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Exploring farmer perceptions of agricultural innovations for maize-legume intensification in the mid-hills region of Nepal

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ABSTRACT

Maize-legume intercropping is a fundamental component of mixed farming systems in the mid-hills of Nepal. However, its productivity is constrained by several biophysical and social factors, and limited adoption of proven agricultural innovations. In this study, we assessed the productivity impact of a selection of relevant agricultural innovations and changes in the associated perceptions of farmers through a series of two-year participatory on-farm trials. The evaluated innovations resulted in higher yields as compared to farmers' current practices. The active involvement of farmers enlarged our understanding of underlying decision-making factors to adopt or non-adopt agricultural innovations. Additionally, the in-depth farmer engagement in our onfarm trials positively influenced farmer perceptions of the innovations and their interest to adopt the agricultural innovations. Yet, farmers final decisions to adopt some of the evaluated innovations were limited by a host of factors including labour scarcity, the availability of inputs, and by cultural preferences despite the increased yields. This was particularly true for low and medium resource-endowed farmers. This study shows the importance of active farmer participation and context-specific design of research and development projects aiming for local impact.

KEYWORDS

Agricultural innovations; participatory approaches; farmer perception; sustainable intensification; intercropping; adoption

1. Introduction

The increased acknowledgement of the necessity to feed the growing global population, to adapt to climate change and to reach sustainable development goals (e.g. Hunter, Smith, Schipanski, Artwood, & Mortensen, 2017; Rockström et al., 2017) lead to more efforts to enhance productivity of smallholder agriculture in a sustainable manner, i.e. by sustainable intensification (Garnett et al., 2013; Pretty & Bharucha, 2014). In less-favoured areas such as mountainous regions, smallholder farms play an important role in food security, but are often based on traditional practices (Dahal, Nyborg, Sitaula, & Bajracharya, 2009). The aims of the farmers and their context-specific access to financial and labour resources should guide decisions about intensification (Raut, Sitaula, Aune, & Bajracharya, 2011; Tiwari, Nyborg, Sitaula, & Paudel, 2008). Hence, externally proposed technologies and practices that are potential improvements in farming to support the sustainable intensification process should be evaluated by farmers themselves.

Participatory approaches have been emphasized in agriculture in the tropics as an effective method to explore traditional farmers practices. In addition, it has been applied as a means to diffuse agricultural innovations and improve their adoption (Choudhary & Suri, 2013; Hoffmann, Probst, & Christinck, 2007), to develop breeding strategies (Almekinders & Elings,

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2001), to encourage sustainable intensification practices (Blackstock, Kelly, & Horsey, 2007; Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2015), to empower farmers (Hellin, Bellon, Badstue, Dixon, & La Rovere, 2008), and to build adaptive capacity towards climate change (Mapfumo, Adjei-Nsiah, Mtambanengwe, Chikowo, & Giller, 2013). In addition, through participatory approaches, immanent local innovation trajectories could be identified and supported.

Within the participatory approaches there is a vast range of scientist and farmers involvement. The range varies from the independent decision-making from the scientist to a coordinated process in an organized communication between scientist and farmers (Lilja & Ashby, 1999) allowing both stakeholder groups to learn from each other. Among the participatory methods, the Farmer Field School (FFS) approach, developed in Asia in the late 1980s to promote Integrated Pest Management practices, has been broadly used to provide farmers with an opportunity 'for learning-by-doing' (Braun, Thiele, & Fernández, 2000). FFS were shown to increase integrated agricultural knowledge and to improve farmers' decision-making skills (Braun et al., 2000; Mancini, Termorshuizen, & Bruggen van, 2006). Participatory approaches also have been reported to contribute to positive changes in farmer perceptions and willingness to adopt innovations (Kraaijvanger, Veldkamp, & Almekinders, 2016; Misiko, 2009). Even though the positive impact of these approaches on rural development has been demonstrated in numerous studies, participatory technology evaluations have only been applied in some cases in South-Asia (Karki, Sah, Thapa, McDonald, & Davis, 2015). Actively involving farmers in the selection and exploration of new technologies and system improvements, might also lead to a better understanding of the reasons of farmers for adoption or rejection. For instance, in the western and far-western mid-hills districts of Nepal, the use of agricultural technology is incipient. The agricultural practices have remained traditional and inefficient in terms of labour use, and productivity during the last decades. Labour efficiency might be attained by improving crop and livestock management, and by introducing mechanization (i.e. for ploughing) appropriate for the hill zones. The mid-hills represent the largest geographic zone of Nepal, covering approximately 42% of the total land area (MoAD, 2014). Maize is the principal staple food and fodder crop of small-scale farmers in this region covering 73% of the total production in the country (MoAD, 2014). Maize is usually sown together with legumes or cucurbit species, with finger millet often relay-planted into the standing crop (Subedi 1996 in Tiwari, Brook, & Sinclair, 2004). However, over the last two decades the productivity of maize remained at a low level of about 2 to 2.5 Mg ha^{-1} and only in some cases increased marginally (Devkota et al., 2015; Ghimire & Huang, 2015; Paudel & Matsuoka, 2008).

