered process of re-allocation of irrigation water - that implies also a concentration of land and water - is taking place in the PRD. This is due to the effect of the prevalent open-market economic policies implemented in the last 10 years that have pushed smallholder farmers to quit agriculture, and medium and large farmers to increase their production scale to survive.

12.1.2. Set up of Infrastructure and Official Operational Rules

Improvement of irrigation infrastructure, just as water allocation, followed a long path. The setting up of infrastructure that guaranteed adequacy and reliability of water supply became the main topic of users' claims and government officials' tasks, after an initial stage of heavy confrontation among users to establish and make effective water rights,

However, was the PRD intervention - with its main objectives of transforming traditional protective to productive irrigation, of increasing water productivity and economic outputs and by including a great organizational and technological change - .really a modernization intervention in terms of definitions of Burt and Styles (1999).

The unfinished implementation of the PRD intervention, and the different design criteria in the partial areas reached by the modernization activities, left a heterogeneous mix of conveyance and distribution infrastructure highly dominated by old earthen canals designed for unregulated river flow and a protective irrigation approach.

However in spite of these heterogeneities in design and type of infrastructure, they had important basic elements that could support implementation of a modern flexible and responsive operation of the system (Plusquellec, 1994, Burt and Styles 1999). All the canals, even the modern ones, have high Water Delivery Capacity which supports great variation of cropping pattern and creates the necessary storage capacity for quick response to water demand. All have controlled diversion structures with a fairly high number of cross regulators and measuring devices at the head of all secondary canals, and there is fairly easy access to any point of the network at any time of the year. Facilities are even greater in the modernized sections of Norte and La Cuarteada canals and in the partially modernized network of San Martín and Simbolar secondary canals - with lined canals, controlled diversion structures, measuring devices at low levels of the system, and where another particular feature of modern design appears, short *comuneros* with few users. Burt and Styles 1999 noted that "...modern systems do not rely on user participation...."

In the same way as statutory water rights, operational rules were formally explicitly defined in the time of the PRD intervention, based mainly in existing customary rules. They basically included the frequently mentioned rotational delivery with low delivery frequency (28 days), the rather large *main d'eau* of (300 l/s), and rather low delivery duration (50 min to 1 hr/ha).

As extensively discussed in this thesis, the fact that real water demands were far below those expected based on the technocratic vision adopted in the design stage meant that the infrastructure available was - despite its unfinished construction - very able to cope with these water demands, thus achieving one of the main prerequisites of functionality according to Perry (1995).

12.1.3 Assignment of Responsibilities

The third element of Perry's framework that should match to reach functionality, the assignment of responsibilities on Operation and Maintenance, was also object of controversies and negotiation, and finally well defined and accepted by all actors under the PRD intervention.

The PRD was defined as a jointly-operated irrigation system, with a joint Provincial Government- National Irrigation Agency commission having political control over long-run strategic decisions on water, including water allocation and legal administration, and the main system operated by a government agency. The *comuneros* gate was the level where operational responsibilities changed over to the users.

A change in O&M responsibility away from a provincial agency, whose impartial performance was highly questioned by users, to the professional national agency A&EE was one of the main changes introduced by the PRD intervention in response to farmers' demands. Although there was some resistance from powerful stakeholders, this transfer of responsibilities was highly celebrated by a large group of farmers that saw in this decision the safeguarding of system operation from local politicians previously very active in influencing water distribution.

Perry (1995) considered that whether those assigned responsibility can best fulfil each task was a separate issue. However it is clear in this case that the confidence of the users in the irrigation agency has been a key point. Users strongly promoted and demanded the transference of system administration to a national agency in the 1960s to guarantee a smooth functioning of the irrigation system. Again, when the federal government turned over the system to the province in 1992 as result of users lobby a new provincial agency was created retaining most of the former employees. In this way they avoided the risk that the existing provincial agency – seen as highly politicised and technically inefficient - took control of the system.

12.2 THE REAL FUNCTIONALITY OF THE SYSTEM AND ITS OUTPUTS.

Truncation of the PRD intervention by the very conservative provincial government that assumed power in 1973 (with a nationalist discourse that hid its real objective of keeping the *status quo* and avoided the risk of empowering new political actors), and the continuity of this policy by the subsequent provincial government, had considerable and highly relevant effects on PRD development in the last 30 years.

The effects of the unfinished PRD intervention were evident and important in construction of the irrigation infrastructure. However, the results of this thesis make it clear that it had even more important effects not only in the socio-technical performance of the system but also in its planned contribution to the development of the area. These less evident effects were a logical consequence of the lack of development policies by the successive provincial governments, and the concomitant lack of political support to the irrigation agencies that led to the premeditated reduction of financial support to the CRD (the provincial agency in charge on improvement of on-farm irrigation and agriculture services) and provoked its progressive involution and final disappearance in 1994.

From these circumstances, the technically unmotivated agency (at first national agency, provincial after 1992) and the heterogeneous group of users, have reached - by trial and error, by struggles and agreements and with remarkable adaptive behaviour from both sides during 30 years of contested processes of irrigation use - a real functionality in water delivery. However this is a real functionality that has been optimized around resources other rather than water but definitely covered most of their own expectations in terms of water supply.

12.2.1 The Role of the Agency in Constructing Real Functionality

Free of any demand from wider systems in the provincial agricultural production or rural economy (Small and Svendsen, 1990) and free of any commitment to impose or promote any improvement of irrigation technology at any level of the system, A&EE was accountable to its headquarters in Buenos Aires (only interested in bureaucratic issues) and to system users at local level. A similar situation faced the provincial irrigation agency, UER, when the provincial government reassumed the responsibility over the system management in 1992 and continued without any development plan for the area- its only demands came from water users.

Easily controlling the bureaucratic demands of their headquarters with formal statistical reports, the main task of both agencies was to satisfy users' demands. This justifies the assertion that both had as their main objective to minimize numbers of user complaints as the main indicator to assess their performance (Chapter 10).

Regarding the conceptual framework for large-scale bureaucratic systems of Eggink & Ubels, (1984) discussed in section 1.5, the above findings justify the addition to this framework of government interest and agency power and its identification with government irrigation policies in the upper component (Main System Irrigation Management) as shown in Fig 1.7).

Under this context the main contribution of agencies to construct a real functionality was their progressive predisposition to made water distribution more flexible than the official rotational water delivery system. In fact, as shown in chapter 5 to 9, the system has clearly moved from the official programme of turns to an arranged rotational water delivery.

Actual implementation of arranged rotational water delivery in Colonia Simbolar (Irrigation Zone 5) and incorporation of downstream controlled automatic gates by designers in Zone IV and V from the beginning of the PRD, suggest that the "modern" service approach was promoted by at least a group of engineers from the Agency at the design stage. However, the responsive management adopted, that was highly in agreement with the postulated principles of the "modernization" package, was not however actually a reflexive and professional decision of the agency. Rather it was a logical consequence of their demanded commitment to users that extended to the 'front line'. Here *tomeros* without any strict mandates from the agency have been highly accountable to users, who are their neighbours and not uncommonly their close relatives.

Many unplanned elements outside agency control, such as farmer irrigation practices (section 12.2.2); a favourable mismatch between water supply and water demand (section 12.2.3) and the large water delivery capacity of most canals (section 5.1.1) made it possible to move to a more flexible water delivery schedule without appealing to any sophisticated water technologies. However it is also true that many "internal indicators" that show a positive assessment, in terms of supporting a responsive flexible and modern system operation (Burt and Styles, 1999) were put in place or developed by the agency. As shown in this study, some of these were: a relatively low number of turnouts per gatekeepers (ranging from 6 to 23 with a mean value of 13 for the whole project); the fairly short length of canals controlled by a *tomero* (7 km); low number of users/*tomero* (142); good mobility of gatekeepers; and good accessibility of canals and turnouts throughout the whole year. Also one of the points that improved greatly during the last 10 years, by a direct decision of the agency with the objective of increase flexibility in water distribution, was communication between field officials, and between them and the district office and even with upstream control points. Communication is very good with all *tomeros* having a hand radio.

Another condition that gave the agency a great capacity to be responsive to users' demand was its internal organization, with 4 district offices operating from secondary canals to *comuneros* gates independent of each other, and each with enough power, water and room to take its own decisions. Room to manoeuvre is also with the *tomeros* on the front line, due the high volume of available water created by the bureaucratically determined delivery times (based on water righted area rather than on actual cropped areas) and the normal practice of users to irrigate fewer times in areas smaller than the righted ones.

12.2.2 The Users' Role in Constructing Real Functionality

According to the research findings, the users (through participation, collective actions and on farm irrigation practices) have been a determining force in construction of the irrigation systems' functionality -in definition and effectiveness of water rights, development of infrastructure and assignment of system management responsibility to reliable agencies.

Participation and collective actions of users

Through this thesis it is clear that users have been a determinant in the construction of irrigation in PRD area but their participation seemed to decrease progressively over time. Referring to the three different paradigms of participation mentioned by Vincent (1998), it has shifted from more collective domains in negotiating change and means of service provision, to more individual responses around livelihood opportunities.

In the initial period, the participation of small sharecroppers and settlers of public and private colonization plans reached a high level. Following the strong movement generated by settlers and sharecroppers in the rich humid *pampa* and advised by their organization, this local group of users acquired a high organization and capacity of collective actions (Chapter 2). Through self mobilization they gradually opened up new opportunities for themselves: by consolidating and making effective their water rights; making claims for a fair water distribution; and managing a definitive incorporation and recognition in the agrarian structure of the area. Besides this strong and effective political participation, maintenance of public and obviously of private *acequias* was highly dependent on users' participation in this period that registered the highest cooperative behaviour of farmers in collective action, according to testimonies.

Self mobilization continued to be the main characteristic of user participation in a second stage, marked by the congregation of all types of farmers in users' organizations. There was also a change of their discourse from equity principles and recognition of water rights of small farmers, to a more technology-focused discourse claiming development of the infrastructure needed for water acquisition and to decrease internal tension and conflicts. This was a consequence of the evident lack of functionality between water rights (highly increased at that time) and the available technology to manage water distribution. In this period farmers took key positions in the agency encouraged by the populist orientation of the Peronis government, and continued to be involved in collective actions for maintenance of the systems.

Despite its unfinished implementation, the successive improvement of the main physical infrastructure during the Los Quiroga intervention, Rio Hondo reservoir construction and in the initial stage of the PRD, together with the change of responsibility on water distribution and the low water demand (see section 12.2.3 below) the PRD reached a level of functionality that made successful irrigation possible, but at the same time formal participation of users declined sharply.

Farmers' participation in upstream tertiary units was first reduced to representation from the different administrative zones that integrated a Consultant Board of the Agency (Participation by consultation as in the typology cited by Feitsma, 1996) for a short period. It declined even more later, when involvement of users was restricted to consultations only in exceptional times of low river discharges, giving user participation very close to that described as 'Manipulative participation' in the typology cited by Feitsma (1996).

At *comuneros* level, water distribution remained under the responsibility of users through SARCCs (Water User Association), whose actual constitution ran progressively apart from the official rules and re-assumed its historical organization around a farmer leader. However farmers' participation also declined at this level, due to the increased role of *tomero* to whom many users had access directly, the modern design of *comuneros* with few users and low maintenance requirements, and the many other *comuneros* where maintenance of the water course was assumed only by the active farmers.

However despite the decline of formal users' participation over time, the change of water use patterns to users' wishes and field practice suggests that users' participation has been subtle, less visible but still very effective in the last 30 years to make the official water delivery schedule more flexible and close to their preferences.

These results suggest that users have exercised to some extent their political control over water throughout this long period and therefore they have no reason to claim for constitution of formal channels of participation and representation.

In summary participation, mobilization and commitment of users with water issues have been an important factor for building functionality. Its level of public manifestation appears to be negatively related with the increment of water availability promoted by development of the physical infrastructure and organization of water distribution. However participation has taken other more subtle forms and still kept water allocation and water distribution under control.

Users' on-farm irrigation practices

As discussed in the empirical case study chapters and comparative analysis in chapter 11, users' on-farm irrigation practices (in irrigation strategies and application practices) of all types of farmers continued to be largely the same as those practiced under the protective irrigation of the initial stages of development (Michaud, 1942; Romanella, 1971) and uncertainty of water supply.

They did not evolve as expected in the positivist vision of PRD designers (with a more diversified copping pattern and very technically proficient on-farm irrigation) under the incentive of having a higher and more reliable water supply. However, these practices highly determined the real water use pattern in the system by setting a water demand very different to that expected under new designs.

These irrigation practices were characterized by irrigation strategies that included, for most crops: a heavy pre-seeding irrigation and few applications during crop growth; by basin irrigation with very low to zero systematization of irrigated fields as the application method; and a large and rather homogeneous irrigation gift per event (276 mm) despite the heterogeneity of infrastructure and type of farmer. These practices made a great contribution to the construction of a real functionality of the systems, through their great capacity to support change in the frequency, discharge and duration of water delivery - or in other words buffering the low quality water distribution service provided by the Agency as a result of the mismanagement of available infrastructure (This confirms the relevance of the on farm irrigation practices as element of the framework – Figure 1.7 - to be taken in consideration when studying irrigation management in large-scale bureaucratic-communal irrigation system).

12.2.3 Contribution of the Relatively High Water Availability to Real Functionality.

The increased water supply of the Rio Hondo reservoir, and an actual water demand far below that expected at the design stage created by the non-modernized irrigation practices at farm level, together with a water righted area endemically greater than the cropped area, created an annual water surplus most of the years.

This "constructed" annual water surplus also made a great contribution to the real functionality reached in the PRD. Under this water rich context there has been enough room for the agency to made water distribution less reflexive and more flexible for *tomeros* and farmers at the front line, to explore and find an acceptable discharge for both sides, and to avoid to put pressure on farmers to improve or change their water management. At the same time requirements of hydraulic water control became much lower along the distribution system and farms, discouraging application of water management technology.

In short the relatively high water availability in relation to water demand created by a contested process among the main stakeholders, meant that water gradually but with high intensity substituted for other resources such as labour and capital not available at both systems and farm level (Levine, 1980). However, irrigation has reached an actual functionality that allowed PRD system to continue working for many years without any serious conflict among the active stakeholders.

12.3 Performances Studies and Indicators

The study shown the management of the irrigation systems has some features of the service oriented management highly promoted by the prescriptive manuals of the "modernization" approach. However the interest in service provision is of a very different kind to the business orientation underpinned in that approach.

It has been also shown that none of the so-called process indicators were really in use or considered by the different agencies that were in charge of the management of the irrigation systems. Over the long term, information was only collected for statistical purposes about cropped area, harvested area and mean yields. There was no attempt to register delivery water downstream of the main canal. Since the re-assumption of management responsibility by the province through the UER, information on discharges to secondary canals has been collected: however collection of information about cropped area was surprisingly careless and there has no attempt by the agency to relate both types of information in some way.

The use of indicators originally proposed for comparative studies (Molden *et al*, 1998; Kloezen and Garces-Resptrepo, 1998) among irrigation systems has proved to be very useful to understand diversity within large irrigation systems as the PRD. Further their use on a seasonal basis as proposed by Jurriens (1996) and even on a monthly base (Chapter 5 and 10) has been highly useful to describe the real water management that many times remained undiscovered using those indicators prescribed for an annual basis.

Finally alternative indicators have been relevant to survey the meshing of conditions for functionality and those based on users and agency perspectives (chapter 11) the grade of satisfaction of users and operators with a particular situation highly controlled by the actual conditions of possibilities.

12.4 The environmental impact

The practice of applying large irrigation depths has logically led to the process of rising water tables and secondary soil salinization, and supported the supposition of a large return flow to the river. However this case study has shown that the particular distribution of water allocation defined by the contested process among stakeholders gives particular and sometimes different environmental impact of irrigation.

The net upward water flow in the two-thirds unirrigated command area makes this area the main salt sink and confers on the PRD the two main characteristics of a closed system - a high non-beneficial use of the delivered water and a minimal return flow of usable water for new developments downstream.

12.5 Revisiting the theoretical framework

The academic and scientific objectives and contribution of any PhD research, both from my own vision and our commitments as scientists, is with the improvement of irrigation and with the improvement of livelihoods of people depending on irrigation.

From this point of view, the interdisciplinary sociotechnical approach, collectively developed by the staff and students of the IWE group, assumed in my research proved to be a competent tool to understand the functioning and malfunctioning of collective irrigation systems. It has the capacity to include and sometimes focus the analysis on issues rather than physical behaviour of infrastructure and water flow, to explain additional reasons on why they behave as they do.

In this way the sociotechnical approach has contributed to the modernization discussion by making it clear that it is not only about getting an appropriate concept and prescriptive policies of change derived from international consensus on valid arrangements of irrigation hardware and software techniques. It shows that it could help modernization approaches to accept local specificities (that question "benchmarking approaches" in some ways,) - by looking at real objectives and strategies in using new systems, and to open possibilities for all stakeholders recognizing diversities within large irrigation systems and to take into account local cultures and possibilities.

However perhaps an intrinsic drawback of interdisciplinary approaches as stated by Vos, 2002 (page 204), is that some factors may only be analysed somewhat superficially, especially in a study done individually. This certainly restricts possibilities of specific definitions of cause-effect and construction and implementation of specific models for improving the situation whatever was the approach to do this.

Thus, independent of the above concern, the insights gained from this study of the management of large irrigation systems - the PRD in Santiago del Estero, Argentina - will certainly be useful for many other cases, at least in the non-Andean countries of South America. It has contributed in my opinion to enrich the sociotechnical approach in two main aspects that few others treated in earlier works:

- The need to re-construct the paradigm of irrigation agencies as a bureaucratic arm of the political system and of the agency's engineers as mere "technocrats", that apply technology in a prescriptive way . The study has shown that under certain circumstance they can be social actors both independent of the political power and also interacting with it. The study has also shown them constructing networks with other actors at supra and sub system level, and taking up strategies - sometimes common, sometimes different from those taken by agency field officials - but always making their own contribution to irrigation construction through acting over systems operation and even on water allocation.
- The need to extend the concept of irrigation systems to include irrigation management at farm level that has proved in this study to be so determinant of the irrigation systems' performance – as much or more than the others components such as water allocation, water distribution processes and system maintenance or operation.

Reconsideration of the role of irrigation agency in large jointly-managed irrigation systems is necessary and requires more study of the relationship between the agency and the political system in both long-term water resources development policies and in its involvement in the structuring of daily processes of water distribution.

Inclusion of farm-level practices in irrigation management necessary renews attention to, on the one side, the role of irrigation in agriculture, its relationship with other agronomic practices and with the existing production systems, and on the other to the need for better understanding of informal but nevertheless effective ways of user participation in irrigation issues. This will also be indispensable when water productivity becomes one of the main objectives of future interventions

A detailed study of on farm irrigation practices will also be needed, to provide a survey of the different water demands that can assure provision of differentiated services to a diverse range of sub-systems, in a way that necessary modernization will need to follow in the near future.

12.6 Rethinking the Agenda for a New Collective Modernization Cycle of PRD

Going from the general to the particular it is clear that:

- Improvement of the contribution of irrigation to the development of the area and to the Province of Santiago del Estero would require a clear identification of new collective development goals.

- Under contemporary conditions driven by market forces, concentration of water will continue. Therefore involvement of the state, especially of the provincial government and organization of smallholder users, appeared to be a necessary condition to guarantee a greater social contribution from water exploitation for irrigation. To improve water use the smallholder producers highly constrained by economic factors will need direct support from the government otherwise they will continue leaving agriculture activities or they will continue overcoming capital and labour restrictions with water.

- As regards water resources exploitation at basin scale, future interventions should give priority to actions for reducing the non-beneficial use of water within the PRD command area, and take into consideration that PRD is a closed irrigation system.

- Improvement or modernization of water use in PRD should continue to be a, participative, pragmatic and negotiated process in agreement with its history, but the state should also guarantee that collective objectives predominate over particular ones.

- The irrigation agency has many possibilities to provide to this process through a more reflexive analysis of its own and system performance. However, it should not move from its historical service-oriented approach responsive to users' demands and its assumed role as one - but not the most important actor - in the process.

- Comparative performance indicators applied in monthly or seasonal time steps, also with "alternative indicators" based on users' perspectives seem to me as the best combination to monitor the evolution of irrigation and the diversity of users within the system.

- Volumetric delivery could be a solution, for all actors but its application should be done carefully and recognize the heterogeneity of actors to avoid introduction of new inequities. As Vos (2002) shows, there are different dimensions to volumetric water control – water allocation and scheduling, volumetric delivery and volumetric charging which have to be studied apart and together in relation to local technology and users, to find relevant and acceptable local approaches – especially in a system as diverse as PRD. . Without due care, undifferentiated approaches will promote better use of water by large farmers with high land and capital availability, but would not be beneficial for small farmers if other resources are not made available for them. Further, the building of confidence of the agency and users in volumetric delivery should be a gradual and negotiated process since it can be seen as a threat and strongly rejected by small farmers.

- The water use pattern characterized by high RWS and RIS will not change in the short time. For this purpose a change in irrigation practices at farm level will be needed and this is highly linked with better profitability of the production systems which depends on change of many other factors and of the differentiated official policies, recognizing the diversity of production systems within the command area.

12.7 Conclusions

To understand clearly the main outputs of the contested process of construction of irrigation in the PRD area it is necessary to accept that the PRD evolved without any long-term and strategic targets in terms of water use exploitation, and what is more important, without a supra system of development objectives. This is the logical consequences of the weak role of the state during the first intervention (Los Quiroga) and its total absence after truncation of the PRD intervention in 1973, as shown in the historical analysis made in this thesis.

Given the above circumstance, and despite the two weak modernization interventions, the evolution of PRD has been driven by a contested process between the day-to-day actors - the irrigation agency and a heterogeneous group of users. Both sets of stakeholders managed to reach their objectives and simultaneously reach the above discussed functionality that coped with the real water demand of the different production systems that coexisted in the area during many years.

It was just as a logical consequence of the pragmatic management of irrigation issues, and not as any reflexive decision based on a planned intervention, that water management in PRD came to incorporate many core elements of the advocated modernization package - with an agency accountable to users, with a "service" oriented operation that included a high flexibility in water delivery to closely follow water demands of its users, and even the introduction of pseudo-marketing procedure in water allocation.

This has also happened without any systematic use of performance indicators or benchmarking. Of the many indicators potentially available for use as shown in this study, none are used systematically to check performance and many of the measurement devices in the system stay idle and unused. The many indicators of the 'process assessments' discussed in Chapter 1 also remain unused, as agency and farmers are driven by other indicators of conflict minimisation and low investment of inputs. Rather, the thesis has shown how the subjective ideas of Jurriens (1996) around user satisfaction, and several alternative views are necessary to really understand why the PRD runs as it does, and how and where it might change (if at all).

On the other hand, the PRD also offered positive feature from the alternative visions that focus on the agency of users. This research shows that first large users and all users that remained active latter, appeared as the stakeholders that have held the real political control of water much of the time - controlling the process of water allocation in crucial periods and water distribution process overall, without any apparent formal participation in irrigation issues in most of the last 30 years. To keep this control, users with the complacency of the agency, have been active agents to limit the cropped area far below the "potential" irrigable area under "full irrigation" paradigms.

With a water availability far above their low water requirements, and coping with their basic delivery requirements derived from on-farm water management rooted in "protective" irrigation principles (practiced even in production systems applying modern technology in other components of irrigated agriculture), the resulting satisfaction of the users and the agency with the performance of PRD is logically high (Chapter 11).

It is also clear from the research that as a consequence of these practices of users and the uncommitted agency, water became a non-restrictive production factor for the included beneficiaries (with transaction cost very low). After the PRD intervention, water distribution practices at system level and production practices at farm level have maximized return to factors other than water - available labour and capital in small farms, land productivity in large farms. It is these practices that explain the low performance from the technical point of view based on RWS, RIS, and on any other now classical performance indicators (Chapter 5 and 10), and lead me to define the PRD as a "wet irrigation system in a dry area".

On the other hand this thesis has also shown that despite the improvement of infrastructure and systems operation introduced by state interventions irrigation practices at local levels of the system have not changed too much from the historical practices before both Los Quiroga and PRD interventions. While some technocrats might argue that the incomplete implementation of the modernization limited its contribution to the improvement of irrigation the performance shown in Zone I, where all irrigation and drainage infrastructure was finished, discredits this possible argument. This has also contributed to keeping water productivity very low and justifying my second statement about PRD as a "wet irrigation system in a dry area with dry crops in the wet season".

The study is in accordance with the socio-technological approach, that irrigation is a social force and has been highly related with development. It is clear from the study of the evolution of irrigation in the area, that irrigation fulfilled that role in the initial stage, bringing new opportunities for agriculture and contributing to settlement of many people in the area. However, after 1973, with irrigated agriculture not limited by water, with entrance of new users almost restricted and with state support to other agriculture services also reduced, the contribution of irrigation to the development of the area sharply decreased.

This was evident after the neo-liberal reforms of the 1990's that completely opened agriculture production to the markets mechanisms, reducing state support for the peasant productions systems predominating in the PRD area. Under these circumstances, the high availability of water and irrigation facilities has not been able to reverse the impoverishment process of that type of farmer. Most small farmers have gradually been leaving agricultural production for economic reasons. The corollary of this policy, highly benefited by the existence of PRETAs, has been a land and water concentration in the PRD.

Further, the fact that the contested process of water allocation has validated the exclusion of many people (implicit in the "mosaic" pattern of water righted and non-water righted areas defined) can be seen as a contribution of irrigation to create or enlarge social differences in the area in the long run. This supports the need to consider social productivity of water as criteria for the assessment of irrigation systems performance, and to develop such indicators in the near future. For example to include a ratio of landowners benefited by irrigation over the total landowners within the command area, or a Gini coefficient based on this ratio or use of water by different agrarian sectors.

Paradoxically, within the mosaic pattern described above - as frequently mentioned in this thesis - the excluded lands not only did not received the benefit of irrigation but were condemned to be the salt sinks of the area, performing an environmental service for the irrigated areas and supporting the definition of PRD as a "closed irrigation system".

Finally it is clear that the system has been able to cope with a large diversity of production and farming styles and that the new round of modernization of PRD and any other irrigation system should find new ways to work and provide differentiated services for this diversity. However we might recognize that even if technology is different, there would be a lot of farmers trying to get the water and services they want and therefore we necessarily should think the next round of modernization as UNA TAREA DE TODOS.

APPENDICES

APPENDIX 1

A.1 Performance Indicators

A.1.1 External indicators for comparing performance of irrigation systems proposed by Molden et al, (1998).

Parameter	Indicator
Irrigated Agricultural Outputs	Output per cropped area (\$/ha) Output per unit command (\$/ha) Output per unit irrigation supply ($\$/m^3$) Output per unit water consumed ($\$/m^3$)
Water Supply	Relative Water Supply Relative Irrigation Supply Water Delivery Capacity (%)
Financial indicators	Gross return on investment (%) Financial self sufficiency

A.1.2 External indicators proposed by Burt and Styles, (1999)

LEVEL OF PERFORMANCE		QUALITY	INDICATORS
Water supply performance	Level of Service	Conveyance	Water Delivery Ratio
			Water Delivery Performance
		Efficiency	Conveyance Efficiency
			Distribution Efficiency
			Field Application Efficiency
			Tertiary Units Efficiency
		Adequacy	Relative Water Supply
		Predictability	Dependability of Supply
			Regularity of Water Deliveries
		Equity	Standard. Deviation of the Relative Water Supply
		Maintenance	Relative Change of Head
			Maintenance Area Ratio
			Effectivity of Infrastructure
			Equipment Effectiveness
Environmental Sustainability and Drainage	Sustainability of Irrigation		Sustainability of Irrigated Area
	Depth of Groundwater		Rate of Change of Groundwater Depth
	Pollution of Water	Salinity	Rate of Change of EC
			EC Increment ratio
		Dissolved Organic Matter	
		Micro Biological Pollution	
		Chemicals	
Economic, Social and Environmental Performance	Economic Viability		
	Financial Viability		Total Financial Viability
			Financial Self Sufficiency
			Fee Collection Performance
			Yields vs Water Cost Ratio
			Yields vs. Water Supply Ratio
			Relative Water Cost
	Viability of Irrigation Cost		Economic Internal Rate of Return
			Financial Internal Rate of Return
	Social Viability		Administrative Viability
		Irrigation Related Labour	Irrigation Employment Generation
			Irrigation Wage Generation
			Relative Prosperity
		Social Capacity	Technical Knowledge of Staff
			Users's stake within Irrigation System

A.1.3 Performance indicators proposed by Malano and Burton (2001) for benchmarking

Irrigation service delivery - System operation

Total annual volume of irrigation water delivery (m^3/year)
Annual irrigation water delivery per unit command area (m^3/ha)
Annual irrigation water delivery per unit irrigated area (m^3/ha)
Annual main system water delivery efficiency
Annual relative water supply
Annual relative irrigation supply
Water delivery capacity
Security of entitlement supply

Irrigation service delivery - Financial indicators

Cost recovery ratio
Maintenance cost to revenue ratio
Total MOM cost per unit area ($/ha)
Total cost per person employed on water delivery ($/person)
Revenue collection performance
Staffing numbers per unit area (Persons/ha)
Average revenue per MCM of irrigation water supplied ($/$m^3$)

Productive Efficiency

Gross annual agricultural production (tons)
Total annual value of agricultural output ($)
Output per unit serviced area ($/ha)
Output per unit irrigated area ($/ha)
Output per unit irrigation supply ($/$m^3$)
Output per unit water consumed ($/$m^3$)

Environmental Performance

Water quality: Salinity (irrigation water, mmhos/cm))
Water quality: Salinity (drainage water, mmhos/cm)
Water quality: Biological (irrigation water, mg/liter)
Water quality: Biological (drainage water, mg/liter)
Water quality: Chemical (irrigation water, mg/liter)
Water quality: Chemical (drainage water, mg/liter)
Average depth to water table (m)
Change in water table depth over time (m)
Salt balance (metric tons)

A.1. 4 Performance indicators used in this thesis and calculation procedures

Indicator	***Units***	***Time Step***	***Irrigation Level***	***Calculation Procedure***
I. External Indicators				
Total irrigation water delivery (W_{der})	Mm^3/year or mm/year	Annual	Main Secondary	Daily register from the Irrigation Agency
			Tertiary/ *Comuneros*	Operation time registered by *tomeros* (hr) x Average Discharge (m^3/s) from adjusted relationship between *tomeros*' registered caudal and measured discharges.
		Monthly	Main Secondary	Daily register from the Irrigation Agency
			Tertiary	Operation time registered by *tomeros* (hr) x Average discharge (m^3/s) from adjusted relationship between *tomeros*' registered caudal and measured discharges.
Irrigation water delivery per unit irrigated area	m^3/ha	Annual	Main Secondary Tertiary	Volume delivered divided by irrigated area registered by the Irrigation Agency.
Relative Water Supply $\left(RWS = \dfrac{W_{der} + P_e}{CWR}\right)$	W_{der} = mm P_e = mm CWR = mm	Annual	Main Secondary Tertiary	Crop Water Requirements calculated with CROPWAT 7.2 using ETo from La Maria Experimental Station, P from the closest P measuring station; Effective P by USDA SC Method[A.1.1]. Cropping pattern registered by the Irrigation Agency.
		Monthly	Main Secondary Tertiary	$RWS = \left(\dfrac{W_{der} + Pe}{I_{req} + P_e} \times \dfrac{I_{req}}{V_{der}}\right) \times RIS$

A.1.1 United State Department of Agriculture - Soil Conservation Method (SCS, 1969 cited by FAO,1993)
$P_e = (P_{dec}*(125-0,6*P_{dec}))/125$ (for P_{mon}<=250 mm); $P_e = 125/3 + 0,1 * P_{dec}$ (for $P_{mon} > 250$ mm)

Indicator	***Units***	***Time Step***	***Irrigation Level***	***Calculation Procedure***
Relative Irrigation Supply (RIS) $\left(RIS = \frac{W_{der}}{I_{req}}\right)$	W_{der} = mm I_{req} = mm	Annual	Main Secondary Tertiary	Irrigation Requirements calculated with CROPWAT 7.2 using ETo from La Maria Experimental Station, P from the closest P measuring station; Effective P by USDA SC Method and cropping pattern registered by the Irrigation Agency
		Monthly	Main Secondary Tertiary	Monthly Irrigation requirements calculated with CROPWAT 7.2 using ETo from La Maria Experimental Station, P from the closest P measuring station; Effective P by USDA SC Method, Cropping pattern registered by the Irrigation Agency and optimal irrigation scheduling considering pre-seeding irrigation
Water Delivery Capacity (WDC) (Actual canal Capacity/Peak demand)			Main Secondary	Actual canal capacity informed by the Irrigation Agency Peak demand calculated with CROPWAT 7.2 according to cropping pattern and optimal irrigation scheduling considering pre-seeding irrigation.
II. Internal Indicators				
N° of turns out, mean canal length, N° of water users, Gross Area and Water Righted Area per *tomero*			Operation Unit	Calculated based on Irrigation Agency information
Number of days/month canal discharge change		Monthly	Secondary	Number of days discharge is 10% greater or lower than the day before. Calculated based on daily discharge registered by the Irrigation Agency.

Indicator	***Units***	***Time Step***	***Irrigation Level***	***Calculation Procedure***
Delivery Ratio[A.1.2] $\left(DR = \frac{Actual\ \ Discharge}{Maximum\ \ Canal\ \ Capacity}\right)$	$Q_a = m^3/s$ $Q_{max} = m^3/s$	Monthly	Secondary	Mean monthly values calculated from daily DR
		Daily	Secondary	Actual Discharge registered by the Irrigation Agency Maximum Canal Capacity reported by the Irrigation Agency
Real irrigation order vs Official irrigation order		Irrigation Turn	*Comuneros*	Real irrigation order registered Official irrigation order informed by the Irrigation Agency
Frequency Delivery Ratio $\left(FDR = \frac{\textit{Actual}\ \text{Irrigation Delivery Frequency}}{\textit{Official}\ \text{Irrigation Delivery Frequency}}\right)$	AIDF= days OIDF= days	Annual	*Comuneros*	Actual irrigation delivery frequency registered Official irrigation delivery frequency informed by Irrigation Agency.
Time Delivery Duration $\left(TDR = \frac{Actual\ \ Delivery\ \ Duration}{Official\ \ Delivery\ \ Duration}\right)$	ADD = h ODD = h	Annual	*Comuneros* *Farms*	Actual Delivery Duration registered by *tomeros* or *administrador*. Official Delivery Duration informed by the Irrigation Agency.
		Irrigation Turn	*Comuneros* *Farms*	
Water Delivery Ratio $\left(WDR = \frac{Actual\ \ Irrigation\ \ Depth}{Official\ \ Irrigation\ \ Depth}\right)$	AID = mm OID = mm	Annual	*Comuneros* *Farms*	Actual Irrigation Depth calculated based on time and discharge delivered and irrigated area. Official Irrigation Depth informed by the Irrigation Agency
		Irrigation Turn	*Comuneros* *Farms*	

[A.1.2] This indicator has been used with other names (Water Distribution Equity, Delivery Performance Ratio or Discharge Ratio) and objectives by different authors (Bos et al, (2005), Francis and Elawad (1989), Wolters and Bos (1990), Van de Velde (1990) and Bos (1997)). I decided to use a new name, considering that Water Distribution Equity is not a good name since it is not used in this thesis to assess Equity, I reject also Delivery Performance Ratio considering that the term Performance should be restricted to those indicators that used "intended" or "target" values as denominators. I did not adopt Discharge Ratio since Bos (1997) used this to quantify the effective functioning of delivery structures and not to assess the underutilisation of the available conveyance capacity and/or the available on-line storage capacity in the canal network

APPENDIX 2

A.2 THE NATIONAL POLITICAL – ECONOMICAL CONTEXT [A.2.1]

A.2.1 *1880 -1914 The liberal development model of the National government.*

This main characteristic of this period was the consolidation of a Nation State and the implementation, under the dominant influence of a young highly educated oligarchic group, known in Argentinean history as the 80's generation, of a liberal-positivist economic model. This had the main objective of incorporating Argentina into the international capitalist world as a producer of raw materials and goods and as a consumer of manufactured goods from key countries (mainly from Europe in those days).

Development of a modern state and the guarantee of private ownership of land were two key prerequisites for the successful implementation of the proposed agro-exportation model. They would offer the best conditions for foreign investments and assure investments of the landowning oligarchic group. For the first objective, the national dominant social group established alliances at provincial level with local oligarchic groups. To achieve the second native people, *indios,* were exterminated or displaced to marginal lands in the north or south by military actions. "Cleared" lands were then allotted to the dominant oligarchy and to chiefs of military actions enlarging the base of their power.

In productive terms the model required a large increment and improvement of animal and agricultural production. Land-owners took direct responsibility for improving animal production making large investments in high quality animals and extensive areas of pasture, while the establishment of a large number of meat processing plants in association with foreign investors assured access to European markets.

Increased agriculture production was more problematic since the large amount of manpower required with the technology of those days was not available. For that reason to populate the country became the main *social objective* and the National Government defined, and undertook, actions to open the country to a massive immigration from Europeans countries.

The plan was highly successful in this objective. Around 2.000.000 Europeans migrants (most from the south of Spain and Italy) arrived between 1895 and 1914 and settled in Buenos Aires city and in rural areas of the Humid Pampa (mainly in the provinces of Buenos Aires, Santa Fe and south of Córdoba). The national cropped area increased four times from 1900 to 1914 and the country became one of the three greatest world producers of grain crops

The plan also succeeded in the consolidation of a national government but it had negative aspects as well. It did not generate an independent capitalist economy; there was no large national productive investment in other sectors of the economy; and rural production continued to be the basic support of the economy and landowners - a powerful and hegemonic social group - and the country remained highly dependent on European markets.

In geopolitical terms the model concentrated its development actions in the Pampa Humeda provinces, and with less intensity in provinces whose production did not compete with production in this central area - for instance Mendoza (grape and wine production), Tucumán (sugar cane), Chaco (leather first, cotton latter) and a few others.

[A.2.1] This Appendix is highly based on Girbal-Blancha, 1998

However, the growth of Argentinean agriculture did not follow the Farmer Model implemented in U.S.A. Instead, the powerful oligarchic group controlled land ownership, the base of their power, and most foreign settlers were leasers or sharecroppers under very unfair short-term contracts that established high rents or shares; restricted production marketing to these landowners, and imposed the requirement, after 2 or maximum 3 years of agriculture, to sow alfalfa or other pasture that the landowner would use for animal production.

It was this internal structure and their confidence in the power of collective action that the migrants[A.2.2] brought with them that made the model to enter a crisis around 1910, when maximum horizontal expansion occurred and costs of renting increased sharply.

In June 1912 in the city of Alcorta south of the Santa Fe province, lessees and sharecroppers, mainly foreign people, declared a strike demanding: longer duration of the land use agreement, lower lease prices and shares for the landowners, and free decisions for selling their production. The protest, that is known in the Argentinean National History as the "Grito de Alcorta" expanded quickly to other areas involving finally around 100.000 lessees and sharecroppers. One month latter they created their own organization the Federación Agraria Argentina (FAA). Through the FAA the lessees and sharecroppers and small farmers would continue their fight for better production conditions (there was other strikes in 1917 and 1919).

"Grito de Alcorta" was not a revolutionary movement; it was a movement of a new social group within Argentinean society that asked to be recognized as such (Ansaldi, cited by Tasso, 2002) but that at the same time sent a message to lessees and sharecroppers of other regions.

A.2.2 *1914 - 1930 Model crisis and social conflicts in rural areas*

In political terms the main characteristic of this period was the emergence of modern political parties and the inclusion of the newly developed urban mid-class in political aspects.

In economic terms, although there were no deep structural changes, the changing international context after the First World War brought some relative transformations. There was an incipient industrialization process based on substitution of imported goods and more important there was an important increment of animal production at the expense of agricultural lands due to the big marketing problems of agricultural goods and the increased demand of animal products.

The backward nature of agricultural areas and the increased organization and fighting spirit of lessees and sharecroppers organizations increased social conflicts. Public demonstrations of this group became more frequent and stronger. In 1921 they resulted in a Federal Law that regulated renting conditions of agricultural lands (Coincident in this period were the farmers' demonstration in Santiago del Estero, claiming greater equity in access to water).

Though the end of the period was defined by the effect of the international economic crash of 1929, it was animal production that entered a crisis in the post-war scenario and arable production re-assumed its priority economic role. The National Government promoted public

[A.2.2] Immigrants were not only important to transform Buenos Aires into a cosmopolitan city and for the development of agriculture, they were also determinant in other social aspects such as diffusion of socialism and anarchism and formation of trade unions in the cities and organization of small farmers in rural areas.

and private colonization plans responding to the new economic scenario but also to the new internal socio-political conditions.

A.2.3 *1930 – 1945 The interventionist state - exigencies and subsidies.*

The international economic crash of 1929, evident in Argentina from 1932, added its effects to an evident internal crisis of the liberal agro-exportation model. This affected not only the social and economic sectors but even political institutions. Although responding to different causes there were two military *coups d'etat* (1930 and 1943) in this period.

The Nation state redefined its role in this period, looking for social and economic equilibrium, and assumed an interventionist behaviour. In the first years of the period Regulating Councils for different production (Cereals, sugar, wine, yerba mate, etc) were created with the objective to control and assure minimum prices for the producers. In other words, for the first time the state formally subsidized the rural sector. The state also assumed directly some services for the rural sector creating official institutions for instance, in bulk commercialization of cereals (Red General de Elevadores de Granos).

During the Second World War, a new crisis affected agriculture production and the national economic model of the country, which were still highly associated with export of arable and animal products. Under these circumstances, and during the military government established in 1943, a new model focusing on the internal market and industrialization for substitution of imported goods was implemented. The state reinforced the role of Regulating Councils, and even took structural actions (in this period construction of Los Quiroga delivery dam started) and intervened in the legal framework reducing the price of renting etc. in order to avoid a massive migration of people from rural areas to the cities.

A.2.4 *1945 – 1955 The controller, popular and omnipotent state. Confrontations and agreements*

The election of the pragmatic leader Juan D. Perón in the national election of 1946 reinforced the focus of the economic model on internal markets and benefited the most popular sectors. The implemented economic model conducted by a nationalist, populist, planner and determined to lead the process, focused on the internal markets but also had as main goals a re-distribution on the national income to the small and middle-sized industries and to the popular sectors of the population.

In this period many public services were nationalized (railways, electricity, telephone, gas, etc). Foreign trade was monopolized by the state and the government even established a 20% reduction in the renting price, a measure seen by the FAA as the initial stage of the promised agrarian reform.

In general, confrontations and sometimes contradictory agreements, between the National government and the different rural actors, were the key feature of this period. The constitution of limited companies, and division of large farms among relatives that benefited landowners avoiding the payment of tax and reduced the risk of being affected by the promised agrarian reform, were allowed. These were happening at the same time that, as in the case of the irrigated area in Santiago del Estero, benefits of irrigation were limited through restricting water rights to a maximum area of 50 ha or nationalizing private *acequias* to incorporate groups of small farmers to the public irrigation systems. Also the Government restricted the activity and removed the chief, of the National Agrarian Council when this institution promoted a radical agrarian reform.

Towards the end of the period, the reduction of international prices of commodities produced by Argentina (that decreased the profit of the government by their centralization of foreign trade) and other internal factors harassed the national economy and inflation increased. The government was forced to change its economic model by adding some liberal elements and to look again to the rural sector as source of foreign currency rather than the industrial sector. The second five-year plan of the government for the period (1953-1957) whose main objective was the increase in rural production, included specific decisions to promote colonization plans, re-order land use, introduce mechanization and to re-orient official grants to the rural sectors.

A.2.5 *1960 – 1990 New agrarian impositions*

The assumption of a new military government in 1955 in a context of deep social confrontation, that continued with changes in the economic plan introduced by *peronism* in its last period to benefit the rural sector, was highly supported by farmers's organizations.

The interests of the traditional Sociedad Rural Argentina were highly accepted and the economic power of this sector that participated in many decision-making processes increased greatly. The new conditions encouraged a recovery in the cropped area and an increment in productivity, and the official discourse talked about a second agriculture revolution based on deep technological changes (The National Law that created INTA is from this period).

The new democratic government - established in 1958 with a development orientation had a "desarrollista" vision that focused its economic action on the foreign exchange and foreign trade - also looked for support in the export of rural production. However, in this period - that locally promoted the PRD- regional differences increased. The technological and economic dependency of the country increased, while both internal migrations and immigration from neighbouring countries consolidated the urban centres over the rural areas, and there was a prominent expansion of the service sector over the productive ones.

Despite the efforts of the government, and the increment of the production by mechanization and improvement of technology, the exchange rate for Argentinean commodities deteriorated strongly in this period and its international prices sharply decreased. This forced national policies to promote export of non traditional products to non traditional markets. However this policy had only a relative impact and the country sharply increased its foreign debt.