Many interventions have focused in closing yield gaps of maize in the mid-hills of Nepal by promoting improved technologies and the adoption of modern inputs such as new crop varieties (Becerril & Abdulai, 2010; Ghimire & Huang, 2015). By conducting on-farm experiments, Devkota et al. (2015) determined that there is a remarkable scope for improving maize productivity by maintaining higher plant densities, cultivating hybrids, and increasing fertilizer use. However, the adoption of the combinations of such technologies is still low in the mid-hill regions. The reasons include, among others, lack of information of technology and motivation of farmers (Ransom, Paudyal, & Adhikari, 2003; Tiwari et al., 2004), and increased costs and risks for the farmers. Furthermore, there are still gaps between the results obtained in experimental research stations and farmers' fields (Ghimire & Huang, 2015; Karki et al., 2015; Paudel & Matsuoka, 2008) that could be bridged by improving the communication between farmers and extension systems (including the non-governmental community) (Karki et al., 2015; Ransom et al., 2003), and possibly a stronger role of the private sector.

Farmers' subjective preferences for the characteristics of new agricultural technologies (Adesina & Baidu-Forson, 1995) and their knowledge and perceptions when involved in participatory experimentation and exchange, could influence their adoption behaviour. Moreover, it would lead to accumulation of knowledge and adjustment of initial perceptions, which can influence attitudes that can result in the adoption of technologies (Meijer et al., 2015). Farmer knowledge and perceptions are intrinsic factors that influence the decision for adoption of innovations, while the technology, the external environment, and the adopter (structural) characteristics are the extrinsic factors that affect farmer decisions (Meijer et al., 2015).

Our objectives were (i) to assess the changes in farmer perceptions of the agricultural innovations compared to traditional technologies and practices during participatory field experiments and (ii) to gain more insights on their perceived constraints to the adoption of agricultural innovations in the region. We addressed these objectives using a two-year participatory approach based on a portfolio of methods including the FFS approach, participatory on-farm trials, field discussions, and perception and adoption assessments (Braun et al., 2000; Hoffmann et al., 2007; Mancini et al., 2006; Meijer et al., 2015; Zabala, Garcia-Barrios, & Pascual, 2013). The trials included different sustainable intensification options that include the following technologies and practices: (1) Crop composition (maize and legume intercrop instead of maize sole cropping), (2) Sowing methods (in line instead of broadcasting), (3) Tillage (mechanized instead of animal traction), (4) Use of fertilizers (instead of farmyard manure), and (5) hybrid seeds (instead local seeds). These agricultural innovations were selected as best-bet options to increase crop productivity on the basis of previous trials in the region (Devkota et al., 2015).

2. Materials and methods

2.1. Description of the study sites

The study took place in Nepal in two villages, governmentally referred to as village development committees (VDCs), in the western region (Palpa district) and two VDCs in the far-western region (Dadeldhura district) (Figure 1). In socio-economic terms, the far-western regions are less developed and less exposed to information and technology than the western region (Central Bureau of Statistics, 2014) (Table 1).