APPENDIX 3

Table A.3.1 Precipitation (P) and Effective Precipitation (P_e) for different growing season

	Growing Seasons					
	95-96		96-97		98/99	
	P	P_e	P	P_e	P	P_e
January	120	80	151	80	209	120
February	133	93	179	91	92	54
March	51	45	112	81	128	100
April	30	27	10	10	15	14
May	130	77	16	15	3	3
June	1	1	1	1	28	26
July	0	0	0	0	0	0
August	0	0	1	1	1	1
September	11	11	34	31	1	1
October	12	12	39	32	61	43
November	39	35	51	46	33	29
December	45	41	17	16	75	61
Total	572	422	611	404	646	452

	Growing Seasons					
	99-2000		2000-2001		2001-2002	
	P	P_e	P	P_e	P	P_e
January	209	99	132	104	140	109
February	121	97	202	155	109	90
March	146	70	100	84	151	115
April	11	11	83	72	50	46
May	18	18	5	5	15	15
June	9	9	9	9	0	0
July	6	6	2	2	0	0
August	0	0	0	0	3	3
September	5	5	1	1	71	63
October	74	50	31	30	38	36
November	41	35	93	79	92	79
December	92	76	42	39	125	100
Total	732	476	700	580	794	656

Table A.3.2 Maximum Crop Water Requirement (ETc), Effective Precipitation (P_e) and Irrigation Requirements (IR) for 6 growing seasons

	Growing Seasons								
	1995-1996			1996-1997			1997-1998		
	ETc mm	P_e mm	IR mm	ETc mm	P_e mm	IR mm	ETc Mm	P_e mm	IR mm
Garlic	224	78	199	248	17	235	208	30	181
Alfalfa	1682	422	1229	1712	408	1318	1477	453	1058
Cotton	730	295	443	764	278	499	647	285	365
Sweet Potato	665	335	369	696	348	378	589	410	264
Barley	296	10	286	312	3	309	268	28	240
Onion	298	87	264	318	18	305	277	31	249
Citrus	1156	422	736	1175	408	814	1005	453	637
Forages	341	20	321	342	46	307	313	71	268
Sunflower	653	203	450	653	193	494	549	232	350
Guinea Sorghum	597	185	413	606	259	377	495	258	253
Vegetables	149	88	106	165	21	145	147	40	111
Lettuce	123	88	92	134	21	116	118	40	82
Maize	706	304	417	739	272	495	613	259	360
Melon	428	50	378	391	67	324	370	67	303
Potato	484	70	417	447	81	366	420	81	339
Nat. Pasture	1520	422	1057	1556	424	1152	1342	499	905
Water Melon	428	50	379	391	67	324	370	67	303
Soybean	651	270	341	683	315	401	579	319	282
Sorghum	712	262	467	728	238	508	601	282	356
Tomato	684	185	503	655	134	524	591	171	437
Wheat	248	29	233	267	12	260	230	28	209
Carrots	157	88	111	174	21	153	146	34	116
Pumpkin	259	10	249	273	3	271	242	28	232

	Growing Seasons								
	1999-2000			2000-2001			2001-2002		
	Etc mm	P_e mm	IR mm	ETc mm	P_e mm	IR mm	ETc mm	P_e mm	IR mm
Garlic	208	30	181	165	16	149	220	30	191
Alfalfa	1477	436	1051	1131	568	608	1260	636	640
Cotton	647	291	360	514	413	179	522	415	145
Sweet Potato	589	361	257	496	435	115	488	465	96
Barley	268	28	240	204	12	192	274	62	214
Onion	277	31	249	204	12	192	278	75	203
Citrus	1005	436	627	668	568	264	857	636	271
Forages	313	71	268	222	36	185	279	97	183
Sunflower	549	238	343	411	238	181	436	310	133
Guinea Sorghum	495	264	246	353	319	115	396	340	84
Vegetables	138	34	109	116	50	78	147	34	115
Lettuce	113	34	84	91	50	68	123	34	102
Maize	613	264	353	453	391	170	496	385	137
Melon	370	67	303	269	102	167	295	171	137
Potato	420	81	339	304	113	191	335	186	155
Nat. Pasture	1342	452	900	1116	581	585	1156	653	520
Water Melon	370	67	303	265	102	163	295	171	137
Soybean	579	324	276	476	399	130	471	421	107
Sorghum	601	287	349	441	299	190	481	340	147
Tomato	591	177	430	446	172	274	455	306	156
Wheat	230	28	209	166	12	155	235	53	184
Carrots	146	34	116	125	50	87	155	34	123
Pumpkin	0	0	0	178	12	167	231	62	169

REFERENCES

Abernethy, C. L., 1986 Performance Measurement in Canal Water Management. ODI/IIMI network paper 86/2d.

Abernethy C. L. 1989 Performance Criteria for Irrigation Systems: Conference on Irrigation Theory and Practice, Southampton.

Abernethy C. L. 1990 Indicators and Criteria of the Performance of Irrigation Systems in *Improved Irrigation System Performance for Sustainable Agriculture.* Paper Presented at the FAO Regional Workshop on Improved Irrigation Systems Performance for Sustainable Agriculture 22/26 October, Bangkok, FAO, Rome.

Agua y Energia, 1970, Reglamento para el Aprovechamiento de las Aguas del Río Dulce en la Zona del Proyecto Río Dulce. Santiago del Estero, Argentina.

Allen, R. G., L.S. Willardson and H.D. Fredriksen, 1997. Water Use Definitions and their Use for Assessing the Impacts of Water Conservation. International Commission for Irrigation and Drainage, Oxford, UK.

Angella, G. A., 1999 Study of Irrigation Performance in Representative Farms of the Río Dulce Project (PRD), Santiago del Estero, Argentina. Master of Science Thesis, Wageningen, Agriculture University.

Balsa, J. 2001 Las Formas de Producción Predominantes en la Agricultura Pampeana al Final de la Primera Expansión Agrícola (1937). ¿Una Vía "Argentina" de Desarrollo del Capitalismo en el Agro? *Mundo Agrario. Revista de estudios rurales* N° 3. CEHR-UNLP. La Plata, Argentina.

Bastiaanssen W.G. and M.G. Bos 1999 Irrigation Performance Indicators Based on Remotely Sensed Data: A review of Literature. *Irrigation and Drainage Systems*, Vol 13(4): 291-311.

Bauer, C.J., 1997 Bringing Water Markets Down to Earth: the Political Economy of Water Rights in Chile, 1976-1995. *World Development*, Vol 5: 639-656.

Bauer, C.J., 1998 *Against the Current: Privatization, Water Markets, and the State in Chile,* Kluwer Publishers, Dordrecht, The Netherlands.

Beccar L., R. Boelens, and P. Hoogendam. 2001 'Water Rights and Collective Action in Community Irrigation' In: Boelens R. and P. Hoogendam (eds). *Water Rights and Empowerment.* Assen, The Netherlands: Royal Van Gorcum Publishers.

Benda-Beckmann, F. and K. von Benda-Beckmann. 2001. Recognizing Water Rights. Focus 9 (October) IFPRI. Washington D.C. U.S.A.

Bertranou, A and E. Schulze, 1992. Report on the Development of an IIMI Program in Latin America (Draft version). International Irrigation Management Institute, Colombo, Sri Lanka.

Bird J.D. and P. W. K. Gillot, 1992 A Quantitative Review of Adequacy and Equity Indicators for Irrigation System Distribution. In *Proceedings of International Conference on Advances in Planning, Design and Management of Irrigation Systems as Related to Sustainable Land Use* Vol 3. Leuven, Belgium.

Bishop A. A. and A. K.Long 1984 Irrigation Water Delivery for Equity between Users' *Journal of Irrigation and Drainage Engineering.* Vol 109(4)

Boelens, R. and P. Hoogendam (ed) 2002 *Water Rights and Empowerment.* Assen, The Netherlands: Royal van Gorcum.

Boelens R. and G. Dávila, (ed) 1998 *Searching for Equity. Conceptions of justice and equity in peasant irrigation.* Assen, The Netherlands: Royal van Gorcum.

Boelens, R. and M. Zwarteveeen, 2005. Anomalous Water Rights and the Politics of Normalization. Collective Water Control and Privatization Policies in the Andean Region. Presentation at the Ceres Summer School, The Hague.

Bolding, A, 2004 *In Hot Water.* Phd. Thesis, Wageningen, University. Wageningen. The Netherlands.

Bolding A. and P. Wester, 2005 Three Waves of River Basin Development and Management: The Might and Myth of the TVA Model. Presentation at the CERES Summer School, The Hague, The Netherlands.

Bonaudo, M and E. Sonzogni, 2000. Cuando Disciplinar fue Ocupar (Santa Fe, 1850-1890). Mundo Agrario. Revista de estudios rurales. N° 1. CEHR-UNLP. La Plata, Argentina.

Bos, M. G. and J. Nugteren, 1982 On Irrigation Efficiencies. ILRI, Pub. 19. Wageningen, The Netherlands

Bos M.G., D.H. Murray-Rust, D. J. Merrey, H. G. Johnson and W. B. Snellen 1994 Methodologies for Assessing Performance of Irrigation and Drainage Management *Irrigation and Drainage Systems*, Vol 7 (4): 231-261.

Bos, M.G. M.A. Burton and D.J. Molden, 2005 *Irrigation and Drainage Performance. Practical Guidelines*. Alterra-ITAD-IWMI CABI Oxfodshire U.K.

Brewer, J.D. 2000. Negotiating Water Allocation Rules in a Government-Managed Irrigation System: Conflicts in Kirindi Oya. In *Negotiating Water Rights.* Bruns, B.R. and R. S. Meinzen-Dick (eds), IFPRI. Vistaar Publications, New Delhi; Intermediate Technology Press, London. UK.

Briscoe, 1996. Water as an Economic Good: The Idea and What it Means in Practice. In: Transactions of the 16th Congress on Irrigation and Drainage, Vol 1E. Cairo. International Commission of Irrigation and Drainage: 177-201.

Bromley, D. W. 1991. *Environment and Economy: Property Rights and Public Policy.* Oxford, UK Basil Backwell.

Bruns, B. R. and R. s. Meinzen-Dick (ed), 2000. Negotiating Water Rights. IFPRI.

Burt C.M. and S.W. Styles, 1999 Modern Water Control and Management Practices. In *Irrigation. Impact on Performance.* FAO Water Reports N°19. FAO, Rome, Italy.

Burt, C.M., A. J. Clemmens, T. S. Strelkoff, K. H. Solomon and R. D. Bliesner, 1997 Irrigation Performance Measures: Efficiency and Uniformity. *Journal of Irrig. and Drainage Engineering,* Vol 113 (4): 423-441.

Bustos, R., M. Marre and J. Chambouleyron, 2001 Performance of Water Users' Associations in the Lower Tunuyan Area, Argentina. *Irrigation and Drainage Systems,* Vol 15:235-246.

Castor López, G. 1998 El Desempeño Económico Relativo (1870-1995) In: *Retrato de Un Siglo.* El Liberal. Santiago del Estero, Argentina.

Chambers, R. 1988 *Managing canal irrigation: Practical analysis from South Asia.* Oxford & IBH Publishing Co, New Delhi and Calcutta.

Chambouleyron, J, D. Prieto and J. Taboada, (ed), 1994. Memorias del Seminario Nacional Sobre Situacion Actual y Perspectivas de las Areas Regadías Argentinas. INCYTH-INTA-DGI. Tucumán, Argentina.

Checkland, P.B. and J. Sholes, 1990 *Soft Systems Methodology in Action.* John Wiley & Son, West Sussex, England.

Checkland, P.B., 1981 *Systems Thinking, Systems Practice,* John Wiley & Son, West Sussex, England.

Chidenga, E. E. *Leveraging Water Delivery. Irrigation Technology Choices and Operations and Maintenance in Smallholder Systems in Zimbabwe.* PhD. Thesis. Wageningen Univesity. Wageningen, The Netherlands.

Clemmens, A.,1987. 1987): Arranged Delivery Schedules. In: D. Zimbelman (ed.) *Proceedings of the Conference: Planning, Operation, Rehabilitation and Automation of Irrigation Water Delivery Systems,* Irrigation and Drainage Division. (ASCE) Symposium held in Portland, Oregon, ASCE, New York p. 57-67.

CNES, 2003 The Pro and Cons of Irrigation Management Reforms, Paper N° 2 Different Approaches to Reform of Irrigation Management. www.servicesforall.org/html/water/irrigation_management_C2.pdf

Colleman, J. 1990. *Foundations of SocialTheory*. Cambridge, Massachusetts Harvard University Press.

Collins, 1995 English Dictionary, London. UK.

Coward E. W.(Jr). 1979. Principles of Social Organization in an Indigenous Irrigation System. *Human Organization*, Vol 38: 28-36.

Coward E. W. (Jr). 1980. Irrigation Development: Institutional and Organizational Issues. In Coward, E. W. (Jr) (ed) *Irrigation and Agricultural Development in Asia*. Cornell University Press Ithaca, New York , pp 15-27.

Coward E. W. (Jr). 1991. Planning Technical and Social Change in Irrigated Areas. In: M. M. Cernea (ed). *Putting People First: Sociological Variables in Rural Development*. Second Edition. Oxford University Press. Published for the World Bank.

Craig D. and D. Porter. 1997. Framing Participation: Development Projects, Professionals, and Organizations. *Development in Practice*, 7(3): 220-236.

Cummings R.G. and V. Nercissiantz, 1992. The Use of Water Pricing as a Means for Enhancing Water use Efficiency in Irrigation, Case Studies in Mexico and the United States. *Natural Resources Journal* 32:731-755.

Douglas, M. 1992 *Risk and Blame: Essays in CulturalTtheory*. London: Routledge.

Echenique, J, 2000. Pampa Libre, Anarquistas en la Pampa Argentina, Santa Rosa (La Pampa). Mundo Agrario. Revista de Estudios Rurales N°1. CEHR-UNLP. La Plata, Argentina.

Eggink, J.W. and L. Ubels, 1984 *Irrigation, Peasants and Development: An Attempt to Analyse the Role of Irrigation insocial Change in Third World Societies*. MSc. Thesis Agricultural University of Wageningen, The Netherlands.

FAA (Fed. Agraria Argentina),1999 Grito de Alcorta. *Prensa Socialista Revista* 3.

FAO 1997. Management of Agricultural Drainage Water Quality. Water Report 13 Food and Agriculture Organization, Rome, Italy.

FAO/RAP 1997. Modernization of Irrigation Schemes: Past experiences and Future Options. In *Proceedings of the Expert Consultation*, Bangkok, November 1996

FAO 2004 Anuario Estadístico 2004. Rome Italy.

Feitsma, M., 1996 *Land Use in the Coastal Area of the Mekong Delta, Vietnam. A Participatory (?) Rural Appraisal*. Project MHO-8 IMCR. Can Tho University, Vietnam-Wageningen Agricultural University, Wageningen, The Netherlands. MSc Thesis, Wageningen University.

Fiorentino, Raúl, 1988 Apuntes para una Estrategia de Desarrollo de la Agricultura de Riego en la Argentina" *Desarrollo Económico*, Vol 27: 539:558.

Flammini, M.A. 2001. Algunas Reflexiones sobre los Cambios Económico-Sociales del Agro Pampeano en el Siglo XX. *Mundo Agrario – Revista de Estudios Rurales*. Vol 2 La Plata Argentina

Fraga, R. 2003 La desigualdad Provincial. www2.invertironline.com/contenido/Broda/Articulo_Br.asp?id_research=8103

Frederiksen, H.D. and R.J. Vissia 1998, Considerations in Formulating the Transfer of Services in the Water Sector. Colombo: International Water Management Institute

Freeman D. M. 1990 Designing Local Irrigation Organizations for Linking Water Demand with Supply'. In: Sampath R. K. and Robert A. Young (ed). *Social, Economic, and Institutional Issues in Third World Irrigation Management. Studies in Water Policy and Management*, No. 15. Westview Press, Boulder Colorado.

Garcés-Restrepo, C. S.H. Johnson, G. Levine and C.A. Scott, 1997 *Mexico Irrigation Sector Profile*. Colombo, Sri Lanka. International Irrigation Management Institute.

Gerbrandy, G. and P. Hoogendam, 2002. Materializing Rights: Hydraulic Property in the Extension and Rehabilitation of Two Irrigation Systems in Bolivia. In: Boelens, R. and P. Hoogendam (ed) 2002 *Water Rights and Empowerment*. Koninklijke van Gorcum, Assen, The Netherlands.

Ghasemi, F., A.J. Jakeman and H.A. Nix, 1995. Salinization of Land and Water Resources: Human Causes, Extent, Management and Case Studies. Centre for Resources and Environmental Studies. Australian National University. CAB International, Wallingford, UK.

Giddens A. 1979 *Central Problems inSocialTheory: Action, Structure and Contradictions in Social Analysis*.. The Macmillan Press. Ltd., London.

Girbal-Blancha, N.M., 1998 Ayer y Hoy de la Argentina Rural. Gritos y Susurros del Poder Económico. REUN/Página 12. pp 15 – 38 Buenos Aires, Argentina

Girbal-Blancha, N.M. 1998. Acerca de la Vigencia de la Argentina Agropecuaria. Estado y Crédito al Agro Durante al Gestión Peronista (1946-1955). Proceedings of the 1998 Latin American Studies Association. Chicago, Illinois. USA.

Girbal-Blancha, N.M. 1999. Estado y Economía en la Argentina de los Años 30. La Organización del Régimen Agrícola como Antecedente del Nacionalismo Económico Peronista", in: Academia Nacional de la Hisotoria: *X Congreso Nacional y Regional de Historia Argentina, Santa Rosa (La Pampa)*, pp. 1-16 Buenos Aires, Argentina.

Gowing John, Andrew Tarino, and Omer El-Awad. 1996. A Rational Method for Assessing Irrigation Performance at Farm Level with the Aid of Fuzzy Set Theory. *Irrigation and Drainage Systems* Vol 10(4): 319-330.

Graciano, O. F., 2001. Historia del Agro Argentino. Desde la Conquista Hasta Fines del Siglo XX. *Mundo Agrario. Revista de estudios rurales* N°3. CEHR. UNLP, La Plata, Argentina.

Groenfeldt 1988. The Potential for Farmer Participation in Irrigation System Management. *Irrigation and Drainage Systems*, Vol 2(3):241-257.

Groenfeldt, D. and P. Sun. 1997 Demand Management of Irrigation Systems through Users' Participation. In: M.Kay, T. Franks and L.E.D. Smith (eds). *Water: Economics, Management and Demand*. London, Chapman Hall, 304-311.

Guillet, D. 1998. Rethinking Legal Pluralism: Local Law and State Law in the Evolution of Water Property Rights in Northwestern Spain. *Comparative Studies in Society and History*, Vol 40 (1): 42-70.

Gutierrez, T. V. 2002. El Peronismo y el "Mundo Agrario". Una Visión Sobre el Agro Argentino, 1949-1955. *Mundo Agrario. Revista de estudios rurales* N° 4. CEHR-UNLP. La Plata, Argentina.

Gutierrez, Z. 2005. *Appropriate Designs and Appropriating Irrigation Systems. Irrigation Infrastructure Development and Users' Management Capability in Bolivia*. Ph.D. Thesis. Wageningen University.

Gunderson, L.H. and C.S. Holling, 2002 *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press, Washington, DC, USA.

Halsema, G.E. van, 2002 *Trial & Re-trial, The evolution of irrigation modernization in NWFP, Pakistan*. PhD Thesis, Wageningen University, Wageningen, The Netherlands.

Harriss, J. and P. de Renzio. 1997. Missing Link or Analytically Missing, the Concept of Social Capital. An Introductory Bibliography. *Journal of International Development*, Vol 9(7): 919 – 937.

Harza Engineering Company, 1965. Feasibility Report Rio Dulce Project. Supporting Studies. Buenos Aires, Argentina.

Hebinck, P. G. Verschoor and N. Long, 2001. *Resonances and Dissonances in Development: Actors, Networks and Cultural Repertoires.* Assen, The Netherlands: Royal van Gorcum.

Hellegers P.J.G. J. and C. J. Molden, 2004. Water as an Economic Good in Irrigated Agriculture. Report 3.04.12. Agricultural Economics Research Institute (LEI) The Hague, The Netherlands.

Hendricks, J. 1998 Water as Private Property: Notes on the Case of Chile. In R. Boelens and G. Dávila (ed). *Searching for Equity: Conceptions of Justice and Equity in Peasant Irrigation.* Assen, The Netherlands: Royal van Gorcum: pp 297-309.

Hoeberichts, A. 1996 In Search of Water Users' Perspective of Irrigation Performance: A Participatory Research Approach. International Irrigation Management Institute Lahore, Pakistan.

Hofwegen, P. van, 1996 Accountability Mechanisms and User Participation on Three Agency Managed Systems in Morocco, Indonesia, and the Netherlands. In: *Transactions of the 16th Congress on Irrigation and Drainage,* Vol. 1B. Cairo: International Commission on Irrigation and Drainage: pp 231-244.

Hofwegen, P. van 1999. Asset Management Programs for Financial Planning and Management in Irrigation and Drainage. *Irrigation and Drainage Systems* Vol 13:131-143.

Horst, L. 1983. Irrigation Systems. Lecture Notes Irrigation Systems Course. MSc Course. Agricultural University Wageningen. Wageningen, The Netherlands.

Horst L. 1998. *The Dilemmas of Water Division: Considerations of Criteria for Irrigation Systems Design.* International Water Management Institute. Colombo.

Hoorn J.W.van and J.V. van Alphen, 1988 Salinity Control, Salt Balance and Leaching Requirement of Irrigated Soils. Lecture Notes N°12, International Course on Land Drainage, ILRI, Wageningen, The Netherlands.

Horst, L. 1996 Technology Implications of Irrigation Water Delivery Policies: Irrigation Delivery Oolicy and technology'. In: Howsam P. and R. C. Carte (ed). *Water Policy: Allocation and Management Practice.* Proceedings of International Conference on Water Policy. 23/24 September 1996. Silsoe College, Cranfield University, Silsoe. E & FN SPON, London.

Hunt R.C. 1989. Appropriate Social Organization? Water User Associations in Bureaucratic Canal Irrigation Systems'. *Human Organization.* Vol 48(1): 79-90

Hunt R. C. 1990. Organization Control over Water: The Positive Identification of Social ConstraintS on Farmer Participation; In: Sampath R. K. and Robert A. Young (ed) *Social, Economy, and Institutional Issues in Third World Irrigation Management. Studies in Water Policy and Management,* No. 15 Westview Press, Boulder Colorado.

Hunt, R. C. 1988 Size and the Structure of Authority in Canal Irrigation Systems. *Journal of Anthropological Research,* Vol 44 (4).

Huppert, W. 1989 Situation Conformity and Service Orientation in Irrigation Management. Basic Concepts. Sonderpublikation der GTZ No. 242, Eschborn, Germany: GTZ.

Huppert, W. and K. Urban. 1988 Analyzing Service Provision. Instruments for Development Cooperation illustrated by Examples from Irrigation. Schrifternreihe der GTZ, no. 263. Wisbanden, Germnay: GTZ-GmbH.

INDEC, 1988 Censo Nacional Agropecuario www.indec.mecon.gov.ar

INDEC, 2001 Censo Nacional de Población
www.indec.mecon.gov.ar/webcenso/index.asp

INDEC, 2002 Censo Nacional Agropecuario www.indec.mecon.gov.ar

INTA, 1986 Documento del Programa Nacional de Riego y Drenaje INTA, Buenos Aires, Argentina.

INTA- UER, 1998 Data base of PRD users. INTA-Sgo. Del Estero, Argentina

Johnsom, J.R., Vermillion and J.A. Sagardoy, 1995 Irrigation Management Transfer. Selected papers from the International Conference on Irrigation Management Transfer. FAO Water Report N° 5 Rome, Italy.

Johnson, J.R. 1997 Irrigation Management Transfer in Mexico: A Strategy to Achieve Irrigation District Sustainability. *Research Report 16*. Colombo, Sri Lanka: International Irrigation Management Institute.

Jurriens, R. 1996 Assessing Seasonal Irrigation Service Performance, IFPRI Working Papers on Irrigation Performance 3 Washington DC, U.S.A.

Kay, M., T. Franks and L. Smith, 1997 Water: Economics, Management and Demand, in Proceeding of the 18th European Regional Conference "Water – *A*n economic good?" E&FN SPON. London, UK

Keller A. A. and J. Keller, 1995 Effective efficiency: A Water Use Efficiency Concept for Allocating Freshwater Resources. Discussion Paper 22, Center for Economic Policy Studies, Winrocking., Arlington, VA. USA.

Keller and Keller, 1996. Integrated Water Resource Systems: Theory and Policy Implications. - *Research Report 3*. International Water Management Institute, Colombo, Sri Lanka.

Keller Jack. 1990. A Holistic Approach to Irrigation Scheme Water Management;. In: Sampath R. K. and Robert A. Young (ed). *Social, Economic, and Institutional Issues in Third World Irrigation Management*, No. 8. Westview Press, Boulder Colorado.

Kemper, K. E. 2001. Markets for Tradable Water Rights. Focus 9 (October) IFPRI. Washington D.C. U.S.A.

Kielen N. 1996. Farmers' Ability to cope with Salinity and Sodicity: Farmers' Perceptions, Strategies and Practices for Dealing with Salinity and Sodicity in their Farming Systems. *Research Report 6* National Program. International Irrigation Management Institute, Lahore.