Nepal development gradient ranges from low to high from east to west, and from south to north. The Terai (valley) is the mainagricultural production area and the most connected and developed region of Nepal (Figure 1). A large proportion of the male workforce in the mid-hill region temporarily migrates to obtain additional income. In Dadeldhura, migration mainly entails seasonal work in India, while in Palpa men migrate for longer periods to the Persian Gulf countries. Due to the high rate of male migration, farming has become a predominantly female activity in both the western and far-western regions.

The topography of the two regions is similar with Dadeldhura situated at a slightly higher altitude (1500 m a.s.l.) than Palpa (1300 m a.s.l.). Overall, the soils in both mid-hills are chromic cambiosols (Dijkshoorn & Huting, 2009) with a silty-loam texture in Dadeldhura, and loam to silty loam in Palpa. The climate in the two areas as described by the Koppen climate classification is subtropical-dry winter with monsoonal influence. The wet summers (June–September) have a similar average precipitation with 990 mm in Dadeldhura and 1052 mm in Palpa, while in the dry winters (December–March) the precipitation is slightly higher in Dadeldhura (349 mm) than Palpa (228 mm) (Department of Hydrology and Meteorology of Nepal, 2015).

Farming in both Dadeldhura and Palpa is rain-fed, and is characterized by small-scale (on average 0.5 ha) mixed farms. The average number of tropical

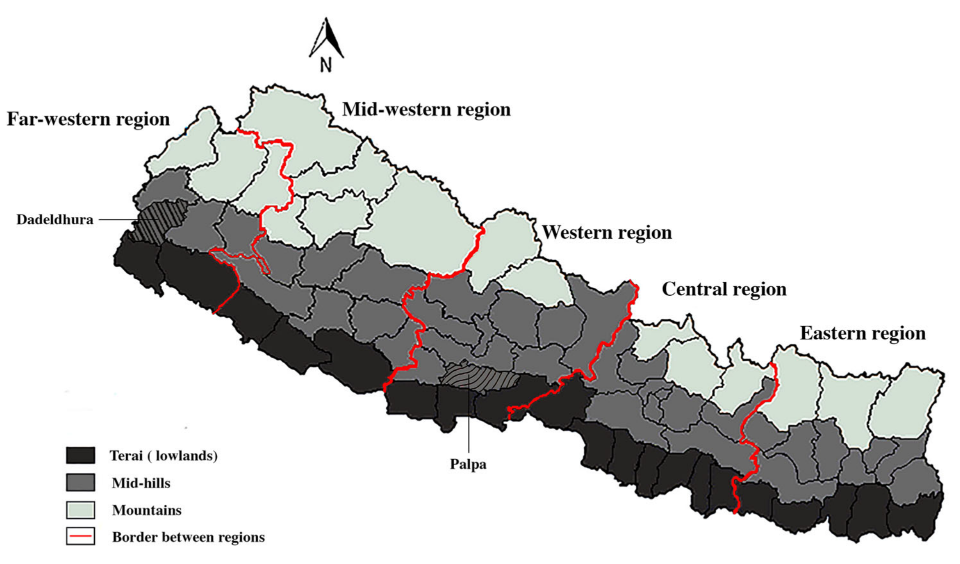

Figure 1. Map of the geographical and developmental regions in Nepal. The Palpa and Dadeldhura districts, where the study sites were located, are indicated.

Table 1. Characteristics of farms and agricultural households in the western and in the mid- and far-western mid-hill regions of Nepal (Central Bureau of Statistics, 2014)

Characteristics	Western region	Mid- and far-western region
Agricultural households (%)	93	97
Literacy of agricultural household head (%)	60	47
Average age agricultural household head (years)	48	43
Average farm size (ha)	0.5	0.5

livestock units (TLU) per farm is 2 in Dadeldhura and 3 in Palpa. Both regions commonly have two cropping seasons per calendar year, namely summer (May–September) and winter (October–December). However, in some cases a third season is added during spring (January–April).