Kijne, J. W., R. Barker and D. Molden (eds), 2003. *Water Productivity in Agriculture. Limits and Opportunities for Improvement.* IWMI and London: CABI Publishing..

Kloezen, W. H. and P.P. Mollinga. 1992 Opening Closed Gates: Recognizing the Social Nature of Irrigation Artifacts. In: G. Diemer and J. Slabbers (Eds) *Irrigators and Engineers*. Amsterdam: Thesis Publishers: 53-64.

Kloezen, W. H. 2002 *Accounting for Water: Institutional Viability and Impacts of Market-Oriented Irrigation Interventions in Central Mexico.* Ph.D. Thesis. Wageningen University, The Netherlands.

Kloezen W H. and Carlos Garces-Restrepo. 1998. Assessing irrigation performance with comparative indicators: The case of the Alto Rio Lerma Irrigation District, Mexico. *Research Report 11*. International Water Management Institute, Colombo.

Kloezen, W. H. and C. Garces-Restrepo, and S. H. Jonhnson III 1997. Impact Assessment of Irrigation Management Transfer in the Alto Rio Lerma Irrigation District, Mexico. *Research Report 15*. Colombo, Sri Lanka: International Irrigation Management Institute.

Kuper, M. 1997. *Irrigation Management Strategies for Improved Salinity and Society Control.* Ph.D. Thesis, Wageningen Agricultural University, the Netherlands.

Lam, V.F. 1996 Institutional Design of Public Agencies and Co-production: A Case Study of Irrigation Associations in Taiwan. *World Development*, 6:1039 - 1054

Lankford B.A. and J. Gowing. 1996. Understanding Water Supply Control in Canal Irrigation Systems: Analysis of Irrigation Water Control'. In: Howsam P. and R. C. Carter (eds).

Water Policy: Allocation and Management Practice. Proceedings of International Conference on Water Policy. 23/24 September 1996. Silsoe College, Cranfield University, Silsoe. London: E & FN SPON.

Lankford B.A. and J. Gowing. 1997. Providing a Water Delivery Service through Design Management Interactions and System Management: Achieving Control for Water Pricing. In: Kay Melvyn and Tom Franks (ed) *Water: Economics, Management and Demand.* International Commission on Irrigation & Drainage. Proceedings of the 18th European RegionAl Conference. "Water-An Economic Good?" Held in Osford, Uk, Semptember '97. E & FN SPON, London: pp 238:246.

Lattuada, M. 2002. El Peronismo y los Sectores Sociales Agrarios. La Resignificación del Discurso Como Articulador de los Cambios en las Relaciones de Dominación y la Permanencia de las Relaciones de Producción. Mundo Agrario. Revista de estudios rurales N° 5. CEHR-UNLP. La Plata, Argentina.

Lenton, R., 1982. *Management Tools for Improving Irrigation Performance.* Lecture Notes Special Course on Water Management in Irrigation Systems. Central Water Commision. New Delhi.

Lenton R. 1986. On the Development and Use of Improved Methodologies for Irrigation Management' In: Nobe K.C. and R.K. Sampath (ed). *Irrigation Management in Developing Countries: Current Issues and Approaches.* Studies in Water Policy and Management, No. 8.Westview Press, Boulder Colorado.

Levine G. 1980 'The Relationship of Design, Operation and Management'. In: Coward E. Walter Jr.. *Irrigation and Agricultural Development in Asia: Perspectives from the Social Sciences.* Cornell University, Ithaca and London.

Levine G. 1982. Relative Water Supply: An Explanatory Variable for Irrigation Systems. *Technical Report No. 6.* Cornell University, Ithaca, New York, USA.

Levine G. and E.W. Coward, 1989 Equity Considerations in the Modernization of Irrigation Systems. ODI/IIMI network paper 89/2b London, U.K.

Levine, G., A., Cruz, D., C. Garcés, and S. Johnson III. 1998. Performance of Two Transferred Modules in the Lagunera region: Water relations. *Research Report 23.* Colombo, Sri Lanka: International Water Management Institute.

Long N. (ed). 1989. *Encounters at the Interface: A Perspective on Social Discontinuities in Rural Development.* Wageningen Studies in Sociology VWW 27. Wageningen Agricultural University.

Long, N. 1988. Sociological Perspectives on Agrarian Development and State Intervention. In: A. Hall and H. Midgley (eds.) *Development Policies: Sociological Perspectives.* Manchester: Manchester University Press.

Long, N. 2001. *Development Sociology: Actor Perspectives.* London: Routledge.

Long, N. and J. D. van de Ploeg 1989. Demythologizing PlanNed Intervention: An Actor Oerspective. *Sociologia Ruralis*, Vol 3/4: 226 – 249.

Malano, H. and M. Burton, 2001 Guidelines of Benchmarking in the Irrigation and Drainage Sector. Knowledge Synthesis Report N° 5 IPTRID-FAO Rome, Italy.

Malik Saleem, Waheed-uz-Zaman and M. Kuper. 1996 Farmers' Organized Behavior in Irrigated Agriculture in Pakistan: A Case Study of Six Watercourse Command Areas in Junejwala Minor, Lower Canal System. IIMI Working Paper No. 39. International Irrigation Management Institute, Colombo.

Martin E. and R. Yoder, 1988. Organizational Structure for Resource Mobilization in Hill Irrigation Systems. In: IIMI (eds.). *Irrigation Management in Nepal: Research Papers from a National Seminar.* Kathmandu, Nepal: International Water Management Institute.

Martinez Beltrán, J. 1986. Drenaje Agrícola Vol 1. Serie de Ingeniería Rural y Desarrollo Agrario. Manual Técnico N° 5. IRYDA, Ministerio de Agricultura, Pesca y Alimentación. Madrid, España.

Mazzota, M. E, Generación del '80, su proyecto http://www.monografias.com/trabajos11/genedel/genedel.htm

Meinzen-Dick R., M. Mensoza, L., Sadoulet, G. Abiad-Shields and A. Subramaniam 1994. Sustainable Water Users Associations: Lessons from a Literature Review. Paper prepared for the World Bank Water Resources Seminar, December 1994. Wahsington D.C. World Bank.

Meinzen – Dick, R., 1997. Farmer Participation in Irrigation. 20 Years of Experience and Lessons for the Future. *Irrigation and Drainage Systems*. 11:103-118. Kluwer Academic Publishers. The Netherlands.

Meinzen – Dick, R., R. Reidinger and A. Manzardo. 1995 Participation in Irrigation. *Participation Series N° 3.* Washington D.C. World Bank., Social Policy and Resettlement Division.

Meinzen-Dick, R. S. and B.R. Bruns. 2000. Negotiating Water Rights: Introduction. In *Negotiating Water Rights*. Bruns, B.R. and R. S. Meinzen-Dick (ed), IFPRI. Vistaar Publications, New Delhi; Intermediate Technology Press, London. UK.

Meinzen-Dick, R. S. and Bakker, 2000. Water Rights and Multiple Water Uses: Framework and Application to the Kirindi Oya Irrigation System. Sri Lanka. EPDT Dissussion Paper No 59. International Food Policy Research Institute. Washington D.C.

Meinzen-Dick, R. S. and Bakker, 2001. Water Rights and Multiple Water Uses. *Irrigation and Drainage systems,* Vol 15: 129-148.

Merrey D. J. 1986 'Reorganizing Irrigation: Local Level Management and the Improvement of Local Level Water Management in Punjab, Pakistan. *Water Management Technical Report No. 53*. Colorado State University. Fort Collins.

Merrey, D. J. 1996. Institutional Design Principles for Accountability in Large Irrigation Systems. *Research Report 8*. Colombo, Sri Lanka: International Water Management Institute.

Merrey D. J. 1997. Role of Water Users Association in Improved Irrigation System Performance. Paper Presented at the PIM seminar in Lahore, Pakistan, in Starkloff Ralf and Waheed-uz-Zaman (eds) 1999. *Farmers' Participation, Empowerment and the Institutional Reform of Pakistan's Irrigation and Drainage Sector: Key Concepts and Farmers's Perception.* Research Report R-89. Pakistan National Program. International Water Management Institute, Lahore.

Merrey, D. J. and S. Bulankulame. 1987. Responsibility in Irrigation Systems Management: Some Policy Suggestions for Sri Lanka. IIMI Management Brief, 5 Colombo, Sri Lanka International Management Institute.

Michaud, C. 1942 Regadíos en Santiago del Estero, Informe Resumen. Gobierno de Santiago del Estero. Santiago del Estero, Argentina.

Molden D. J. 1997. Accounting for Water Use and Productivity. SWIM Paper 1. Colombo, Sri Lanka: International Irrigation Management Institute.

Molden D. J. and T. K. Gates. 1990. Performance Measures for Evaluation of Irrigation Water Delivery Systems. *Journal of Irrigation and Drainage Engineering*. ASCE. Vol 116(6):804-823.

Molden D. J., R. Sakthivadivel, C. J. Perry, C. de Fraiture and W. H. Kloezen. 1998. Indicators for Comparing Performance of Irrigated Agricultural Systems. *Research Report 20*. International Water Management Institute. Colombo

Molden, D. J. and R. Sakthivadivel, 1999 Water Accounting to Assess Use and Productivitiy of Water. *Water Resources Development* Vol 15 (1/2) 55-71.

Molle, F. 2003. Development Trajectories of River Basins. A conceptual Framework. *Research Report 72*. IWMI. Colombo, Sri Lanka.

Mollinga Peter P. 2003. *On the Waterfront: Water Distribution, Technology and Agrarian Change in a South Indian Canal Irrigation System*. Wageningen, University Water Resources Series 5 Orient Longman, Hyderabad, India.

Mollinga, P. 1998 *On the Waterfront: Water Distribution, Technology and Agrarian Change in a South Indian Canal Irrigation System*. PhD. Thesis, Wageningen Agricultural University, The Netherlands.

Mollinga, P. P. 2001. Water and Politics: Levels, Rational Choice and South Indian Canal Irrigation. *Futures*, Vol 33: 733 – 752.

Moore, M. 1990. The Rational Choice Paradigm and the Allocation of Agricultural Development Resources. *Development and Change*, Vol 21:225-246.

Morabito, J., M.G.Bos, S. Vos and R.Brouwer, 1998.The Quality of Service Provided by the Irrigation Department to the Users Associations, Tunuya System. Mendoza, Argentina. *Irrigation and Drainage Systems* Vol 12:49-65.

Mosse, D. 1998. Process Oriented Approaches to Development Practice in Social Research. In: D. Mosse, J. Farrington and A. Rew (ed.). *Development as process: Concepts and methods for working with complexity*. London And new York: Routledge: pp 3-30.

Mundra, S.N. and A.K. Garg, 1999 Participatory Irrigation Management in The Cahmbal Command. In *Modernization of Irrigation System Operations*. Proceedings of the Fifth International IT IS Network Meeting Thailand.

Murray-Rust, D. H. and W.B. Snellen, 1993. *Irrigation Systems Performance Assessment and Diagnosis*. Colombo, Sri Lanka: International Irrigation Management Institute.

Murray-Rust D. H. and G. van Halsema. 1998. Effects of Construction Defects on Hydraulic Performance of Kalpani Distributary, NWFP, Pakistan'. *Irrigation and Drainage Systems* Vol. 12. No. 4: 323-340.

Murray-Rust D.H., B.Lashari and Y. Memon, 2000 Water Distribution Equity in Sind Province. Working Paper 9. Internacional Water Management Institute, Lahore, Pakistan.

Nihenson, L. 1970. Clasificación y Estudios de Suelos en el Area del Proyecto Río Dulce. CRD, Santiago del Estero, Argentina.

Nugent, J.B. 1993. Between state, markets and households: A Neoinstitutional Analysis of Local Organizations and Institutions. *World Development*, Vol 4: 623-632.

Oad, R. and R. K. Sampath. 1995 Performance Measures for Improving Irrigation Management. *Irrigation and Drainage Systems*, Vol 9: 357:370.

Ostrom Elinor and Roy Gardner. 1993. Coping with Asymmetries in the Commons: Self-Governing Irrigation Systems can Work. *Journal of Economic Perspectives*, Vol 7 (4): 93-112.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. New York: Cambridge University Press.

Ostrom, E. 1992. *Crafting Institutions for Self-governing Irrigation Systems*. San Francisco: Institute for Contemporary Studies Press.

Ostrom, E. 1996. Crossing the Great Divide: Coproduction, Synergy and Development. *World Development*, Vol 6:1073-1087.

Ostrom, E. 1999. Social Capital: A Fad or a Fundamental Concept? In: P. Dasgupta and I. Serageldin (eds.). *Social Capital: a Multifaceted Perspective*. Washington, D.C. The World Bank: pp 172-214.

Ostrom, E., T. Dietz, N. Dolsak, P. _C. Stern, S. Stonich and E. E. Weber (eds), 2002 *The Drama of the Commons*. National Academy Press, Washington. DC, USA.

Perry C. J. 1996. Quantification and Measurement of a Minimum Set of Indicators of the Performance of Irrigation Systems. International Irrigation Management Institute. Colombo.

Perry C. J.1996. Determinants of Function and Dysfunction in Irrigation Performance, and Implications for Performance Improvement. *Water Resources Development*, Vol. 11(1): 25-38.

Perry C.J., 1999. The IWMI Water Resources Paradigm – Definitions and Implications. *Agricultural Water Management,* Vol 40: 45-50. Elsevier Science B.V. The Netherlands.

Perry, C.J., M. Rock and D. Seckler. 1997 Water as an Economic Good: A Solution, or a Problem? *Research Report 14.* International Irrigation Management Institute Colombo, Sri Lanka.

Perry, C.J., M. Rock and D. Seclkler, 1997 Water as an Economic Good: A Solution or a Problem? In *Water: Economics, Management and Demand,* Kay, M., T. Franks and L. Smith (ed). ICID, London: E & FN Spon.

Peter, J.R., 2004 PIM - Lessons from International Experience. www.inpim.org/leftlinks/ Documents.

Plusquellec, H., C. Burt and H. W. Wolter 1994 *Modern Water Control in Irrigation. Concepts, Issues, and Applications* World Bank Technical Paper N° 246 Irrigation and Drainage series. Washington D.C. USA.

Plusquellec, H. C. 2002. *How Design, Management and Policy Affect the Performance of Irrigation Projects. Emerging Modernization Procedures and Design Standards.* FAO, Bangkok, Thailand.

Postel, S.1993. Water and Agriculture. In: Gleick, P. H. (Ed.). *Water in Crisis: A Guide to the World's Fresh Water Resources.* New York and Oxford: Oxford University Press: pp 56-66.

Poudel, R. 2000. Farmers's Laws and Irrigation. Water Rights and Dispute Management in the Hills of Nepal. PhD. Thesis. Wageningen, The Netherlands

Pradhan, R. and U. Pradhan. 2000. Negotiating Access and Rights: Disputes over Rights to an Irrigation Water Source in Nepal. In: *Negotiating Water Rights.* Bruns, B. R. and R. S. Meinzen-Dick (ed),IFPRI. Vistaar Publications, New Delhi; Intermediate Technology Press, London. UK.

Pradhan, R; F. von Benda-Beckmann; K. von Benda-Beckmann; H.L. J. Spiertz, S. Hadka, K. Azharul. Haq. (ed), 1996. Water rights, conflict and policy. Proceedings of a workshop held in Kathmandu, Nepal, January 22-24 IWMI, Colombo Sri Lanka.

Prieto, D., 1990. Estado de Situación y Estrategia de Investigación de la Estación Experimental Santiago del Estero sobre Salinidad y Drenaje. Memorias del Taller de Salinidad de Suelos. Santiago del Estero, Argentina.

Prieto, D, J. vaan de Eijk and G. Angella, 1994 Eficiencia de Uso del Agua en el PRD. Parte III: Eficiencia y Uniformidad de Aplicación in Procedings of the Jornadas Provinciales de Riego. Santiago del Estero, Argentina

Prosap, 2005. Informe de Avance sobre Proyectos de Modernización de Riego en Argentina (personal communication).

Putman, R. 1993. *Making Democracy Work: Civic Traditions in modern Italy.* Princeton, New Hersey: Princeton University Press.

Radrizzani A., 2000. Los Sistemas Productivos del Area de Riego del Río Dulce. Una Visión desde la Sustentabilidad. M.Sc. Thesis Universidad Internacional de Andalucía. Santa María de la Rábida, España.

Rao P.S. 1993. Review of Selected Literature on Indicators of Irrigation Performance. Research Paper. International Irrigation Management Institute, Colombo, Sri Lanka.

Reidinger R. 1994. Observations on Water Markets for Irrigation Systems. In: Le Moigne G., K. W. Easter, W.J. Ochs and S. Giltner (eds). *Water Policy and Water Markets*. World Bank Technical Paper No. 249, Washington DC.

Renault. D. 1999 Off-take Sensitivity, Operation Effectiveness, and Performance of Irrigation Systems. *Journal of Irrig. and Drain. Eng.*, Vol 125 (3) 137 – 147.

Renault, D. 1999 Modernization of Irrigation Systems: A Continuing Process. In *Modernization of Irrigation System Operation*. Proceedings of the fifth International IT IS Network Meeting ITIS 5 Thailand.

Renault, D., 2001. Re-engineering Irrigation Management and System Operations. *Agric. Water Management,*, Vol 47: 211 – 226.

Renault D. and G. G. A. Godaliyadda. 1999. Generic Typology of Irrigation Systems Operation. *Research Report 29*. International Water Management Institute, Colombo, Sri Lanka.

Renault, D. and I.W. Makin, 1999. Modernizing Irrigation Operations: Spatially Differentiated Resource Allocations. *Research Report 35*. International Water Management Institute, Colombo, Sri Lanka.

Renault, D. and M. Hemakumara, 1999 Irrigation Offtake Sensitivity. *Journal of Irrig. and Drain. Eng.*, Vol 125 (3): 131 – 136.

Renault, D., M. Hemakumara, and d. Molden. 1999. Importance of Evaporative Depletion by Non-Crop Vegetation in Irrigated Areas of the Humid Tropics. Internal paper Colombo: International Water Management Institute.

Renault, D. and P. W. Vehmeyer, 1999. On Reliability in Irrigation Service Preliminary Concepts and Application. *Irrigation and Drainage Systems*, Vol 13: 75-103.

Renolfi, C. C de, 2003. Determinación del Optimo Económico en Explotaciones Tipo del Area de Riego del Río Dulce de Santiago del Estero. Argentina. Tesis Doctoral Universidad Politécnica de Madrid. Madrid, España.

Repetto, R. 1986. *Skimming the Water: Rent-seeking and the Performance ofPpublic Irrigation Systems. Research Report 4*. Washington, D.C.: World Resources Institute.

Romanella, C.A., 1971. Planificación del Riego en el Area del Proyecto del Río Dulce. Informe Final. Santiago del Estero, Argentina

Rosegrant M.W. and R. Gazmuri, 1994. Tradable water rights: Experience in Reforming Water Allocation Policy. Irrigation Support Project for Asia and Near East (ISPAN), Washington DC. USA.

Rosegrant, M.W. and H. P. Bisnwanger, 1994 Markets in Tradable Water Rights: Potential for Efficiency Gains in Developing Country Water Resource Allocation. *World Development* Vol 22 (11) 1613-1625.

Rosegrant, M.W., R. G. Schleyer and S. N. Yadav. 1995. Water Policy for Efficient Agricultural Diversification: Market-Based Approaches. *Food Policy*. Vol 3:202-223.

Roth, M.; K.Wiebe, and S. Lawry. 1993. Land Tenure and Agrarian Structure: Implications for Technology Adoption. In Proceedings of a Workshop on Social Science Research and the CRSPs: June 9-11, 1992, University of Kentucky, Lexington, KY. Washington, D.C. USAID.

Sakthivadivel, R. C. de Fraiture, D. J. Molden, C. Perry and W. Kloezen, 1999. Indicators of Land and Water Productivity in Irrigated Agriculture. *Water Resources Development*, Vol 15 (1/2) 161-179. Taylor and Francis Ltd.

Saleth, R. M. 1994. Toward a new Water Institution: Economics, law and policy. *Economic and Political Weekly*, September 24: A-147-A-155.

Saleth, R.M. 2001. Water Pricing: Potential and Problems. Focus 9 (October) IFPRI. Washington D.C. U.S.A.

Sanaee-Jahromi, S., J. Feyen, G.Wyseure and M. Javan, 2001 Approach to the Evaluation of Undependable Delivery of Water in Irrigation Schemes. *Irrigation and Drainage Systems,* Vol 15: 197-213.

Sampath, R.K. and R. A. Young (ed), 1990. Social, Economic, and Institutional Issues in *Third World Irrigation Management. Studies in Water Policy and Management,* N°15. Westview Press, Colorado, USA.

Schlager, E. and E. Ostrom. 1992. Property Rights Regimes and Natural Resources: A Conceptual Analysis. *Land Economics* Vol 68 (3): 249-262.

Sharma D. N., Ramchand Oad and R. K. Sampath. 1991. Performance Measures for Irrigation Water Delivery Systems. ICID Bulletin. Vol. 40. No.1.

Shashi K. and J. d. Brewer, 1999. Facilitating User Participation in Irrigation Management. *Irrigation and Drainage Systems,* 13: 249-273.

Small, L. E. and M. Svendsen. 1990. A Framework for Assessing Irrigation Performance. *Irrigation and Drainage Systems,* 4:283:312

Small, L. E. and M. Svendsen. 1992. A Framework for Assessing Irrigation Performance, Working Papers on Irrigation Performance No. 1. International Food Policy Research Institute, Washington.

Small, L.E. and I. Carruthers (eds), 1991. *Farmer-financed irrigation. The Economics ofRreform.* Cambridge: Cambridge University Press in association with the International Irrigation Management Institute.

Smedema L.K. 2000. Irrigation Induced River Salinization. International Water Management Institute, Colombo, Sri Lanka.

Smedema L.K. and K. Shiati, 2002. Irrigation and Salinity: A Perspective Review of the Salinity Hazards of Irrigation Development in the Arid Zone. *Irrigation and Drainage Systems* Vol 16: 161-174.

Smith, L.E.D., T. Franks and M.Kay. 1997. Water- an Economic Good? Theory and Practice. *ICID Journal,* Vol 2:1-14.

Snellen W. B. Performance Assessment of Public Irrigation Systems. In: Annual Report 1998. International Institute for Land Reclamation and Improvement, Wageningen.

Spiertz, H.L. J. 2000. Water Rights and Legal Pluralism: Some Basics of a Legal Anthropological Approach. In *Negotiating Water Rights.* Bruns, B.R. and R. S. Meinzen-Dick (ed), IFPRI. Vistaar Publications, New Delhi; Intermediate Technology Press, London. UK.

Sutawan, N., 2000. Negotiation of Water Allocation among Irrigators' Associations in Bali, Indonesia. In: *Negotiating Water Rights.* Bruns, B.R. and R. S. Meinzen-Dick (ed), IFPRI. Vistaar Publications, New Delhi; Intermediate Technology Press, London. UK.

Steenbergen, F. van. 1997. *Institutional Change in Local Water Resources Management: Cases from Balochistan.* PhD. Thesis. Utrecht: Netherlands Geographical Studies.

Strosser P. and C. Garcés-Restrepo. 1992. Performance of Chashma Right Bank Canal: Technical and Economic Indictors in the Context of Crop-Based Irrigation Operations. In: Advancements in IIMI's Research 1992: A Selection of Papers Presented at the Internal Program Review. International Irrigation Management Institute, Colombo.