In both sites, maize is commonly sown with different species of beans, pumpkin, and finger millet. The plant population and species varies among the fields. The main crop grown in summer in Palpa is maize (mainly mixed with legumes, cucurbits, and finger millet), while in winter mustard mixed with chickpea or lentil is prevalent. In Dadeldhura, maize (mixed with legumes, cucurbits, and finger millet) and upland rice are alternated in the fields each year during the summer. In the winter, wheat is the main crop. From January to April or May most of the fields are fallow. In the case of a spring season, vegetables are the main crop limited to farmers that have access to irrigation.

On average, 14% of the households in Palpa, and 6% in Dadeldhura use improved seeds for cereals and vegetables, while respectively 30% and 19% of the farmers use mineral fertilizers (Central Bureau of Statistics, 2014). Previously, the International Maize and Wheat Improvement Centre had projects in Palpa (IFAD-supported, 2011–2013) and in Dadeldhura (USAID-supported, 2013–2015). Both projects were based on on-farm experiments with the objective to close maize yield gaps. The experiments were composed of single or layered combinations of five agronomic practices: i.e. use of hybrid cultivars, adjusted plant density and fertilizer rate, weed control and crop establishment practices (Devkota et al., 2015).

2.2. Participatory process

Our research targeted agricultural intensification in small-scale mixed farms in the mid-hills of Nepal through the following activities: (1) Participatory on-farm trials, (2) Farmer field discussions (FFD), (3) Perception assessments (PA), and (4) Innovation adoption assessment (IAA) (Figure 2). The project was conducted over two years, 2014 and 2015, in Dadeldhura and for one year (2014) in Palpa, where it was not possible to continue the project for the second year due to the major earthquake of April 2015.

Traditional farmer practices and agricultural innovations were explored. We assessed seeding method (seeding in lines vs. broadcast), tillage method (land preparation with a mini-tiller vs. oxen-ploughing), cropping pattern (sole cropping vs. intercropping), type of fertilizer (mineral vs. farm yard manure (FYM)), and crop cultivars (hybrids vs. local and/or open pollinated varieties). The proposed practices were demonstrated in the on-farm experimental trials and compared with the traditional farmer practices in their own fields. Farmer perception was assessed by comparing (1) costs, (2) amount seed required, (3) labour requirement, (4) weed pressure, and (5) yield potential of the traditional and proposed practices. These five key factors were identified together with diverse farmers/households through a rapid rural appraisal at start of the participatory project, in 2013. The farmers/households were selected randomly in each site using a Y-shaped method described by Tittonell et al. (2010), and characterized through typologies based on their resource endowment. Only the practices which could be compare with the traditional ones were part of this comparative assessment, the inputs such as mineral fertilizers and crop cultivars were excluded since such inputs were part of the key factors to test perceptions of the practices assessed: mini-tiller vs. ploughing with oxen and the line sowing vs. broadcasting practice. In addition, we explored all the practices and input technologies through the IAA and the FFD. All the field activities and evaluations are summarized in Table 2.

In total 71 farmers participated voluntarily in the FFD and PA, of whom 39 in Palpa and 32 in Dadeldhura. The on-farm trials took place in fields of 22 representative farmers (11 in Palpa and 11 in Dadeldhura) belonging to different resources endowment categories from existing typology. The 71 farmers were categorized into farm types based on the yearly income, land holding size, number of TLU, available labour force, and food availability during the year. In Palpa the low resource endowment farmers were characterized by low off- and on-farm income (on average 1626 USD per year total income), small productive land holdings (on average 0.20 ha), few TLU (on average one), food self-sufficiency for less than six months per year (on average five months), and