Svendsen, M, J.Trava and S. Johnson III, 1997. Participatory Irrigation Management: Benefits and Second Generation Problems. Lessons from an International Workshop held at Centro Internacional de Agricultura Tropical (CIAT), EDI-IIMI Washington, U.S.A.

Svendsen, M. and H. Murray-Rust, 2001 Creating and Consolidating Locally Managed Irrigation in Turkey: The National Perspective. *Irrigation and Drainage Systems,* Vol 15:355:371.

Tang, Shui Yan. 1992. *Institutions and Collective Action: Self-governance in Irrigation.* Institute for Contemporary Studies Press. San Francisco, USA.

Tasso, A.1993 ¿Que Pasó Antes del 16 de Diciembre? La Política Santiagueña entre 1983-1993. http://www.bibliotecatasso.com.ar/que_paso.htm

Tasso, A. 2000 La Lucha por el Agua. Una Movilización de Agricultores Santiagueños en 1926. *Sociohistórica,* Cuadernos del CISH, N° 7, Primer Semestre, Universidad Nacional de La Plata. La Plata, Argentina o http://www.bibliotecatasso.com.ar/agua.htm

Tasso, A. 2002 Fuerza de Trabajo, Tierra y Regadío en la Estructura Agraria de Santiago del Estero (1870 - 1940). Tesis Doctoral, Facultad de Filosofía y Letras, Universidad de Buenos Aires. Buenos Aires, Argentina.

Thompson, M. 1998. Style and Scale Two Structures of Institutional Inappropriateness. In: M. Goldan (ed) *Privatizing Nature. Political Struggles for the Global Commons.* London: Pluto Press and TNI. 198-228.

Unidad Ejecutora de Riego, 2002 Informe Interno sobre Características de los Canales en el Proyecto del Río Dulce, Santiago del Estero, Argentina

Uphoff Norman, M. L. Wickramasinghe and M. M. Wijayaratne. 1990. "Optimum" Participation in Irrigation Management. Issues and Evidence from Sri Lanka'. *Human Organization.* Vol 49 (1): 26-40.

Uphoff Norman. 1986. *Improving Internationallirrigation Management with Farmer Participation: Getting the Process Right.* Studies in Water Policy and Management. No. 11. Westview Press, Boulder Colorado.

Uphoff, N., P. Ramamurthy and R. Steiner, 1991. *Managing Irrigation: Analyzing and Improving the Performance of Bureaucracies.* New Delhi and London SAGE Publications.

USBR, 1997. Water Measurement Manual: A Water Resources Technical Publication. A Guide to Effective Water Measurement Practices for Better Water Management. Third Edition. US Department of the Interior Bureau of Reclamation. United States Department of Agriculture.

Vander Velde E. J. 1991. Performance Assessment in a Large Irrigation system in Pakistan: Opportunities for Improvement at the Distributary Level". In *Proceedings of the Regional Workshop on Improved Irrigation System Performance for Sustainable Agriculture. Organized by FAO 22-26 October,* Baghdad. Rome.

Vermillion D. L, 1995 Irrigation Management Transfer; Towards an Integrated Management Revolution. In Johnson, J. R., Vermillion and J. A. Sagardoy, 1995 Irrigation Management Transfer Selected papers from the International Conference on Irrigation Management Transfer. FAO Water Report N° 5 Rome, Italy.

Vermillion, D. L., 1997. Management Devolution and the Sustainability of Irrigation: Results of Comprehensive Versus Partial Strategies. Presented at the FAO/World Bank Technical Consultation on Decentralization and Rural Development, 16-18 December 1997, Rome.

Vermillion, D.L. and J. A. Sagardoy 1999. Transfer of Management Services, Guidelines. FAO Irrigation and Drainage Paper, 58. Rome: Food and Agricultural Organization of the United Nations.

Vessuri, H., 1972 Tenencia de la Tierra y Estructura Ocupacional en Santiago del Estero. Desarrollo Económico. *Revista de Ciencias Sociales* Vol 12 (46): 351 – 385.

Vessuri, H. M. C. La Expansión Agrícola de la Década del Ochenta. 1972b El Caso de una Región Mediterránea. CIS-UNT, San Miguel de Tucumán, (unpublished).

Vincent L. F. 1995 *Hill irrigation: Water and development in mountain agriculture.* London: Intermediate Technology Publications.

Vincent, L. F. 1996 Irrigation as technology, irrigation as resources: Hill irrigation and natural resource systems. In: Shivakoti, G. Varughese, E. Ostom, A. Shukla and G. Thapa (eds) Proceedings of an International Conference on *People and Participation in Sustainable Development. Understanding the Dynamics of Naturla Resource Systems*. Rampur, Chitwan, Nepal.

Vincent L. F. 1997. Irrigation as a Technology, Irrigation as a Resource: A Sociotechnical Approach to Irrigation. Inaugural Lecture. Wageningen Agricultural University.

Vincent L.F. 1998. Participation Paradigms and Their Prospects to Enhance Production through Improved Irrigation Management. Workshop on People's Participation in Irrigation Systems Management to Enhance Agricultural Production. Directorate of Water Management Research, Patna, India.

Vincent L. F. 2001 *Field and Farm Water Management: Course Introduction*. Study Program 'Tropical Land use'.

Vincent Linden F. 2001. Struggles at the Social Interface: Developing Sociotechnical Research in Irrigation and Water Management. In: P. Hebinck and G. Verschoor (Eds). *Resonances and Dissonances in Development*. Assen, The Netherlands: Royal van Gorcum B.V.: pp 65-82.

Vincent, L. 2001. Water and Rural Livelihoods. Focus 9 (October) IFPRI. Washington D.C. U.S.A.

Vincent, L. 2005 Science, Technology and Agency in the Development of Drought prone Areas: A Cognitive History of Drought and Scarcity. Development Policy and Practice, Technology Faculty, Open University, UK.

Visser S. J. 1996. Canal Water Distribution at the Secondary level in the Punjab, Pakistan: Development of a Simplified Tool to Estimate the Canal Water Distribution at the Distributary Level. Research Report R-10. Pakistan National Program. International Irrigation Management Institute, Lahore.

Vos, J. 2002. *Metric Matters. The Performance and Organization of Volumetric Water Control in Large-scale Irrigation in the North Coast of Peru.* PhD Thesis. Wageningen University, The Netherlands.

Vuren, G. van (ed), 1998. Farmers' Participation in Water Management. Proceedings of the 2nd Netherlands National ICID Day. WU-Kivi-ICID. Rotterdam. The Netherlands.

Wade R. 1988 *Village Republics: Economic Conditions for Collective Action in South India.* South Asian Studies. Cambridge University Press.

Wade R., 1979 A Social Response to Irrigation: An Indian Case Study'. *Journal of Development Studies*, Vol 16(1): 3-26.

Wade Robert. 1990 'On the "Technical" Causes of Irrigation Hoarding Behavior, or why Irrigators Keep Interfering in the Main System'. In: Sampath R.K. and Robert A. Young (ed) *Social, Economic, and Institutional Issues in Third World Irrigation Management*. Studies in Water Policy and Management, No.15 Westview Press, Boulder and London.

Wade, R. 1995. The Ecological Basis of Irrigation Institutions: East and South Asia. *World Development*, Vol 23(12): 2041-2049.

Wahaj, R., 2001 *Farmers' Actions and Iimprovements in Irrigation Performance Below the Mogha. How Farmers Manage Water Scarcity and Abundance in a Large Scale Irrigation System in South-Eastern Punjab, Pakistan.* PhD Thesis, Wageningen University, The Netherlands.

Wahl, T.L., M.G.Bos, J.A. Replogle and A.J. Clemmens, 2000 WinFlume Version 1.03 www.usbr.gov/pmts/hydraulics_lab/winflume

Willardson, L.S., R.G. Allen and H. D. Fredriksen. 1994. Universal Fractions for the elimination of irrigation efficiency. 13th Technical Conference of USCID, Denver, Colorado, USA.

Wilson, B. 2001 *Soft Systems Methodology*. John Wiley & Sons, Ltd. West Sussex, UK.

Winpenny, J. 1994. *Managing Water as an Economic Resource*. London: Routledge.

World Bank, 2005 Electronic Learning Guidebook on Participatory Irrigation Management www.worldbank.org/wbi/pimelg/

Yin, R. K, 1994 *CaseStudy Research. Design and Methods* (Sec. Edition). Applied Social Research Methods Series. SAGE Publications, Inc. California, U.S.A.

Zaag, van P., 1992 *Chicanery at the Canal: Changing Practice in Irrigation Management in Western Mexico*. PhD Thesis. Wageningen Agricultural University, The Netherlands.

SUMMARY

The Rio Dulce Irrigation Project (PRD), with its irrigable area of 120000 hectares, is one of the most important irrigation systems in Argentina. It has contributed more than 40% of the gross agriculture product of Santiago del Estero province for many years and supports the livelihoods of more than 50 % of its population.

Irrigation in the area of the Rio Dulce started before 1900, first through the spontaneous action of local settlers developing local canals for irrigation for local markets. However, political changes and new commercial possibilities since the beginning of the twentieth century brought a succession of public and private impulses to enlarge and modernize the irrigation system. The economic and political importance of the PRD made the system an 'ongoing' project of interventions by provincial and national politics.

Irrigation first evolved in relation to the maximum area cultivable under the unregulated source of Rio Dulce water. Motivated by continuous conflicts between users and its own interventionist policy, the National Government planned its first structured intervention in irrigation during the 1940's. This presumed the development of physical infrastructure to improve water capture and conveyance, and a reorganization of irrigation operations to achieve the objective of maximizing production per unit of water (protective irrigation). While "modern" physical infrastructure was constructed in some parts of the system, the management of the system was never systematically reorganized. Administration continued under the responsibility of the provincial agency, but the area continued its "wild" evolution and operation.

Then a second intervention in the area, the Rio Dulce Project (PRD) was planned as a joint effort of the National and Provincial government after construction of a reservoir by the Federal Government that started its operation in 1966. Its focus was on new water regulation technologies and a broader rural transformation that implied a complete "modernization package". This package included development of the water storage capacity, reallocation of water, direct involvement of a professional national agency in system administration, strong promotion of "modern" irrigation practices and full government extension support to irrigated agriculture production.

This program was truncated by political reasons in 1973-1975 in its early stages, leaving - besides the reservoir - only a partially improved infrastructure for conveyance and distribution of water and a National Agency in charge of system operation, maintenance and management. Since then, the evolution of the project has been shaped first by a progressively unmotivated (in irrigation terms) national agency, and then by a provincial agency from 1992, but also by a heterogeneous group of users and general stakeholders and highly unpredictable incentives set by a changed political and economic context.

Through political and technical negotiations, project representatives have been able to control different interests and threats that would be source of conflicts in many other areas. Large and small farmers, farmers with permanent water rights that do not crop and farmers that crop significant areas with only annual water rights have coexisted without serious conflicts for many years.

The hypotheses behind this thesis are that the relatively conflict-free operational environment in PRD has been possible at a cost to provincial development, through an important underutilization of the irrigation scheme that also involves low water productivity, inefficient and ineffective use of suitable land, loss of economic opportunities, and a high dependency of small farmers on populist policies of both National and Provincial Governments.

This thesis documents the evolution of this in-system diversity and the sociotechnical arrangements, contestation and adaptation that allowed water to keep flowing effectively despite a complex and often chaotic history of public intervention and technological changes. It also examines the motivations and strategies of farmers and agencies, the output (performance) of the system from different points of view, and the 'room for manoevre' to improve irrigation performance of the system.

Chapters 2, 3 and 4 provide the reader with an overview not only of the physical and technical context of the PRD by the time of this research (1999-2001) , but also of the social dynamics characterized by a weak role of the state in irrigation activities in particular and development initiatives in general.

With the main objective to demonstrate how social actors, political and economic context and natural environment have shaped evolution of designed physical systems, Chapter 2 reviews the social construction of irrigation in the area, since beginning of the twentieth century. It describes the changing roles and strategies of the main actors - a heterogeneous set of users with different power and capacities to mobilize resources, the irrigation agencies as independent entities and the provincial and national governments. The historical analysis was useful to understand specific features and institutions present in the PRD that have their roots in early stages of irrigation development in the area and in primitive irrigation practices. In particular Chapter 2 shows that the characteristic social structure of the PRD was made up by large and small farmers. This signified socially a definitive exclusion of many people from the benefits of irrigation and physically the formation of a mosaic pattern of water righted and not water righted areas. The important institution to control head-tailender problems that *tailenders irrigate first* were established in the initial period without any significant role of the state.

The evolution of farmer participation and farmers' organization discourses also shown in Chapter 2 demonstrates that as water availability, water control by physical infrastructure and organization of water distribution improved, at the same time farmers' participation, mobilization and their commitment with water issues decreased from self-mobilization in early stages to passive participation by the end of the 1990s. In parallel with this change, the main topics of debate by farmers' organizations changed from the need for equitable access of small farmers to water to the technocratic demand for better infrastructure.

Chapter 3 also makes an historical overview of the political process of water allocation. It shows that like the infrastructure, water allocation in PRD evolved without a planned project by Federal or Provincial Governments since the beginning of irrigation to the present situation. The chapter highlights how, within this unplanned context, allocation of water has been a continuous contested process across the 100 year period of irrigation development in the area. There has been a negotiated social process subject to political decisions, but shaped by social actors with changing roles and adaptive strategies that reflect the changing context but have a main objective to get as much water as they can.

Within these changing roles, a key determinant for the future development of irrigation was the shared political control over water allocation exercised in the initial period by the Provincial Government in La Cuarteada irrigation system and by the owners of private *acequias*. Most of the people excluded in this period were not seriously reconsidered during either of the two state interventions, that had a common criteria of acknowledging existing water rights up to a maximum area (400 ha) and limited new rights to a maximum area of 50 ha.

Regarding adaptive action, one relevant trend for the development of irrigation has been the generalized adoption by users of a strategy to get water rights for more area than that cropped. This was a response to the positivist technical decisions of the provincial agency, in this case reducing the volume allocated per unit of land during the first important state intervention in the 1950's. This action "kidnapped" water by existing users, which could not be permanently released until present times. It provoked the emergence of PRETA's - a sort of "water banking" system managed by the agency to re-allocate annually any surplus of water. PRETAs have persisted in time and are becoming a permanent institution for water allocation in the area due to their high functionality for the agency and for large farmers- the sub-group of users demanding more water in the last 20 years.
Chapter 4 closes the series of descriptive chapters, describing briefly the main production systems present in the PRD area, the agrarian structure based on official information, the cropping patterns and main agriculture outputs, and crop yields and water productivity based on mean production prices at market places. Eight production systems has been identified in PRD are, however for this research they have been re grouped in two types, the small and familiar production systems and the entrepreneur production systems.

Chapter 5 is the first of the 5 empirical chapters. It describes the infrastructure and water management practices for operation and water distribution in the main system (upstream of tertiary units). Also it presents the main outputs (performance) and the comparative analysis of performance the indicators for the whole PRD system and each of its 8 main secondary canals. The infrastructure for physical water control includes different types of canals, division structures and water measurement structures. It is not the output of a planned intervention but the result of the different irrigation concepts behind the two main modernization interventions. Different design criteria were applied during the last intervention (PRD) and its incomplete implementation. However from the operational point of view the PRD is a gated operated system with diversion structures including gated offtakes and gated cross regulators.

Despite the official fixed rotational full supply water delivery schedule to tertiary and farm units, many features required for a responsive "modern" management of irrigation systems are present. Four independent district offices operate the system from secondary canals downstream; a very high water delivery capacity of most canals confers a relatively high on-line storage capacity; communications among the operational units and even among field staff is excellent, operators live in the area they control, the number of turnouts field officials have to operate is low, their mobility is good and accessibility of turnouts is permanent even in the rainy season. In fact the monthly pattern of canal discharges presented in the chapter indicates that the water delivery schedule has moved away from the official schedule to a more responsive schedule to water demand dictated by the cropping patterns and irrigation practices of users.

Regarding water supply and irrigation adequacy on an annual basis, results support the statement that the PRD is ***"a wet irrigation system in a dry area"***. Mean annual RWS for the

3 years period studied was 1,9, and 2,4 for a longer 20 years period, while RIS were 2,3 and 3,7 for the same periods. Water supply and irrigation adequacy were also high for all of the 8 main secondary canals. However there were rather large differences between them with mean annual RWS and RIS ranging from 1,2 to 2,8 and 1,2 to 4.2 for the period studied.

There is no "tail" effect among the 6 secondary that take water directly from the Matriz canals. However, the two most downstream secondary canals (Sud II and Simbolar) that are fed indirectly from a large canal (Jume Esquina) designed to transfer water from Rio Dulce to Rio Salado showed the lowest values of both indicators. Inter-annual variations were high and daily discharge fluctuations increased along the main canal, suggesting a poorly planned and executed delivery operation, and a mismanagement of diversion structures that have a hydraulic flexibility lower than 1.

Monthly analysis of water supply and adequacy indicators revealed particular features of the local irrigation practices hidden in the annual analysis, that have important consequences for the performance of the system. There is a high concentration of water use in the final months of the dry season (from July to September) with RWS and RIS that reached values as high as 15 or 20 in some canals, and a very low use of irrigation during the rainy season with RWS and RIS close to or even lower than 1. These results, that reflect the predominant cropping pattern and the traditional irrigation practices at farm level, justify the characterization of the PRD as "a wet system in a dry area with dry crops in the wet season".

The empirical Chapters 6 to 9 deal with the study of the 4 sampled tertiary units selected as representative of the most common physical characteristics found within PRD.

Chapter 6 presents the case of the JS tertiary unit, a modernized tertiary unit with modern hydraulic water control and old small farmers' irrigation practices. The modernization package applied in this redesigned tertiary unit included a reduction of its size, a complete modernization of irrigation structures, control delivery discharge and largely improved farmers water acquisition so this was no longer a restrictive production factor but did not change any of the irrigation practices at farm level. The main conclusion is that this modernization package applied and did not reverse the impoverishment process that other political and economical factors imposed over the type of production systems predominating in the area (the number of farmers decreased almost 60%, and there has been a concentration of land and water by more successful local farmers)

Furthermore, the water management at the tertiary unit was reshaped by the users to adapt it to their preferences that include a few heavy irrigation gifts per year. The mean gross irrigation depth per irrigation event has risen to 230 mm (2,6 times greater than the gross official irrigation depth of 90 mm) by increasing up delivery duration to three times the official 50 min/ha. This is possible because the irrigated area per turn is far below the water righted area but also lower than the actual cropped area. In spite of the high use of water in individual events, average annual water use by JS farmers is not more than 60% of the volume allocated to them. This is due to a reduction of cropped area to 57% of the water righted area, and the afore-mentioned farmers' irrigation strategies including few irrigations events in most crops.

Chapter 7 analyzes the case of B1-TTS, a tertiary unit in a newly developed irrigated sub-area created by the PRD, where small farmers from other areas were re-settled in 25 ha parcels. The modernization package, as in JS, included a modern design of tertiary units, irrigation structures and in this case also a modern design of irrigation facilities at farm level. The other main difference from other areas is the implementation of an arranged rotational water delivery schedule. The findings in this area, as in JS, highlight that modernization has not improved water management at either tertiary level or at farm level and it was not able to reverse the impoverishment of the farmers who gradually reduced their cropped area to acreage similar to what they used to crop in their original plots.

The modern irrigation delivery package implemented in B1-TTS was less reshaped by users than elsewhere, because the proposed water delivery schedule and its 'soft' application by field officials brings them flexibility to implement their irrigation preferences. The mean annual water use of 8620 m^3/ha was only 90% of the water allocated to them, but the highest among study areas. On average B1-TTS farmers used only three irrigation events, mainly concentrated in times of pre-seeding of their predominant vegetable crops. The mean discharge delivered, 398 l/s, was 30% greater than the official 300 l/s. Although there was variation during the year and between farms, mean time delivery duration at farm level was 3,3 hr/ha, the greatest among the study areas, and almost 4 times greater than official 50 min/ha. High discharges and long delivery times led to mean gross irrigation depth (327 mm) to be on average 3,6 times greater than the official gross irrigation depth of 90 mm and obviously the greatest amongst the areas studied.

The RS tertiary unit case presented in Chapter 8 is a representative case of modernization of water distribution of an old *acequia,* under control of a heterogeneous group of users. The main differences with the previous cases are that the modernization package applied to this area only included a change in water delivery schedule, and a minimum improvement of delivery structures. There was heterogeneity of production systems coexisting in the area – that ranged from small-family holdings to very large entrepreneur farmers - and a large presence of PRETAs that represented 30% of the Total Water Righted Area in the RS unit in the 2000/2001 growing season.

The main finding in this case showed that, as in previous cases RS farmers have had capabilities to reshape official irrigation schedules to make water distribution more flexible and able to suit their real needs. Actually farmers' irrigation practices are not different from those of farmers in other areas and they do not change in relation to type of farmer or water right status. They present the same contradictory features from the water exploitation perspective. Irrigation strategies were mainly based on high irrigation for pre-seeding and few applications during crop growth, resembling protective irrigation practices. Water is not treated as a scarce resource during water application and, as elsewhere, is a substitute for other less available resources (including capital for land levelling, manpower for a better control of water application, and capital for infrastructural change to control endemic reduction of discharges at the tail of the water course).

Delivery duration in this area was on average 1,8 to 2 times higher than the officially scheduled mean delivery discharge, 487 l/s, the second highest of the study cases. This results in a mean irrigation depth of 291 mm/turn, 2,7 times greater than the official 90 mm/turn. There were no substantial differences in irrigation practice and water use between different types of farmer, or between different positions along the water course (head and tail) and type of water rights. This makes it clear that PRETAs did not lead to a better use of water.

Modernization was also not able in this case to reverse the impoverishment of small farmers who were negatively affected by neo-liberal policies and lack of official support, and not from any struggle around water. The fact that most of them have abandoned agricultural activities has gave room for medium and large farmers to increase their areas, and led to a more intensive concentration of land and water in this area than elsewhere.

Chapter 9 presents the SMFN case. It is representative of entrepreneurial water use in an unmodernised unit. The area with permanent water rights is similar to that of the previous cases studied, but unlike them only 10 large farmers held this. The mosaic pattern of irrigated and non-irrigated areas is still present, since in spite of the large area under permanent water rights, this actually only covers 37% of the gross command area. The availability of land, complemented by the diversified entrepreneurial production systems with high capacity to respond to market incentives, has made the use of PRETAs a frequent tool by which these farmers respond to market demand. These factors have supported steady growth of the irrigated area that reached 1020 ha in the 2000/2001 growing season.

The study showed that this tertiary unit functions more closely than others to official criteria in some aspects. Average annual water used ranges between 80 and 90% of the volume allocated and, unlike other units; cropped area remained close to water righted area. Yet still the users, who apply more water control at farm level, were able to reshape many aspects of water delivery to make it more flexible and highly responsive to their demand.

The official farm irrigation order was mostly the exception rather than the rule in almost all the 20 irrigation turns analyzed. In spite of being one of the *comuneros* at the tail of San Martín secondary canal, discharges delivered during the research period were 1.9 times greater than the official planned discharge, the largest of the 4 studied areas. The delivery duration varied between irrigation turns and farms, but in most cases it was 20- 70% greater than the official duration, yielding a mean annual delivery 1,5 higher than the official one - but the lowest among the study areas. The mean irrigation depth per turn was 257 mm, the second lowest in this study, but still similar to those applied in other areas and almost triple the official gross irrigation depth.

Chapter 10 makes a comparative analysis of the findings on the tertiary units studied and looks for explanatory ideas and causal relations. The analysis based on the calculated performance indicators presents the views of higher level stakeholders on the management of the PRD and allowed many and varied conclusions.