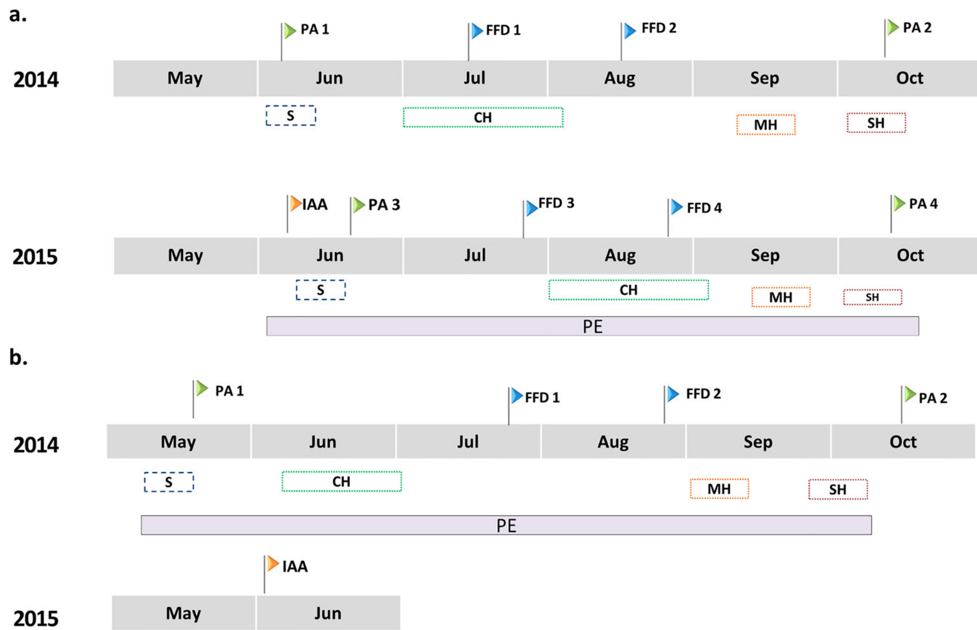

Figure 2. Time line biophysical and social processes for year 2014 and 2015 in (a) Dadeldhura and (b) Palpa. PA: perception assessment; FFD: farmer field discussion; PE: participatory on-farm experiment; IAA: innovation adoption assessment; S: sowing; CH: cowpea harvest; MH: maize harvest; SH: soybean harvest. CSISA project have had summer and winter trials from 2013 to 2015 in Dadeldhura; and IFAD-CIMMYT project had had summer and winter trials in 2012 and 2013 in Palpa.

limited labour force. The 'high' resource endowment farmers obtained greater income (on average 4752 USD per year), had larger land holdings (on average 0.40 ha) and number of TLU (on average 6), were food self-sufficient for more than six months (on average 9 months), and had more labour available. In Dadeldhura, the types followed the same pattern but in general the farms had a considerable lower yearly income than those in Palpa. For instance, the yearly income from the high and low resource endowment farmers in Dadeldhura was approximately half and one third of the average income of the high and low resource endowment farmers in Palpa, respectively.

2.2.1. On-farm trials

The experiments were designed in collaboration with farmers and CIMMYT researchers. The objectives were: (1) to improve maize grain yields under farmer management to reach the attainable yield of 6.5 Mg ha^{-1} previously obtained in on-farm trials conducted by CIMMYT (Devkota et al., 2015), and (2) to explore possibilities to attain additional biomass for livestock feeding from legumes through intercropping. We

Table 2. Overview of the assessments and the improved and traditional technologies and practices explored.

	Seeding		Crop pattern[a]			Tillage		Fertilizers		Variety	
Assessment	Line	Broadcast	Intercrop	Sole crop	Mix crop	Mini tiller	Animal traction	Mineral	FYM	Hybrid	Local
Experimental trials	✓		✓	✓		✓		✓		✓	
Farmer practice		✓			✓		✓		✓		✓
Perception assessment	✓	✓	✓	✓		✓	✓				
Innovation adoption assessment	✓		✓			✓		✓		✓	
Perceived constraints to adoption	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Farmers field discussion	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓

[a]Intercrop refers to the mix: legumes-maize in optimal plant population (used in the trials), while mixed-cropping refers to the traditional farmers practice of maize mixed mainly with legumes, cucurbits, and millet.

Table 3. Treatments of the on-farm trials in Palpa (2014) and Dadeldhura (2014 and 2015).

Year	Cropping system	Plant population[a] (ha^{-1})	Mineral fertilizer (N–P–K; kg ha^{-1})	Crop varieties	Tillage
2014	Sole maize	66,666	150–60–60	Rajkumar	Mini-tiller (two-wheel tractor)
	Sole soybean	194,444	10–40–30	Puja	
	Sole cowpea	194,444	10–40–30	Tane bodi	
	Maize + soybean	55,555/111,111	150–60–60/60–60–40[b]	Rajkumar/Puja	
	Maize + cowpea	55,555/111,111	150–60–60/60–60–40[b]	Rajkumar/Tane bodi	
	Farmers practice	35,000[d]	0	Local	Oxen/tractor
2015	Sole maize	66,666	150–60–60	Kanchan	Mini-tiller
	Sole soybean	194,444	10–40–30	Local	
	Sole cowpea	194,444	10–40–30	Mei Wu Jia	
	Maize + soybean	55,555/111,111	90–60–40	Kanchan/local	
	Maize + cowpea	55,555/111,111	90–60–40	Kanchan/Mei Wu Jia	
	Farmer practice	35,000[d]	0	Local	Oxen

[a]The plant population was obtained by a line sowing.
[b]In 2014, different mineral fertilizer application rates were used for maize and legumes.
[c]The farmers practice consisted of maize and different species of legumes and pumpkin intercropping and application of 9 Mg ha^{-1} farmyard manure.
[d]The plant population in average was taken for a previous study in the zone (Devkota et al., 2015).

compared productivity of maize mono-crop with maize-cowpea and maize-soybean intercrops. The main characteristics of the cropping systems are presented in Table 3. Maize in monoculture was sown in lines (in contrast to broadcasting methods used by farmers) with spacing of 0.60 m between lines and 0.25 m within lines separating plants. The intercrop spacing between maize lines was 0.70 m, and within lines 0.25 m. The legumes were planted in a single line between the maize lines (0.35 m distance) and 0.10 within lines, while distances of 0.50 m between lines and 0.10 within lines were used for the sole legumes. In the second year, we slightly adjusted the trials in discussion with the farmers. The initial hybrid maize cultivar was changed for an early-maturing hybrid. The improved soybean variety used in the first year was changed to a local variety. Cowpea was replaced from a climbing to a bush cultivar. The rate of mineral fertilizer was reduced in the intercrop treatments. We analysed the trials as a randomized complete block design with the farms as blocks individually for each year. To determined significant differences between cropping systems, we performed an Analysis of Variance with Tukey HDS test. Additionally to the grain and biomass yield, we calculated the Land Equivalent Ratio (LER) which represents the total land area of sole crops required to achieve the same yields of intercrops (Li et al., 2011).

2.2.2. Farmer field discussion

Following the FFS (Braun et al., 2000; Mancini et al., 2006) approach, we organized FFD twice every year during the growing season, once after sowing and once right before harvest (cf. Figure 2). In each of the FFD, three trials on three different farms were visited. On each of the farms, farmers were asked to discuss and summarize in keywords their discussion in subgroups of 2 to 3. Thereafter, they were asked to share a summary of their discussion with the whole group. The topics to discuss were introduced one by one and included: (1) the performance of the trials, (2) the proposed practices explored in the trials, (3) the pros and cons of the proposed practices, (4) the feasibility of integrating the proposed practices in current farmer's management strategies. In the last FFD, yields of the trials were also presented and discussed. These discussions were taped with the permission of the participants and notes were taken during the sharing of views.

2.2.3. Perception assessments

The impact of actively involving farmers in research was evaluated by assessing changes in farmer perceptions of the agricultural practices explored in the on-farm trials before and after they took place. Through comparing the before and after the trial perceptions each year, we aimed to determine if and how farmers changed their pre-conceived ideas on the innovations. Farmer perceptions were assessed for three choices: (1) Cropping pattern – intercrop or monocrop, (2) Sowing methods – broadcasting or line sowing, and (3) Tillage – minimum tillage through the use of a mini-tiller or conventional ploughing with oxen.