Modern irrigation infrastructure, high water availability and responsive management of the main system to users needs have not been sufficient to guarantee economic development, and/or simply overcome negative effects of open market policies for small farmers. Modern facilities were also not a sufficient condition to improve water management at farm level. Most farmers, including those who applied modern agricultural technologies in their crop production, continue with traditional irrigation practices.

Despite the modern irrigation facilities, including the Rio Hondo reservoir, which assured a monthly irrigation water supply, due the fact that irrigation practices at farm level have not changed too much, farmers do not use more than 30% of the available irrigation turns and basin irrigation is the application method of all of them.

The comparative analysis also showed that in all cases there is a high lack of uniformity in most parameters of water distribution: the frequency of irrigation turns is very different from the official; irrigation order is frequently changed within the tertiary units especially by *administradores;* the mean delivery duration and delivery discharge are 2,2 hrs and 396 l/s with a variation coefficient of 43 and 41 % respectively while the mean irrigation depth per irrigation event is 275 mm and its variation coefficient only 15% due a high compensation of delivery duration and discharge. Due to the low number of irrigations during the year, the mean annual water use (781 mm/year) remained below the water-righted volume, despite the heavy individual applications.

Regarding water supply and irrigation adequacy, results from the 4 units studied showed a similar annual and monthly pattern to the whole project and secondary canals. There are variations between the studied units but the RWS and RIS performance indicators indicate that all of them are, on an annual base well-wetted - irrespective of infrastructure, production systems, predominant crops and homogeneity of users. Monthly results were also similar to upstream sections of the system; with high peak of water use from July to November confirms the high influence of irrigation practices on secondary canals (subsystems) and system performance.

Chapter 11 explores alternative approaches to irrigation performance assessment from agency officials and user visions, and it enquires into the environmental impact of the PRD's outputs on system (mainly soil salinity) and on river basin water use. Alternative assessments of system performance from agency and user perspective revealed their high satisfaction with outputs, and different understandings of some of the classic assessment parameters such as adequacy, timeliness and equity.

The present and former irrigation agencies have used the number of user complaints as a unique, explicit and powerful indicator to internally assess their performance, and to keep them as low as possible as their main targets. This has led them to be highly responsive to users, incorporating flexibility in water delivery - a core element of the modern irrigation system operation – as a logical consequence of this pragmatic management and not as a reflexive decision based on a planned intervention. At the same time this responsive behaviour of the agency gives users strong opportunities to influence the way water is delivered in the system. In practice the relatively high water availability in relation to the cropped area has been a key determinant to achieve these goals (and support the high satisfaction with the agency) in spite of their low technical skills.

Farmers' satisfaction with system performance is also high. It is highly related to the full coverage of their low water requirements stemming from their water management practices rooted in "protective" irrigation principles and their preferences in terms of the way water is delivered to their farms.

In relation to salinity hazard the PRD has been synonymous with secondary salinity in the Argentinean irrigation sector. That the local irrigation practices characterized by a few but concentrated heavy water applications produce a rise of water table and an active process of secondary salinization would not be a surprising conclusion. However the particular feature in the PRD is that the mosaic pattern of irrigated and non-irrigated lands, a product of negotiated water allocation process, gave the non-irrigated area (that is almost 60% of the command area) the unplanned role of being the salt sink within the PRD. Therefore this process affecting non-irrigated area within the command area has also increased the negative effects on these landowners also affected by the early exclusion from irrigation, and represents a high cost for provincial development.

At the same time, the use of water by natural vegetation over the large areas of non-irrigated land greatly increases the non-beneficial use of irrigation water and reduces to a minimum the expected return flow, and is making the PRD a closed irrigation system. This feature should be seriously considered in future interventions and in planning water management at basin level.

Chapter 12 closes the thesis with a review of the questions and a framework developed in this research study and its main conclusions, and gives a brief discussion of topics that should be in the agenda for any new cycle of modernization in the PRD.

The conclusions cover a large number of topics but highlight the pragmatic character of the evolutionary path of PRD; the de-coding of modernization interventions by local actors to provide their real requirements, including persistence of traditional practices in modernized areas; and the adaptive management of the irrigation agency to become close to the service approach of the "modernization" package without use of any of the proposed performance indicators proposed by the literature. Also, it notes the usefulness of comparative indicators used on monthly base to unmask the diversity within large irrigation systems. At the larger scale, the study stresses the changing role that irrigation has had in the area as a social force for development, and as a cause of social exclusion and social differentiation.

The chapter stresses that the PRD case should be useful to show that a new round of modernization of PRD - and any other large irrigation system - should find new ways to work and provide differentiated services for this diversity. Therefore we should necessarily think of the next round of modernization as UNA TAREA DE TODOS (A COLLECTIVE ACTION).

SAMENVATTING

Het "Rio Dulce Irrigatie Project" (PRD), met 120.000 hectare irrigeerbare landbouw, is een van de meest belangrijke irrigatiesystemen in Argentinië. Het heeft al vele jaren meer dan 40% bijgedragen aan de bruto landbouwproductie van de provincie Santiago del Estero en ondersteunt in het levensonderhoud van meer dan 50% van de bevolking.

In het gebied van de Rio Dulce ('zoet water rivier') is irrigatie al vóór 1900 begonnen, in eerste instantie door spontane acties van lokale kolonisten die kleine kanalen voor irrigatie aanlegden voor de lokale markt. Echter, in het begin van de 20ste eeuw brachten politieke veranderingen en nieuwe commerciële mogelijkheden een groot aantal publieke en private impulsen om het irrigatiesysteem te vergroten en te moderniseren. Het economische en politieke belang van de PRD maakt het systeem een doorlopend project van interventies door de provinciale en nationale politiek.

Irrigatie ontwikkelde tot het maximale bebouwbare gebied onder een niet-gereguleerde afname van water uit de Rio Dulce. De nationale overheid plande, gemotiveerd door een doorlopende strijd tussen watergebruikers en haar interventiepolitiek, de eerste gestructureerde interventie in irrigatie gedurende de jaren 1940. Deze interventie hield in dat de fysieke infrastructuur werd ontwikkeld met doel zoveel mogelijk water van de rivier af te tappen en te transporteren. Daarnaast werd het irrigatie beheer gereorganiseerd met als doel een maximale opbrengst te verkrijgen per eenheid water (beschermende irrigatie). In sommige delen van het irrigatiesysteem werd "moderne" fysieke infrastructuur aangelegd, maar het beheer van het systeem werd nooit systematisch gereorganiseerd. Het systeem viel nog steeds onder de administratie van de provincie, en het irrigatiegebied ging verder met de "wildgroei" in ontwikkeling en beheer.

Een tweede reorganisatie in het gebied van het "Rio Dulce Irrigatie Project" werd gepland door de nationale en provinciale overheid na de aanleg door de federale overheid van een dam en stuwmeer in 1966. Aandachtspunten van deze interventie waren gericht op nieuwe waterregelende technologieën en een bredere rurale transformatie dat werd gezien als een geheel 'modernisatie pakket'. Dit pakket bevatte verdere ontwikkeling van wateropslagcapaciteit, herverdeling van water, directe betrokkenheid van een professionele nationale instantie voor het systeembeheer, sterke promotie van 'moderne' irrigatiepraktijken en volledige ondersteuning door overheidsvoorlichting aan geïrrigeerde landbouwproductie.

Vanwege politieke redenen tussen 1973 en 1975 werd dit programma in een vroeg stadium afgebroken. Naast het aangelegde stuwmeer was er slechts een gedeeltelijk verbeterde infrastructuur voor watertransport en –verdeling en een nationale instantie die het systeem beheerde, onderhield en te werk stelde. Vanaf die tijd wordt de ontwikkeling van het project gekenmerkt door een steeds minder gemotiveerde (wat betreft irrigatie beheer) nationale instantie - vervolgens vanaf 1992 een provinciale instantie -, maar ook door een zeer wijd verspreide groep water gebruikers en algemene belangenhouders en hoogst onvoorspelbare prikkels vanuit een veranderende politiek en economisch klimaat.

Projectvertegenwoordigers waren in staat om, door politieke en technische onderhandelingen, de verschillen in belangen en dreigingen te controleren die een bron van conflict waren in andere gebieden. Grote en kleine boeren, boeren met permanente waterrechten maar zonder landbouwproductie en boeren die produceerden met slechts jaarlijks toegewezen

waterrechten hebben vele jaren samen in één irrigatiesysteem geleefd zonder noemenswaardige botsingen.

De hypothese van dit proefschrift is dat het relatieve gebrek aan botsingen in de operationele omgeving van het PRD alleen mogelijk zijn geweest ten koste van provinciale ontwikkeling door een belangrijk ondergebruik van het irrigatiesysteem, resulterend in lage waterproductiviteit, inefficiënt en ineffectief gebruik van vruchtbaar land, verlies van economische mogelijkheden, en een grote afhankelijkheid van kleine boeren op populistische politiek van zowel de nationale als de provinciale overheid.

Dit proefschrift documenteert de ontwikkeling van de diversiviteit in het systeem, de sociaal-technische regelingen, aanvechtingen en aanpassingen die er aan toe hebben gedragen dat water effectief bleef stromen, ondanks een complexe en vaak chaotische geschiedenis van publieke interventies en technologische veranderingen. Het bestudeert ook de motivatie en strategieën van boeren en instanties, de productie (prestatie) van het systeem vanuit verschillende invalshoeken, en de graad van vrijheid om de irrigatieproductie van het systeem te verbeteren.

Hoofdstukken 2, 3 en 4 verschaffen de lezer een overzicht van niet alleen de fysieke en technische context van het PRD voor de periode van dit onderzoek (1999-2001), maar ook de sociale dynamiek die gekarakteriseerd wordt door een zwakke rol van de overheid in irrigatieactiviteiten in het bijzonder en ontwikkelingsinitiatieven in het algemeen.

Hoofdstuk 2 neemt de sociale constructie van irrigatie in het gebied in ogenschouw vanaf het begin van de 20ste eeuw, met als belangrijkste doel om aan te tonen hoe sociale spelers, politieke en economische context en natuurlijke omgeving de ontwikkeling van een bestaand fysiek systeem hebben gevormd. Het beschrijft de veranderende rol en strategie van de belangrijkste spelers – een wijd verspreide groep watergebruikers met verschillende invloeden en capaciteiten om middelen te mobiliseren, de irrigatieinstanties als onafhankelijke eenheden en de provinciale en nationale overheden. Deze historische analyse helpt om specifieke kenmerken en instituten te begrijpen die zich binnen het PRD bevinden en hun wortels hebben in het vroege stadium van irrigatieontwikkeling en primitieve irrigatiepraktijken in het gebied. Zeer van belang in hoofdstuk 2 is dat de karakteristieke sociale structuur van het PRD bestond uit zowel kleine als grote boeren. Door deze tweedeling ontstond er fysiek gezien binnen het PRD een mosaicpatroon van velden met en zonder irrigatie rechten. Sociaal gezien ontstond er daardoor ook voor velen een uitsluiting van de voordelen van irrigatie. Het klassieke 'head-tail' probleem in irrigatie, waarbij velden aan het begin van een irrigatiekanaal betere toegang tot water hebben dan de velden aan het eind van een kanaal, werd al vroeg opgelost door het principe "tailenders irrigate first" (velden aan het eind van het kanaal krijgen als eerste de beurt om te irrigeren). Dit principe werd toegepast zonder noemenswaardige rol van de overheid.

De ontwikkeling van boerenparticipatie en verhandelingen van boerenorganisaties, ook beschreven in hoofdstuk 2, laat zien dat wanneer waterbeschikbaarheid, controle over water door fysieke infrastructuur en de organisatie van water verdeling verbetert, tegelijk ook de boerenparticipatie, mobilisatie en hun betrokkenheid bij watergerelateerde onderwerpen vermindert, veranderend van zelf-mobiliserend in de eerdere periodes tot passieve participatie tegen het einde van de jaren '90. Parallel aan deze processen ontstond er een verandering van discussieonderwerpen door boerenorganisaties, namelijk van de noodzaak voor een rechtvaardigere toegang tot water voor kleine boeren naar de technokratische vraag om een betere infrastruktuur.

Hoofdstuk 3 geeft een historische beschrijving van het politieke proces van waterverdeling. Het toont aan dat, net als de infrastruktuur, waterverdeling binnen het PRD ontwikkelde zonder planning van de nationale of provinciale overheid in de gehele periode tussen het begin van irrigatie en de huidige situatie. Het hoofdstuk belicht hoe, zonder planning, waterverdeling is een continue bevochten proces gedurende de 100 jaar van irrigatieontwikkeling in het gebied. Het sociale proces van onderhandelingen werd gestimuleerd door politieke besluiten, maar werd beheerst door sociale spelers met veranderende rollen en aanpassende strategieën die de veranderende context weergaven, maar altijd gericht waren op het verkrijgen van zoveel mogelijk water.

Binnen alle veranderingen bleef de politieke controle over waterverdeling een belangrijke factor voor de toekomstige ontwikkelingen van irrigatie. Deze controle werd in het begin uitgeoefend door de provinciale overheid in het Cuarteada irrigatie systeem, en door de eigenaren van private veldkanalen (*acequias*). De meeste boeren die tijdens deze periode geen waterrechten ontvingen werden ook in een later stadium, tijdens een van de twee overheidsinterventies niet serieus heroverwogen. Deze interventies hadden een gedeeld criterium waarin bestaande waterrechten tot een maximum van 400 hectare werden erkend, en een beperkt aantal nieuwe waterrechten werden toegekend tot een maximum van 50 hectare.

Een relevante trend in de irrigatieontwikkeling en goed voorbeeld van aanpassend gedrag is de algemeen gebruikte strategie van watergebruikers om waterrechten te verkrijgen voor een groter areaal dan wat wordt bebouwd. Dit ontstond als reactie op een bepaalde technische beslissing van het provinciale instituut, in dit geval tijdens de eerste belangrijke overheidsinventie in de 50'er jaren om het volume toebedeelde water per eenheid land te verlagen. Bestaande gebruikers 'ontvoerden' water met dit gedrag en tot recent was het water nog niet vrij beschikbaar. Het veroorzaakte de verschijning van PRETA's – een soort "water bank" systeem dat wordt beheerd door het instituut om jaarlijks het overschot van water te herverdelen. PRETA's volhardde in de tijd en zijn een permanent instituut voor waterherverdeling aan het worden in het gebied, omdat ze zeer functioneel zijn voor het provinciale instituut en voor grote boeren – de subgroep van watergebruikers die in de afgelopen 20 jaar om meer water hebben gevraagd.

Hoofdstuk 4 is het laatste in de serie van beschrijvende hoofdstukken. Het beschrijft kort de belangrijkste productiesystemen die aanwezig zijn binnen de PRD, de agrarische structuur gebaseerd op officiele informatie, de gewaspatronen en belangrijkste landbouwprodukten, en gewasopbrengsten en waterproductiviteit gebaseerd op gemiddelde productieprijzen op de markt. Acht productiesystemen worden geïdentificeerd in het gebied van de PRD, maar zijn voor dit onderzoek hergroepeerd in twee typen, de kleine en familie productiesystemen en de grotere ondernemingsproductiesystemen.

Hoofdstuk 5 is het eerste van vijf empirische hoofdstukken. Het beschrijft de infrastruktuur en waterbeheersmaatregelen voor dagelijks gebruik en waterverdeling in het hoofdsysteem (bovenstrooms van de tertiare eenheden). Het toont ook de belangrijkste productie (prestatie) en de vergelijkende analyse van prestatie indicatoren voor het gehele PRD systeem en elk van haar acht belangrijkste secondaire kanalen. De infrastructuur voor fysieke watercontrole bevat verschillende types kanalen, verdeel- en meetwerken. Dit is niet het gevolg van georganiseerde interventies, maar het resultaat van verschillende irrigatieconcepten die gebruikt werden tijdens de twee modernisatieinterventies. Verschillende ontwerpcriteria werden toegepast tijdens de laatste interventie en de (incomplete) implementatie. Echter, vanuit een beheersstandpunt gezien is het PRD een 'gate' systeem met verdeelwerken dat 'gate' aftakkingen en 'gate' kruisregelaars bevat.

Ondanks dat officieel een vast rotatiesysteem voor volledige waterlevering aan tertiare en farm eenheden bestaat, zijn veel onderdelen die nodig zijn voor een flexibel 'modern' irrigatiebeheer wel aanwezig. Vier onafhankelijke districtkantoren beheren het systeem vanaf het secundaire niveau; een erg hoge waterleveringscapaciteit van de meeste kanalen betekent dat een relatief hoge opslagcapaciteit van water aanwezig is; er is een zeer goede communicatie tussen het operationele personeel en zelfs tussen het veldpersoneel; operationeel personeel woont in het gebied dat ze controleren, er is een relatief kleine hoeveel inlaten die veldwerkers hoeven te beheren, ze zijn erg mobiel en de toegang tot de inlaten is goed, zelfs tijdens de natte periode. Het maandelijkse patroon van kanaaldebieten dat in dit hoofdstuk wordt besproken geeft in feite aan dat het waterleveringsschema veranderd is van het officiele patroon naar een meer flexibel schema dat meer vraaggericht gestuurd wordt door de gewaspatronen en irrigatiemethoden van de gebruikers.

Als de waterbeschikbaarheid en irrigatienauwkeurigheid op een jaarlijks interval wordt geevalueerd kan verklaard worden dat de PRD "*een nat systeem in een droog gebied*" is. De gemiddelde jaarlijkse indicator 'relatieve water beschikbaarheid' (RWS) voor de 3 jaren van deze studie was 1,9, en een 20 jarig gemiddelde geeft een waarde van 2,4. The indicator 'relatieve irrigatiewater beschikbaarheid' (RIS) was respectivevelijk 2,3 en 3,7 voor deze twee perioden. Waterbeschikbaarheid en irrigatienauwkeurigheid waren ook hoog voor alle 8 belangrijkste secondaire kanalen. Er waren echter grote verschillen onderling, met de gemiddelde jaarlijkse RWS variërend tussen 1,2 en 2,8 en de gemiddelde jaarlijkse RIS variërend tussen 1,2 en 4,2 for de bestudeerde periode.

Er is geen "tail" effect (minder water aan het einde van het kanaal) bij de zes kanalen die hun water direct betrekken van het hoofdkanaal Matriz. Echter, de twee meest benedenstroomse secundaire kanalen (Sud II en Simbolar) die indirect vanuit een groot kanaal gevoed worden (Jume Esquina), dat ontworpen was om water te transporteren tussen de Rio Dulce en de Rio Salado, lieten de laagste waarden van de twee indicatoren zien. Variaties binnen het jaar waren hoog en dagelijkse debietfluctuaties nemen toe langs het hoofdkanaal, wat een indicatie is van slecht gepland en uitgevoerd leveringsbeheer. Slecht beheer van verdeelweken lijkt ook voor te komen, met hydraulische flexibiliteitswaarden van minder dan 1.

Maandelijkse analyses van de waterbeschikbaarheid en irrigatienauwkeurigheid tonen een aantal speciale eigenschappen van lokale irrigatiemethoden die verborgen blijven in de jaarlijkse analyse, maar die een belangrijke invloed hebben op de irrigatieprestatie van het systeem. In de laatste maanden van het droge seizoen (van Juli tot en met September) is er een hoge dichtheid van watergebruik, met RWS en RIS indicaties van 15 of zelfs 20 in sommige kanalen. Tijdens de natte periode is er weinig gebruik van irrigatie met RWS en RIS waarden in de buurt van, en soms lager dan 1. Deze resultaten, die een reflectie zijn van het belangrijkste gewaspatroon en de traditionele irrigatiemethoden op het boerenbedrijf, ondersteunen de stelling dat het PRD een "nat systeem in een droog gebied met een droog gewas in het natte seizoen" is.

De empirische hoofdstukken 6 tot en met 9 behandelen de studie van vier in detail bestudeerde tertiaire eenheden, die geselecteerd zijn als representatief voor de meest algemene fysieke karakteristieken die in het PRD gevonden kunnen worden.

Hoofdstuk 6 behandelt het geval van de JS tertiaire eenheid. Dit is een gemoderniseerde tertiaire eenheid met moderne hydraulische waterwerken en oude kleinschalige irrigatiemethoden. Het modernisatiepakket dat toegepast werd in deze herontworpen eenheid bevatte een vermindering van het areaal, een komplete vernieuwing van de irrigatiewerken, gecontroleerde leveringsdebieten en grotendeels verbeterde wateraanvragen door de boeren. Dit was daardoor niet langer de beperkende productiefactor, maar veranderde niets aan de bestaande irrigatiemethoden op het niveau van het boerenbedrijf. De belangrijkste conclusie is dat dit modernisatiepakket werd toegepast, zonder dat dit het verarmingsproces kon keren dat door politieke en economische factoren werd veroorzaakt voor het belangrijkste productiesysteem in het gebied (het aantal boeren nam met bijna 60% af, en de meer succesvolle lokale boeren konden land en water aan hun bedrijf toevoegen).

Het waterbeheer op tertiair niveau werd door de watergebruikers aangepast naar hun voorkeur voor een klein aantal grote hoeveelheden water per irrigatiebeurt. De gemiddelde bruto waterdiepte per irrigatiebeurt is verhoogd naar 230 mm (2,6 keer hoger dan de officiele bruto irrigatiediepte van 90 mm) door middel van een verlenging van de leveringstijd van drie keer de officiele leveringstijd van 50 minuten per hectare. Dit is alleen mogelijk omdat het bevloeide areaal per irrigatiebeurt kleiner is dan het areaal waar waterrechten voor bestaan, en zelfs kleiner dan het werkelijk bebouwde areaal. Ondanks het hoge watergebruik per individuele irrigatiebeurt bedraagt het gemiddelde jaarlijkse waterverbruik in de JS eenheid niet meer dan 60% van het totaal toegewezen volume. Dit hangt onder andere samen met een verkleining van het bebouwde areaal tot 57% van het areaal waar waterrechten voor bestaan, en de bovengenoemde irrigatiestrategie om weinig irrigatiebeurten te gebruiken in de meeste gewassen.

Hoofdstuk 7 analyseert het geval van B1-TTS, een tertiaire eenheid in een nieuw ontwikkeld irrigatie sub-gebied, ontwikkeld binnen het PRD waar kleine boeren van andere gebieden werden herplaatst op 25 ha percelen. Het modernisatiepakket, gelijk aan het JS gebied, bevatte een modern ontwerp van tertiaire eenheden, irrigatiewerken en in dit geval ook een modern ontwerp van de irrigatiefaciliteiten op het veldniveau. Het andere belangrijkere verschil met andere gebieden is dat een van te voren vastgelegde irrigatierotatie werd geïmplementeerd. De resultaten van dit gebied, net als in JS, tonen dat modernisatie het waterbeheer op tertiair niveau of veldniveau niet heeft verbeterd. Het was ook niet in staat om de verarming van de boeren te keren. Deze boeren keerden, door een verkleining van het bebouwde areaal, langzaam terug naar het areaal dat ze verbouwden op hun originele locatie vóór herplaatsing.