We developed a visual board (Figure 3(a)) to assess farmer perceptions following Zabala et al. (2013). This perception assessment tool consisted of a board that showed all the management practices proposed to

Figure 3. Participatory process with farmers in Palpa and Dadeldhura (a) farmers using the perception assessment board, and (b) farmers farm discussion and mini-tiller use.

farmers and a set of tokens. Farmers rated their expectations about different characteristics of the practices by assigning between 0 and 10 tokens per characteristic for each of the practices. The number of tokens assigned represented a score. The evaluated characteristics were:

- Input requirements in terms of costs, labour, and seeds.
- Severity of incidence of weeds.
- Crop yield.

We considered a change of perception when the number of assigned tokens changed in comparison to previous PA. We defined positive change in perception as a relative decrease of tokens allocated to costs, labour, seeds, and weeds and a relative increase in tokens allocated to yield for the tested technologies. Through using this visual method, we aimed to reach the illiterate farmers and strengthen the focus of the discussion.

We assessed the perception (trough the perception assessment) of 32 farmers in Dadeldhura and 40 in Palpa. The results were analysed using a Generalized Linear Model to test for significant differences of the binomial proportions after Logit transformation. To gain more in-depth understanding on changes in farmer perception, we determined to which endowment type the farmers with a positive change in perception belonged.

2.2.4. Innovation adoption assessment

Before an innovation is incorporated in the farm management, i.e. the actual adoption, farmers experiment with the innovation to determine if it provides a certain degree of relative advantage. In this study, we refer to try-outs, which were described by Misiko (2009) as the decision of farmers to start experimenting with the demonstrated innovations. In order to assess whether farmers who participated in the trials and/or the FFD started trying any of the proposed practices, we used semi-structured open interviews. Farmers were not given pre-selected options (multiple-choices) for their answers. We performed these interviews to assess the use of technology or practices before the start of our participatory project and after each year to assess if farmers started trying each of the proposed practices and technologies as a result of the participatory project. Furthermore, they were asked to elaborate on the reasons why they were or were not using these innovations before, as well as the constraints associated with their implementation. In Palpa and Dadeldhura, 39 and 32 farmers were part of the assessment, respectively.

3. Results

3.1. Participatory on-farm trials

3.1.1. On-farm trials

The average yield of maize mono-crop and intercrop in both districts was about 7.0 Mg ha^{-1} in contrast to 2.5 Mg ha^{-1} in the farmer's practice plot in both years (Table 4). However, in 2015, when mineral fertilizer was reduced in the intercrop system, the yield of the sole maize was slightly higher than the intercrop 6.9 and 5.9 Mg ha^{-1}, respectively. In addition, the legume yield was higher in the sole crop than in the intercrop. In both years, the LER was higher than

Table 4. On-farm trials yield and yield components in Palpa and Dadeldhura in 2014 and 2015.

			Dadeldhura							Palpa						
Year	Treatment	Crop	Grain yield Mg ha^{-1}	# plants harvested (ha^{-1})	Stover yield Mg ha^{-1}	LER	LAI	HI	Gross margin (\$ ha^{-1})	Grain yield Mg ha^{-1}	# plants harvested (ha^{-1})	Stover yield Mg ha^{-1}	LER	LAI	HI	Gross margin (\$ ha^{-1})
2014	Farmers plot	Maize	2.7	33160	4.2			0.4	275	2.5	34141	6.0		0.6		206
	Sole maize	Maize	7.5	49026	10.0		2.0	0.4	1056	6.7	62500	10.6		2.7	0.4	830
	Sole soybean	Soybean	1.8		4.0		5.3	0.3	592	1.8		9.5				258
	Sole cowpea	Cowpea	6.2		1.6			0.8	669	2.5		0.4				−227
	Maize-soybean					1.5	4.8				54043		1.3	2.5	0.4	966
		Maize	7.3	49188	9.7	1.0		0.4	1528	6.5		10.3	1.0			
		Soybean	1.7		1.7	0.6		0.4		0.7		1.5	0.3			
	Maize-cowpea					1.7			1669				1.6	2.8	0.4	968
		Maize	7.7	49675	8.4	1.2		0.5		6.7	52809	10.9	1.0			
		Cowpea	1.5		1.4	0.5		0.7		1.3		0.4	0.6			
2015	Farmers plot	Maize	2.0	37436	2.3			0.5	204							
	Sole maize	Maize	6.9	56204	10.2		2.9	0.5	378							
	Sole soybean	Soybean	3.6		2.4		6.0	0.6	732							
	Sole cowpea	Cowpea	3.6		2.1		1.0	0.7	−222							
	Maize-soybean			50185		1.4	4.9									
		Maize	6.0		7.4	0.9		0.5	861							
		Soybean	1.6		1.2	0.5		0.6								
	Maize-cowpea			50000		1.3	2.9									
		Maize	5.8		6.7	0.9		0.5	309							
		Cowpea	1.5		1.3	0.5		0.5								