Het moderne waterleveringspakket dat geïmplementeerd werd in B1-TSS werd minder hervor*md* door de gebruikers dan elders, omdat het voorgestelde waterleveringsschema en de 'zachte' aanpak door veldwerkers hen al de flexibiliteit gaf om hun irrigatievoorkeuren ten uitvoer te brengen. Het gemiddelde jaarlijkse watergebruik van 8620 m^3/ha was slechts 90% van het water dat aan dit gebied was toegewezen, maar wel het hoogste watergebruik van alle studiegebieden. Gemiddeld gebruiken de boeren in B1-TTS drie irrigatiebeurten, voornamelijk geconcentreerd in de tijd voor zaaien van hun groentengewassen, wat het belangrijkste gewas is. Het gemiddelde debiet dat geleverd werd (398 liter/sec) was 30% hoger dan het officiële debiet van 300 liter/sec. Ook al was er een variatie gedurende het jaar en tussen boeren, de gemiddelde tijdsduur van irrigatie op veldniveau was 3,3 uur per hectare. Dit is de langste irrigatieduur van de studiegebieden, en bijna vier keer groter dan de officiële 50 minuten per hectare. Hoge debieten en lange leveringstijd leiden tot een gemiddelde bruto irrigatiediepte (327 mm) die 3,6 keer groter is dan de officiele diepte van 90 mm, en veruit de grootste binnen de bestudeerde gebieden.

De zaak van de RS tertiaire eenheid wordt beschreven in hoofdstuk 8 en is een representatief geval van modernisatie van waterverdeling binnen een *acequia*, die gecontroleerd wordt door een heterogene groep watergebruikers. Het belangrijkste verschil met de vorige gevallen is dat het modernisatiepakket van toepassing op dit gebied alleen een verandering van irrigatiewaterlevering bevatte, en slechts een minimale verbetering van waterwerken. Er was een heterogeen productiesysteem in dit gebied, waarin kleine familiebedrijven en zeer grote ondernemingen samen bestonden, en een grote aanwezigheid van PRETA's die 30% van het totale gebied met waterrechten vertegenwoordigde binnen de RS eenheid in het 2000-2001 groeiseizoen.

De belangrijkste conclusies in dit geval laten zien dat, zoals in de vorige beschrijvingen, boeren van het RS gebied de mogelijkheid hadden om officiele irrigatierotaties te hervormen en waterverdeling flexibeler te maken om aan hun eisen te voldoen. Het blijkt dat de irrigatiepraktijken niet anders zijn dan van boeren in andere gebieden, en de praktijken veranderen ook niet in relatie met het type bedrijf, of status van waterrechten. Dezelfde tegenstrijdige eigenschappen komen tevoorschijn vanuit een water exploitatie perspectief. Irrigatiestrategie was voornamelijk gebaseerd op een grote irrigatiegift voor het zaaien, en weinig giften gedurende de gewasontwikkeling, wat overeenkomt met beschermende irrigatiepraktijken. Water wordt niet beschouwd als een schaars goed tijdens watergiften, en, zoals in andere gebieden, wordt gebruikt als een vervanging van andere minder beschikbare middelen (onder andere geld voor landegalisatie, mankracht voor een beter controle van watergiften, en geld voor aanpassingen aan de infrastructuur om de endemische reducties van debieten aan het eind van het kanaal tegen te gaan).

De duur van de waterlevering in het gebied was gemiddeld 1,8 tot 2 keer hoger dan het officiële geplande gemiddelde leveringsdebiet (487 liter per seconde), de tweenahoogste van alle studies in dit onderzoek. Dit resulteerde in een gemiddelde irrigatiediepte van 291 mm per irrigatiegift, 2,7 keer hoger dan de officiële 90 mm per gift. Er waren geen substantiële verschillen in irrigatiemethoden en watergebruik tussen verschillende type bedrijven, noch tussen verschillende locaties aan het kanaal ('head' en 'tail' van het kanaal) of verschil in waterrechten. Hieruit kan geconcludeerd worden dat PRETA's niet tot beter gebruik van water leiden.

Modernisatie leidde in dit geval ook niet tot een terugdringing van de verarming van de kleine boeren, wat een gevolg was van neo-liberale politiek en een gebrek aan officiële ondersteuning, niet een gevolg van strijd om water. Het feit dat de meeste van de arme boeren hun landbouwactiviteiten opgegeven hebben resulteerde in een vergroting van het areaal voor gemiddelde en grote boeren. Dit leidde tot een intensievere concentratie van land en water in dit gebied dan in andere gebieden.

Hoofdstuk 9 beschrijft het geval van SMFN. Dit gebied is een representatie van ondernemend watergebruik in een niet-gemoderniseerde eenheid. Het areaal met permanente waterrechten is vergelijkbaar met dat van eerder beschreven gebieden, waarbij het grote verschil is dat deze waterrechten in handen zijn van slechts 10 boeren. Desondanks is het gebied nog steeds verdeeld in een mosaicpatroon van velden met en velden zonder permanente waterrechten. Het gebied met permanente waterrechten beslaat slechts 37% van het bruto irrigatiegebied. De beschikbaarheid van land, gecombineerd met de diversiteit van ondernemende productiesystemen die een grote capaciteit hebben om te reageren op marktprikkels, hebben de PRETA's gemaakt tot een regelmatig gebruikt middel waarmee de boeren op marktvragen kunnen reageren. Deze factoren hebben gestage groei ondersteund van het geïrrigeerde areaal dat de 1020 hectare bereikte in het 2000/2001 groeiseizoen.

De studie laat zien dat deze tertiare eenheid op een aantal aspecten meer dan andere eenheden de officiële criteria volgt. Gemiddeld jaarlijks watergebruik varieert tussen 80 en 90% van het toegewezen water en, verschillend van de andere tertiaire eenheden, het gebied onder gewas blijft dicht bij het gebied dat officieel toegewezen waterrechten heeft. Toch waren de gebruikers, die een hoge mate van water controle op veldniveau hebben, in staat om veel aspecten van waterlevering om te zetten naar een flexibel systeem dat beantwoordt aan de vraag.

De officiëel toegewezen waterhoeveelheid was meer uitzondering dan regel in bijna alle 20 irrigatiebeurten die geanalyseerd zijn. Aan het eind van het San Martin secundaire kanaal werden debieten geleverd tijdens de onderzoeksperiode die 1.9 keer groter waren dan de officieël geplande hoeveelheden, ondanks dat het veld in eigendom was van de '*comuneros*' (kanaalwater beheerder) zelf. De geleverde hoeveelheden varieerden tussen irrigatiebeurten en bedrijven, maar waren in de meeste gevallen 20-70% hoger dan de officiële irrigatieduur. Dit kwam neer, voor de SMFN eenheid, op een gemiddelde jaarlijkse levering die 1,5 keer hoger was dan de officiële levering. Dit was de laagste van de bestudeerde tertiaire eenheden. De gemiddelde irrigatiediepte per irrigatiebeurt was 257 mm, de tweede laagste in de studie, maar vergelijkbaar met de diepte die toegepast werd in andere gebieden, en bijna drie keer de officieel toegekende irrigatiediepte.

Hoofdstuk 10 bevat een vergelijkende analyse van de resultaten van alle teriaire eenheden die bestudeerd zijn en zoekt naar verklarende ideeën en verbanden. De analyse gebaseerd op de berekende productie-indicatoren toont de inzichten van belanghebbenden op hoog niveau op het beheer van PRD. Dit geeft mogelijkheden tot veel en zeer gevarieerde conclusies.

Moderne irrigatieinfrastructuur, grote hoeveelheden waterbeschikbaarheid en een aan de gebruikersvraag beantwoordend beheer van het hoofdsysteem waren niet voldoende om economische ontwikkeling te garanderen, of om de negatieve effecten van een open markt beleid op kleine boeren te overkomen. Moderne faciliteiten waren ook niet voldoende om waterbeheer te verbeteren op bedrijfsniveau. De meeste boeren, inclusief zij die moderne landbouwtechnieken toepassen in de gewasproductie, vervolgen hun traditionele irrigatiepraktijken.

Ondanks de moderne irrigatiefaciliteiten, inclusief het reservoir "Rio Hondo", dat een maandelijkse irrigatiewaterhoeveelheid garandeerde omdat irrigatiepraktijken niet al te veel zijn veranderd, gebruiken boeren niet meer dan 30% van de irrigatiebeurten en is basinirrigatie de methode die ze toepassen.

De vergelijkbare analyse laat ook zien dat in alle gevallen een groot gebrek aan uniformiteit bestaat van de meeste irrigatieparameters. De frequentie van irrigatiebeurten is erg verschillend van de officiële frequentie; de rotatie van irrigatie binnen een tertiaire eenheid wordt vaak veranderd, vaak door de 'administradores'; de gemiddelde leveringsduur en debieten zijn 2,2 uur en 396 liter per seconde, met een varietiecoëfficient van 43% en 41%, terwijl de gemiddelde irrigatiehoeveelheid 275 mm is, met een variatiecoëfficient van slechts 15%. De lage variatiecoëfficient is een gevolg van het compenseren van irrigatieduur en debiet. Als gevolg van het lage aantal irrigatiegiften per jaar blijft het gemiddelde jaarlijkse waterverbruik (781 mm) onder het volume waar waterrechten voor afgegeven zijn, ondanks de grote individuele irrigatiegiften.

De resultaten van de vier studies lieten ook zien dat er vergelijkbare jaarlijkse en maandelijkse patronen bestaan voor de waterbeschikbaarheid en irrigatienauwkeurigheid voor het gehele project en voor de secundaire kanalen. Er zijn variaties tussen de bestudeerde eenheden, maar de relatieve waterbeschikbaarheid en de relatieve irrigatiewater beschikbaarheid geven aan dat alle eenheden op jaarbasis goed nat zijn, onafhankelijk van infrastructuur, productiesysteem, voornaamste gewas of de homogeniteit van de gebruikers. Maandelijkse resultaten waren ook vergelijkbaar met resultaten verkregen in bovenstroomse secties van het systeem, met een hoog watergebruik van juli tot november. Dit bevestigt de grote invloed van irrigatiepraktijken op het veld en tertiair niveau op het beheer van de secundaire kanalen en het hoofdsysteem.

Hoofdstuk 11 onderzoekt de alternatieve aanpakken voor irrigatieproductie evaluaties vanuit het gezichtspunt van instituten en gebruikers. Tevens onderzoekt het PRD's effect op het milieu, voornamelijk bodemverzouting, en op het stroomgebied. Alternatieve manieren om systeemproduktie te evalueren van het perspectief van instituten en gebruikers laat zien dat ze uitkomsten zeer waarderen, en dat er verschillen in interpretatie zijn van klassieke indicatoren zoals nauwkeurigheid, precisie in tijd en equity.

De huidige en vorige irrigatie-instituten hebben het aantal gebruikersklachten als de enige, expliciete en krachtige indicator gebruikt om hun productiviteit te meten. Het voornaamste doel van de instituten was om het aantal klachten tot een minimum te beperken. Hierdoor werden ze zeer klantvriendelijk, en werd flexibiliteit in waterlevering – een belangrijk element van moderne irrigatie systemen – een logisch gevolg van deze pragmatische benadering, en niet van een weloverwogen besluit tot geplande interventie. Tegelijkertijd geeft dit beleid de gebruikers een krachtige mogelijkheid om de manier waarop het water wordt geleverd in het systeem te beïnvloeden. In de praktijk werd een hoge waterbeschikbaarheid ten opzichte van het bebouwde areaal een belangrijke determinant om dit doel te bereiken (en om een grote waardering voor het instituut te verkrijgen), ondanks de lage vaardigheden.

Waardering van de boeren met de productiviteit van het systeem is ook hoog. Dit is zeer gerelateerd aan de volledige levering van hun lage waterbehoefte gerelateerd aan hun waterbeheer onder de principes van "verzekerende" irrigatie, en hun voorkeur over de manier waarop water geleverd wordt.

In relatie tot verzouting staat het PRD synoniem met secundaire verzouting binnen de Argentijnse irrigatiesector. Het is ook geen verrassende conclusie dat de hoge individuele irrigatiegiften resulteren in een ondieper grondwaterniveau en dus een actief secundair verzoutingsproces. Echter, het specifieke element dat het PRD een mosaicpatroon van velden heeft die afwisselend geïrrigeerd zijn en niet-geïrrigeerd, als gevolg van de onderhandelingen in het waterverdelingsproces, heeft er toe geleid dat het niet-geïrrigeerde gebied ongewild als zoutopslag gebruikt wordt binnen het PRD. Dit proces heeft negatieve effecten op de landeigenaren binnen het PRD, die ook al negatief beïnvloed waren door de uitsluiting van irrigatie, en resulteert in hoge kosten voor de provinciale ontwikkeling.

Tegelijkertijd wordt het non-beneficiële gebruik van irrigatiewater vergroot door de waterconsumptie van natuurlijke begroeiing die op de niet-geïrrigeerde gebieden staan. Dit heeft weer tot gevolg dat afvloeing uit het PRD tot een minimum is gereduceerd, en dat het PRD dus een gesloten irrigatiesysteem is. Deze eigenschap moet serieus meegenomen worden in toekomstige interventies en in de planning van waterbeheer op stroomgebied niveau.

Hoofdstuk 12 sluit dit proefschrift met een review van de vragen van het raamwerk dat binnen deze studie ontwikkeld is, en de belangrijkste conclusies. Het geeft ook een korte discussie op onderwerpen die op de agenda gezet moeten worden voor een nieuwe ronde van modernisatie in het PRD.

De conclusies omvatten een groot aantal onderwerpen maar richten zich op het pragmatische karakter van het evolutionaire pad van PRD, het ontrafelen van modernisatie interventies door lokale betrokkenen om hun werkelijke noodzaak te analyseren, inclusief de vasthoudendheid aan traditionele irrigatiepraktijken in gemoderniseerde gebieden; en het aangepaste beheer van de irrigatie-instituten om zo dicht mogelijk de service te benaderen van een modernisatiepakket zonder het gebruik van in literatuur genoemde productiviteit indicatoren. Tevens geeft het de bruikbaarheid aan van vergelijkende indicatoren die op maandelijkse basis gebruikt worden om de diversiviteit binnen het grotere irrigatie systeem aan te duiden. Op grotere schaal benadrukt de studie de veranderende rol van irrigatie in het gebied als een sociale kracht voor ontwikkeling en als een reden van sociale buitensluiting en sociale differentiatie.

Het hoofdstuk benadrukt dat het geval van de PRD is van groot belang om aan te tonen dat een nieuwe ronde van modernisatie van het PRD – en elk ander groot irrigatiesysteem – op een ander manier aangepakt moet worden om effectief te zijn, en een verschillende hoeveelheid oplossingen moet aandragen voor de diversiviteit die in het gebied aanwezig is. Daarom is het noodzakelijk om de volgende modernisatieronde te zien als "UNA TARE DE TODOS" (een collectieve activiteit).

RESUMEN

El Proyecto del Río Dulce (PRD), con un área regable de 120.000 hectáreas, es uno de los sistemas de riego más importantes de la Argentina y ha contribuido por muchos años con más del 40% del producto bruto agropecuario de la provincia de Santiago del Estero

El riego se inició en el área antes de 1900, mayoritariamente en forma espontánea los colonos de entonces construyeron canales y desarrollaron un área de riego cuya producción abastecía al mercado local. Al inicio del siglo XX cambios políticos importantes y nuevas oportunidades comerciales posibilitaron una sucesión de impulsos estatales y privados para incrementar y modernizar el riego y la importancia económica y política que el riego adquiriría en el área del hoy PRD hizo de este un sistema en constante evolución bajo la influencia de la política provincial y nacional.

El riego evolucionó hacia la máxima área regable en condiciones no reguladas de Río Dulce generándose conflictos entre los usuarios. El Gobierno Nacional planeó su primera intervención estructural alrededor del año 1940 motivado por dichos conflictos pero también por su sesgo intervencionista de aquellos años. Dicha intervención presuponía el desarrollo de la infraestructura física necesaria para mejorar la captura y conducción del agua y la reorganización de la operación del riego para alcanzar el objetivo de maximizar la producción por unidad de agua (riego a déficit o "protectivo"). Si bien, se construyó una "moderna" infraestructura en parte del sistema, el manejo o gestión de la operación no fue nunca sistemáticamente re-organizado, la administración del sistema continuó bajo la responsabilidad de una oficina provincial y el área su "libre" evolución.

La segunda intervención estatal en el área, el Proyecto del Río Dulce (PRD) fue planeado como un emprendimiento conjunto del gobierno Nacional y el Provincial luego de la construcción, por parte del primero, de un importante embalse que inició su funcionamiento en 1966. La nueva intervención puso énfasis en nuevas tecnologías de regulación del uso del agua y una transformación global del sector rural bajo riego que implicaba la aplicación de un "paquete" modernizador completo que incluía las tecnologías de producción, comercialización y financiamiento.

Este programa fue truncado entre 1973 – 1975 en sus etapas iniciales por razones políticas, dejando el embalse, una infraestructura de conducción y distribución del agua de riego solo parcialmente mejorada y una institución nacional (Agua y Energía Eléctrica del Estado, A&EE) a cargo de la operación, mantenimiento y manejo del sistema. Desde entonces, la evolución del proyecto fue moldeada inicialmente por esta progresivamente desmotivada (en términos técnicos) oficina nacional y desde 1992 por una también desmotivada (siempre en términos técnicos) oficina provincial y en ambos períodos por un grupo heterogéneo de usuarios e interesados generales y un conjunto altamente impredecible de incentivos fijados por los cambiantes contextos políticos y económicos nacionales y provinciales.

Mediante negociaciones políticas y técnicas los operadores referentes del proyecto han podido controlar diferentes intereses y amenazas que hubieran sido fuente de conflictos en muchas otras áreas. Grandes y pequeños productores, agricultores con derechos permanentes de uso del agua que no cultivan y otros que cultivan áreas importantes únicamente con permisos anuales han coexistido sin conflictos serios por muchos años.

La hipótesis que subyace detrás de esta tesis es que este ambiente relativamente libre de conflictos en el PRD ha sido posible a costa del desarrollo provincial a través de un

importante sub-utilización del distrito de riego que involucra una baja productividad del agua, un uso ineficiente e inefectiva de tierras de muy buena aptitud, pérdida de oportunidades económicas y una alta dependencia de los pequeños agricultores de las políticas populistas tanto del Gobierno Nacional como del Provincial.

Esta tesis documenta la evolución de la diversidad de situaciones internas del sistema, los acuerdos socio-tecnológicos y los procesos de confrontación y adaptación que le permitieron al agua seguir fluyendo con relativa efectividad a pesar de la compleja y a veces caótica historia de las intervenciones públicas y los cambios tecnológicos. La tesis también examina las motivaciones y estrategias de los usuarios y las agencias administradoras así como los resultados (desempeño) del sistema desde diferentes puntos de vista y el "espacio de maniobra" que persiste para mejorar el desempeño del sistema de riego en el futuro.

Los Capítulos 2, 3 y 4 provén al lector una visión no solo del contexto físico y tecnológico del PRD en el momento en que se llevó a cabo la investigación (1999 – 2002), sino también de la dinámica social caracterizada por un débil rol del estado en el sector de riego en particular y en las iniciativas de desarrollo en general.

En el Capítulo 2 se revé la construcción social del riego en el área desde los inicios del siglo XX con el objetivo específico de demostrar como los actores sociales, los contextos políticos y económicos y el ambiente natural han determinado la evolución del sistema físico diseñado. El Capítulo describe los roles cambiantes y las estrategias de los principales actores – un heterogéneo conjunto de usuarios con diferentes poder y capacidad de movilizar recursos, las oficinas administradoras que se han sucedido en la administración del sistema como entidades independientes y los gobiernos Provincial y Nacional. El análisis histórico fue útil para entender rasgos específicos e instituciones presentes en el PRD que tienen sus raíces en los estadios iniciales de desarrollo del riego en el área y en las prácticas de riego de aquella época. En particular el Capítulo 2 muestra como se definió la estructura social actual del PRD caracterizada por productores pequeños, medianos y grandes y como esa definición significó socialmente la exclusión de muchas gente de los beneficios del riego y en términos físicos la definición de un patrón tipo mosaico de tierras con y sin riego dentro del área dominada por la infraestructura actual de riego. El Capítulo también muestra que la institución de que los últimos regantes de un curso de agua riegan primero importante para el control de las diferencias entre los regantes de la cabecera y cola de los cursos de agua, fue también establecida en la etapa inicial de riego sin la participación del estado.

La evolución de la participación de los usuarios y el discurso de sus organizaciones también es presentada en Capitulo 2. Se demuestra que dicha participación, movilización y compromiso con los asuntos de riego decrecieron desde la auto-movilización de las primeras etapas a la participación pasiva a finales de 1990 al mismo tiempo que la mejora de la infraestructura aumentaba la disponibilidad de agua y el control físico del flujo y se mejoraba en algunos cuestiones básicas la organización de la distribución.

En el Capitulo 3 también se realiza una revisión histórica, en este caso del proceso político de la distribución de los derechos de uso del agua. Se muestra que como la infraestructura, la concesión de derechos de uso del agua evolucionó desde el inicio del riego hasta nuestros días sin un proyecto planificado desde el Gobierno Federal o Provincial. El capítulo resalta como dentro de este contexto no planificado la concesión de derechos de uso del agua ha sido un proceso continuo de negociación y confrontación de intereses a lo largo de los 100 años de desarrollo del riego en el área. Ha sido un proceso social negociado sujeto de decisiones políticas pero moldeado por actores sociales con roles y estrategias cambiantes como forma de adaptación a las condiciones variables de contexto pero con un objetivo fundamental, y estable conseguir tanta agua como les fuera posible.

Dentro de los roles cambiantes de los actores fue determinante para el futuro desarrollo del riego el control político compartido sobre la asignación de derechos de uso del agua por el Gobierno Provincial en el Sistema La Cuarteada y lo dueños de las acequias privadas en las primeras etapas de desarrollo. La mayoría de los excluidos en este período no fueron seriamente reconsiderados durante ninguna de las dos intervenciones que compartieron el criterio de reconocer los derechos adquiridos hasta un área máxima (400 ha) y limitar los nuevos derechos a un área máxima de 50 ha.
En relación a acciones oportunistas para adaptarse a nuevas situaciones debe destacarse como relevante en el desarrollo del riego en el área la adopción generalizada por los diferentes usuarios en los albores de 1950 de la estrategia de obtener derechos de riego para una superficie mayor a la realmente regada. Esta estrategia fue una respuesta a las decisiones técnicas de la agencia provincial de riego con fuerte raíz positivista de reducir el volumen de agua concedido por unidad de área durante la primera intervención estatal importante. Con estas acciones los usuarios de entonces "secuestraron" agua, que no pudo ser "liberada" de forma permanente hasta la actualidad pero provocó la emergencia de los Permisos Revocables Eventuales Temporales Anuales (PRETA), una suerte de "banco de agua" manejado por la agencia de riego para re-asignación anual del plus de agua concedida en forma permanente que no es utilizada. Los PRETAs han persistido en el tiempo y se convirtieron en una institución para la asignación de derechos de uso del agua debido a su gran funcionalidad para la agencia y para los grandes productores, el sub-grupo de usuarios que mas los han demandado en los últimos 20 años.

El Capítulo 4 cierra la serie de capítulos descriptivos, con una breve presentación de los principales sistemas productivos presentes en el PRD, la estructura agraria basada en datos oficiales, la evolución del patrón de cultivos, los rendimientos medios y la productividad del agua basada en precios medios de los productos en los mercados mas importantes. Ocho sistemas productivos han sido identificados en el área, la mayoría de ellos con objetivos productivos para los mercados, los que en esta investigación fueron re-agrupados en dos grandes grupos, los sistemas basados fundamentalmente en el trabajo familiar o pequeños productores y los sistemas productivos empresariales basados en el trabajo asalariado y con una fuerte motivación desde los mercados.

El Capítulo 5 es el primero de los cinco capítulos generados a partir de la información recabada en la investigación. Describe la infraestructura y el manejo de la operación y distribución del agua en el sistema (aguas arriba de las secciones de riego bajo responsabilidad de los usuarios). Se presentan también los principales resultados del manejo o desempeño del sistema y se realiza un análisis comparativo del los indicadores desempeño calculados para los 8 principales canales secundarios. La infraestructura para el control físico del agua incluye diferentes tipos de canales, estructuras de derivación y medición de caudales. Esta variación no es el resultado de una intervención planificada sino de los diferentes conceptos del riego subyacentes en las dos principales intervenciones estatales que se produjeron en el área y de los diferentes criterios adoptados en el diseño de las mismas durante la última de las intervenciones (PRD), así como de su incompleta implementación. Independientemente de estas diferencias en las estructuras, en función del tipo de manejo de la operación que se realiza el PRD debe considerarse como un sistema controlado con compuertas ya que la mayoría de las estructuras de derivación incluyen obras de control y derivación operadas en base a compuertas de guillotina.

A pesar de que oficialmente la distribución del agua se realiza por rotación entre las secciones controladas por los usuarios y entre las fincas dentro de cada sección, existen en el sistema muchos de los elementos considerados imprescindibles para un manejo "moderno" con una visión de servicio que responde a las demandas de los usuarios. La operación del sistema esta basada administrativamente en cuatro distritos que operan desde cabecera de canales secundarios en forma independiente; la mayoría de los canales tienen una capacidad de derivación muy alta en relación a las necesidades lo que les da una buena capacidad de almacenamiento de agua "en línea" que facilita la respuesta a nuevas demandas; la comunicación entre las unidades operativas y la de los operadores de campo es excelente, los operadores viven en la cercanía o en el área que controlan, el número de estructuras de derivación controladas por los operadores de campo es bajo, la movilidad del personal es buena y la accesibilidad a las estructuras es permanente aún en la estación de lluvias. De hecho el patrón mensual de las descarga de los canales presentado en el capítulo indica que la distribución del agua se ha desplazado desde el turnado oficial a un distribución que responde a la demanda definida por el patrón de cultivos y las prácticas de manejo del riego de los usuarios.

En relación a la disponibilidad de agua y el ajuste del riego a la demanda a nivel anual, los resultados sustentan la afirmación que el PRD es un "un sistema "húmedo"en un área semi-árida". El Suministro Relativo de Agua (SRA) medio anual del PRD fue de 1,9 en los 3 años estudiados y de 2,4 para un período de 20 años con información, mientras que el Suministro Relativo de Riego (SRR) fue de 2,3 y 3,7 en los mismos períodos. El suministro de agua y de riego fue también alto en los 8 canales secundarios principales, sin embargo hay grandes diferencias entre ellos con SRA y SRR medios anuales en el período estudiado que variaron entre 1,2 a 2,8 y 1,2 a 4.2 respectivamente.

El suministro de agua y riego medio no varió sustancialmente aguas abajo del canal Matriz entre los 6 canales secundarios que toman agua directamente de este. Sin embargo los dos canales secundarios (Sud II y Simbolar) que toman agua desde el canal Jume Esquina diseñado para transferir agua desde el Río Dulce al Río Salado mostraron los menores valores de ambos indicadores. Si se presenta un incremento aguas abajo de la variación interanual de los indicadores y de la fluctuación de las descargas diarias lo que sugiere problemas en el planeamiento y ejecución de la operación y un erróneo manejo de las estructuras de derivación que tienen una flexibilidad hidráulica menor a 1.

El análisis de la disponibilidad de agua y de riego a nivel mensual reveló características particulares relacionadas a las prácticas de manejo del riego que permanecieron ocultos en el análisis a nivel anual y que tienen importantes consecuencias para el desempeño del sistema tanto en lo que hace al uso del agua de riego como de su impacto ambiental. Existe una alta concentración del uso del agua en los meses finales de la estación seca (desde Julio a Septiembre y algunos años a Noviembre) dónde se alcanzan valores de SRA y SRR tan altos como 15 o 20 en algunos canales y un uso muy bajo del riego durante la estación de lluvias con SRA y SRR cercanos y aún menores que 1. Esta variación mensual consecuencia del patrón de cultivos predominante y las prácticas tradicionales de manejo del riego a nivel de finca justifican la caracterización del PRD como "un sistema "húmedo" en una región semiárida con cultivos "secos" en la estación húmeda".

Los Capítulos 6 a 9 analizan lo estudios de 4 casos de áreas bajo el control de los usuarios. Las mismas fueron seleccionadas para representar las características físicas y estructuras sociales y productivas más representativas dentro del PRD.

El Capítulo 6 presenta el caso de la unidad terciaria JS, un sector modernizado con estructuras "modernas" para el control del agua utilizado por un grupo homogéneo de pequeños productores que aplican un manejo tradicional del agua de riego en sus parcelas. El paquete modernizador aplicado en el rediseño del sector incluyó el redimensionamiento del área servida por el canal terciario y sus comuneros y la modernización completa de la infraestructura para asegurar una distribución controlada del agua. Estas mejoras incrementaron sustancialmente el acceso al agua a tal punto que esta dejó de ser un factor restrictivo de la producción, sin embargo no cambió ninguna de las prácticas de riego aplicadas por los usuarios a nivel de finca. La principal conclusión en este caso es que el "paquete modernizador" aplicado no solo no mejoró el uso del agua sino que tampoco revirtió el proceso de empobrecimiento que otros factores políticos y económicos impusieron sobre el sistema productivo minifundista predominante en el área (el número de productores disminuyó casi un 60% y ha habido una concentración de la tierra y el agua a favor de los productores mas exitosos del sector).

Además la "moderna" distribución del agua propuesta para el sector fue paulatinamente modificada por los usuarios para adaptarla a sus preferencias que incluyen la aplicación de pocas pero grandes láminas de riego durante el año. La lámina media bruta de riego por riego se elevó a 230 mm (2,6 veces mas grande que la lámina bruta oficial de 90 mm) mediante el incremento del tiempo de riego por unidad de superficie a tres veces la duración oficial de 50 min/ha. Esto es posible debido a que el área regada por turno es muy inferior el área con derecho de riego en el sector e incluso menor que el área cultivada real. A pesar del alto uso de agua en los eventos de riego individuales (turnos), el consumo medio anual de agua por los productores del área de JS no es más que 60% del volumen anual que tienen oficialmente concesionado. Esto se debe a que el área cultiva ha sido un 57% menor que el área con derecho de riego y a las estrategias de riego antes mencionada de los productores que incluye muy pocos riegos en la mayoría de los cultivos.

El Capítulo 7 analiza el caso del B1-TTS, un sub-sector terciario en un área desarrollada durante la implementación del PRD dónde no existía riego con anterioridad a la intervención y dónde fueron re-asentados en parcelas de 25 ha, productores minifundistas de otras áreas. El "paquete modernizador" al igual que en JS incluyó acá el diseño "moderno" de los sectores terciarios y comuneros las estructuras de control del agua de riego y en este caso particular también un "moderno" diseño de facilidades de riego a nivel de finca (nivelación, acequias sobreelevadas entre otras mejoras). La otra gran diferencias con loas otras áreas del PRD fue la implementación un sistema de distribución de agua del tipo de rotación acordada. Los resultados obtenidos en esta área al igual que en JS, resaltan que la modernización no ha conducido a un buen manejo del agua de riego ni a nivel terciario ni a nivel de finca y no ha sido suficiente para revertir el proceso de empobrecimiento de los productores asentados en el área la mayoría de los cuales gradualmente redujeron su superficie cultivada a áreas similares a las que cultivaban en sus parcelas originales y otros han abandonado la actividad agrícola.

El "moderno" sistema de distribución de agua implementado en B1-TTS fue menos modificado por los usuarios que en otras áreas, debido a que la propuesta y su aplicación poco estricta por los operadores de campo de la agencia de riego les aportó la flexibilidad necesaria para aplicar sus prácticas de riego a nivel de finca sin mayores dificultades. El volumen medio anual por unidad de superficie fue en este caso 8620 m3/ha, un 90% del volumen asignado por los derechos de riego pero el mayor entre todas las áreas estudiadas. En promedio los productores del sector B1-TTS usaron únicamente 3 turnos de riego por año, para los riegos de presiembra de sus cultivos predominantemente hortícola. El caudal medio recibido de 398 l/s fue un 30% mayor que el caudal oficial de 300 l/s. Aunque hubo una variación durante el año y entre las fincas, el tiempo medio de entrega de agua en finca fue de 3,3 hr/ha. Los altos caudales entregados y la larga duración de la entrega derivaron en una lámina media bruta de riego de 327 mm, en promedio 3,6 veces mayor que la lámina bruta oficial de 90 mm y la mayor entre las áreas estudiadas.

El caso del sector terciario RS presentado en el Capítulo 8 es representativo de la modernización de la distribución del agua en una vieja acequia comunera (no modernizada) controlada por un grupo heterogéneo de usuarios. La principal diferencia con los casos anteriores es que la "modernización" aplicada en el área solamente incluyó el cambio de la distribución del agua y una mínima mejora de las estructuras de derivación. Coexisten en esta área un heterogéneo grupo de sistemas productivos desde productores familiares minifundistas hasta grandes productores empresariales y se observó una alta presencia de PRETAs alcanzando el 30% del área total con derecho de riego en la campaña 2000/2001.

Los principales resultados en este caso mostraron que, como en los casos anteriores, los productores del área de RS han tenido al capacidad para modificar la forma oficial de entrega de agua para hacerla mas flexible y compatible con sus necesidades reales. Realmente las prácticas de riego de los usuarios no son diferentes a las de los usuarios de otras áreas y no difieren según el tipo de productor o el tipo de derecho de uso del agua de riego que posean. Las mismas tienen características contradictorias desde el punto de vista de la explotación del recurso: la estrategia de riego en los cultivos es básicamente un fuerte riego de presiembra y la aplicación de pocos riegos durante el crecimiento de los cultivos asemejándose a las prácticas aconsejadas con una visión "protectiva" del riego. Sin embargo el agua no es tratada como un recurso escaso al momento de su aplicación y como en los otros lugares sustituye otros recursos menos disponibles (incluyendo capital para nivelar el suelo, mano de obra para un mejor control de la aplicación y capital para la mejorar de la infraestructura y controlar la disminución endémica de las descargas en la "cola" del sector).

La duración media de la entrega de agua fue en este caso, 1,8 a 2 veces mayor que la duración oficial y el caudal medio entregado en finca 487 l/s, el segundo mas grande entre los casos estudiados. Esto resultó en una lámina media bruta de riego de 291 mm/turno; 2,7 veces mayor que los oficiales 90 mm/turno. No hubo diferencias sustanciales en las prácticas de riego entre los diferentes tipos de usuarios, las diferentes localizaciones a lo largo de la larga acequia o los diferentes tipos de derechos de uso del agua de riego, dejando en claro que los PRETAs no condujeron a un mejor uso del agua.

La "modernización" no fue tampoco en este caso capaz de revertir el empobrecimiento de los pequeños productores consecuencia de las políticas neo-liberales y la falta de apoyo oficial efectivo y no de luchas por el agua. El hecho de que mucho de ellos abandonaran la actividades agrícolas le ha dado espacio a los productores medianos y grandes del área para incrementar sus propias superficies conduciendo a una concentración de la tierra y el agua mas intensiva que en las otras áreas estudiadas.

El Capítulo 9 presenta el caso del SMFN representativo del uso del agua por productores empresariales en el marco de un área no modernizada. La superficie con derechos de uso del agua permanentes en esta área fue similar a la de los otros casos estudiados, pero a diferencia de aquellos pertenece únicamente a 10 grandes productores. El mosaico de tierras con y sin derecho de uso de agua de riego característico del PRD en general está también presente en esta área dado que a pesar de la importante área con derechos permanentes de uso de agua esta solo cubre un 37% del área dominada por la infraestructura de riego del sector. La disponibilidad de tierras complementada con los sistemas de producción empresariales diversificados con gran capacidad para responder a los incentivos del mercado ha hecho frecuente el uso de PRETAs. Esta afirmación está fuertemente soportada por el constante crecimiento del área cultivada con este tipo de derechos de uso del agua que alcanzó las 1020 ha en la campaña 2000/2001.

La investigación mostró que este sector terciario funciona mas cerca que los anteriores a los criterios oficiales en algunos aspectos. El consumo medio anual de agua varió entre el 80 y el 90% del volumen concesionado y a diferencia con los otros casos el área cultivada permaneció cercana a la superficie con derechos de uso del agua. Sin embargo los usuarios que aplican una mayor tecnología para el control del agua durante la aplicación que en las otras áreas fueron capaces igual que aquellos de modificar la distribución del agua para hacerla mas flexible en respuesta a sus demandas.

El orden oficial de riego fue mas una excepción que la regla in casi todos los 20 turnos de riego analizados. A pesar de que el área se abastece de uno de los comuneros en la "cola" del Canal Secundario San Martín, las descargas derivadas durante el período investigado fue 1,9 veces mayor que el oficial y el mayor de las 4 áreas estudiadas. La duración de la entrega vario entre los turnos y las fincas, pero en la mayoría de los casos fue entre 20 y 70% mayor que la duración oficial, resultando en un volumen medio anual derivado 1,5 veces que la oficial pero la mas baja entre las áreas estudiadas. La lámina media bruta por turno fue de 257 mm, la segunda mas baja entre los casos estudiados, pero aún similar a la aplicada en las otras áreas y casi el tripe de la lámina bruta oficial.

En el Capítulo 10 se realiza un análisis comparativo de los resultados obtenidos en las secciones terciarias estudiadas y se buscan ideas explicativas y relaciones causales. El análisis basado en los indicadores de desempeño calculados en las diferentes áreas presenta la visión desde la perspectiva más tecnológica expresada en los indicadores y permite muchas y variadas conclusiones.

La moderna infraestructura de riego, la alta disponibilidad de agua y el manejo sensible del sistema a las necesidades de los usuarios no han sido suficientes para garantizar el desarrollo económico del área y/o simplemente superar los efectos negativos del libre mercado sobre los pequeños productores. Las modernas facilidades no fueron tampoco suficientes para mejorar el manejo del agua a nivel de finca. La mayoría de los usuarios, incluidos aquellos que aplican modernas tecnologías agrícolas en la producción de sus cultivos continúan utilizando prácticas tradicionales de riego.

Debido a esas prácticas tradicionales y a pesar de esa modernas facilidades, incluyendo el embalse de Río Hondo, que asegura al menos un suministro mensual de agua a las fincas, los productores no utilizan mas que 30% de los turnos disponibles y el riego por inundación con escasa tecnología continúa siendo el principal método de aplicación del agua.

El análisis comparativo de los resultados de las diferentes casos estudiados mostró que en todos ellos hay una falta de uniformidad en la mayoría de los parámetros de la distribución del agua: la frecuencia de los turnos de riego es muy diferente a la oficial, el orden de riego dentro de las comuneras es cambiado frecuentemente especialmente por los administradores, la duración media y el caudal medio de las entrega de agua son 2,2 hrs y 396 l/s con un coeficiente de variación del 43 y 41% respectivamente, mientras que la lámina media bruta por turno es 275 mm y su coeficiente de variación 15% debido a la alta compensación entre la duración y el caudal entregado. Por el bajo número de turnos de riego utilizado por los usuarios el uso de agua medio anual (781 mm/año) permanece por debajo del volumen concedido en los derechos de uso a pesar de las grandes aplicaciones por evento individual.

En relación al suministro total de agua y el de riego (SRA y SRR) los resultados de los 4 casos estudiados mostraron patrones anuales y mensuales similares a los encontrados a nivel del sistema y de canales secundarios. Existen variaciones pero los valores obtenidos de SRA y SRI indican que todas las áreas estudiadas son bien provistas de agua a nivel anual independiente del tipo de infraestructura, sistemas de producción, cultivos predominantes y homogeneidad en el tipo de usuarios. Los resultados a nivel mensual fueron también similares a las obtenidos a niveles más altos del sistema, con un pico muy alto de consumo de agua de Julio a Noviembre que confirma la gran influencia de las prácticas de riego a nivel de finca y terciarios sobre el desempeño a nivel de los canales secundarios (sub-sistemas) y sistema.

El Capítulo 11 explora estrategias alternativas de evaluación de desempeño del sistema desde la visión de los operadores y los propios usuarios y realiza un avance sobre la evaluación del impacto ambiental negativo (principalmente la salinización de los suelos) y del uso del agua a nivel de cuenca de los *outputs* del PRD. La evaluación alternativa del desempeño del sistema desde al visión de los operadores y los usuarios reveló, una alta satisfacción de ambos grupos con los *outputs* y las diferentes visiones que estos actores tienen sobre algunos de los parámetros clásicos de evaluación del desempeño como el suministro adecuado, la oportunidad y equidad de las entregas.

Tanto la actual agencia como las anterior administradora del sistema han usado el número de reclamos de los usuarios como el único, explicito y poderoso indicador para evaluar internamente su desempeño y el mantenimiento de dicho número lo mas bajo posible como el objetivo de su gestión. Esto los ha conducido a una gestión que da respuesta a las demandas de los usuarios incorporando flexibilidad en la distribución del agua, un elemento central de la operación "moderna" de los sistemas de riego, como una lógica consecuencia de la operación pragmática y no como una decisión reflexiva basada en una intervención planificada. Al mismo tiempo la conducta servicial hacia las demandas de la agencia administradora da a los usuarios una fuerte oportunidad para influenciar el modo en que el agua es distribuida en el sistema. En la práctica la relativa alta disponibilidad de agua en relación al área cultivada es determinante para lograr el objetivo de las administradoras (y explica la alta satisfacción de los usuarios con la agencia) a pesar de su baja capacidad técnica.

La satisfacción de los productores con el desempeño del sistema es, como se mencionara, también alta y está altamente relacionada con la cobertura total de sus bajas requerimientos de agua y sus preferencias en cuanto a la forma de distribución. Ambos están basados en sus prácticas de manejo del riego con fuertes raíces en los principios del riego "protectivo".

En relación a la salinización de los suelos, el PRD ha sido sinónimo de salinización secundaria a nivel del sector de riego de la Argentina. En este sentido no sería una conclusión sorprendente que el bajo número de aplicaciones anuales de grandes láminas producen la elevación del nivel del agua freática y un activo proceso de salinización secundaria. Sin embargo la particular característica del PRD de presentar en el área dominada por la infraestructura de riego un mosaico de tierras con y sin derecho de uso del agua como producto del proceso negociado de asignación de derechos le han dado a las tierras no regadas (casi un 60% del área con dominio del riego) el rol no planificado de almacenar las sales dentro del PRD. Esta afectación de su calidad incrementa el efecto que estas tierras y sus dueños sufrieron con su temprana exclusión de los beneficios del riego y representa un alto costo para el desarrollo provincial.

Al mismo tiempo, el uso del agua desde la capa freática por la vegetación natural que crece en esta importante superficie sin riego incremente en forma importante el uso no benéfico del agua derivada para riego y reduce al mínimo el esperado flujo de retorno desde el sistema, haciendo del PRD un sistema cerrado a diferencia de muchos sistemas de riego del mundo. Esta característica, que imposibilita el uso por aprovechamientos aguas debajo del los exceso de agua aplicado debería ser seriamente considerada al analizar nuevas posibilidades de inversión y futuras intervenciones así como en la planificación del uso del agua a nivel de cuenca hidrográfica.

El Capítulo 12 cierra la tesis con la revisión de las principales preguntas que movilizaron la investigación, el marco teórico desarrollado para la investigación y sus principales conclusiones y realiza una breve discusión de los principales aspectos que deberían incluirse en la agenda de un nuevo ciclo modernizador del PRD.

Las conclusiones cubren un gran número de temas pero destacan el carácter pragmático el la evolución que el riego ha seguido en el PRD, la descodificación de las intervenciones modernizadoras por los actores locales para adecuarlas a sus reales requerimientos, la persistencia de practicas tradicionales en área modernizadas y el manejo con una alta capacidad de adaptación de las administradoras que han posicionado a la gestión de lo operación muy cercana a la visión de servicio propuesta por el "paquete modernizador" sin el uso de ninguno de los indicadores de desempeño propuestos en la literatura. También en las conclusiones se resalta la utilidad de los indicadores comparativos usados a nivel mensual para desenmascarar la diversidad de situaciones dentro de los grandes sistemas de riego y a mayor escala el rol cambiante que el riego a tenido en el área como fuerza motora del desarrollo y causa de exclusión y diferenciación social.

El capítulo final resalta también que el caso del PRD debiera ser útil para mostrar que una nueva etapa de modernización del mismo y de cualquier otro gran sistema de riego debería encontrar nuevos caminos que los recorridos mayoritariamente hasta ahora para trabajar y proveer servicios diferenciados acordes a la diversidad de situaciones y actores que contiene. Por lo tanto pienso que la próxima etapa de modernización en el PRD debe ser visualizada necesariamente como UNA TAREA DE TODOS.

Curriculum Vitae

Daniel Prieto was born in 1951 in Montevideo, Uruguay. He married Cristina in 1978 and has 3 sons (Salvador, Nicolás and Manuel). He received his B.Sc degree as Agricultural Engineer in 1976 from the Universidad de la Republica of Uruguay and a M.Sc degree from the Agriculture University of Wageningen in 1983 with a fellowship from NUFFIC.

He started his involvement in irrigation issues in 1976 when he joined the Hydrographic Department in the Ministry of Public Work in Uruguay.

In 1977 he was appointed Chief of the regional office for the Rio Tacuarembó basin where he also organized and chaired the Junta de Regantes para la cuenca del Rio Tacuarembó y afluentes (Irrigators Board for the Rio Tacuarembó basin). His main task was to quantify surface water resources, to decide about water exploitation permits, and to approve and control private individual irrigation projects.

In the very dry season of 1978-1979, the year where his first son Salvador was born, the river discharge was the minimum of the historical records. However through participatory work with most farmers for the first time, irrigation turns were organized and controlled and most irrigated hectares could be harvested.

In 1983 we has appointed Coordinator of Regional Offices and he moved to DH headquarters in Montevideo and one year later he was appointed of Chief of the Water Resources Administration Section in charge of water use permits for all surface water courses in Uruguay.

In 1986 he started his career as an agro-hydrology researcher when he joined the National Institute for Agriculture Technology in Argentina at the Santiago del Estero, Experimental Station. He has worked as researched for that Institute for the last 20 years, in which time he occupied different positions at local level (Coordinator of Natural Resources Research group) and at national level (National Coordinator of Water Resources National Sub-program (1991-1998 and from 2005). During this period he published many technical papers on irrigation, drainage and salinity control and more recently in water harvesting for agriculture and GIS and Remote Sensing and he has directed many conferences at local and national level.

Since 1998 he has taught in three M.Sc courses in Argentina (Drainage Course in Mendoza, Water management Course in La Rioja, and Irrigation and Water Management Course in Tucumán).

At international level he has worked for IFAD and for the Argentinean Government as an irrigation expert in missions to Mexico, Nicaragua, Grenada and Bolivia. Since 2005 he is the Argentinean representative in the PROCISUR irrigation network.

In his work he has combined a solid technical background with a social vision of technology acquired during his BSc studies in the highly political period of South America (1970-1976), and reinforced during his MSc. and his subsequent regular ongoing contact with the IWE group. This has been both through thesis research of IWE students (receiving in Santiago del Estero more than 18 Dutch students for practical periods and M.Sc thesis in the last 15 years), and the work for this PhD.

Cover desing: Lucio Auhat
Photo: José Ramón Rodriguez
Printing: Ponsen & Looijen BV, Wageningen, The Netherlands.