Table 5. Treatments of the on-farm trials in Palpa (2014) and Dadeldhura (2014 and 2015).

Mini-tiller	Legume intercrop	Line sowing
• Time/labour saving	• More food and feed production (two crops)	• Weeding and fertilizer application is easier
• Cheaper	• Legume increases soil fertility and loosens the soil	• Prevents maize lodging
• No bullock husbandry	• Legume is a cash crop	• Uniform crop growth
• Easy to use (women might be able to use it)	• Conserves soil moisture/less runoff	• Lower seed quantity (when planted in appropriate density)
• Uniform ploughing and levelling	• Less labour (weeding done at the same time)	• Advantage in land-use
• Better crop performance	• Land-use advantage (used as green manure)	• Less labour (weeding and fertilizer is easier)
• Make soil friable and fine	• Good interaction as maize holds the climbing legume	• Reduces lodging of maize
• Improved cutting of the remainders of the previous crop	• Legume fixes nitrogen	• Higher yield
• To avoid deep ploughing that damages soil		
• All family members could use it		

one in all the intercrop treatments compared to the monocrop treatments (Table 4).

3.1.2. Farmer field discussions

Although farmers listed many perceived benefits associated with the tested practices (Table 5) and technologies during the FFD's, they indicated many reasons why those interventions were not used in their fields (Table 6). Concerning the on-farm trials, both in 2014 and 2015 farmers exhibited marked preferences for intercropping in both districts. In Dadeldhura the maize-cowpea intercrop was most preferred in 2014, and maize-soybean was the first choice in 2015. In Palpa maize-soybean was the first choice in 2014. In both districts sole soybean was the least preferred cropping system.

Table 6. Stated reasons why farmers did not try-out the selected agricultural innovations.

Palpa	%	Dadeldhura	%
Line sowing			
Lack of labour force at planting	55	Lack of labour force at planting	73
Tradition	13	Inappropriate rainfall	8
Lack of capital	12	Tradition	6
Inappropriate rainfall	7	Lack of knowledge	5
		Lack of capital	5
Mini-tiller			
Difficult to take to the sloping plots	25	Not available	43
Not available	16	Lack of capital	12
Availability of tractor	12	Difficult to take to the sloping plots	11
Lack of knowledge	12	Lack of person to operate it	9
Lack of person to operate it	11	Lack of knowledge	2
Hybrid seed			
Insect in storage	19	Preference local variety flavour	25
Prefer to use own seed	11	Not available	18
Tradition(neighbours use local varieties)	10	Expensive	13
Preference local variety flavour	5	Prefer to use own seed	9
Not available	5	Long maturity	8
Long maturity	4	Tradition(neighbours use local varieties)	8
Wild animals/less stover/insects inf.	2		
Mineral fertilizer			
FYM is enough	50	Not enough rainfall (soil becomes hard)	28
Not always available locally	14	FYM is enough	27
Not enough rainfall (soil becomes hard)	13	Lack of capital/expensive	15
Lack of capital/expensive	10	Tradition	13
Reduces soil fertility	2	Reduces soil fertility	11

Note: The percentage of farmers is an average of two observations (before and the trials and after the first year of trials).
[a]We considered answers such as 'because I like it' to be equivalent to 'prefer to use own seed'.

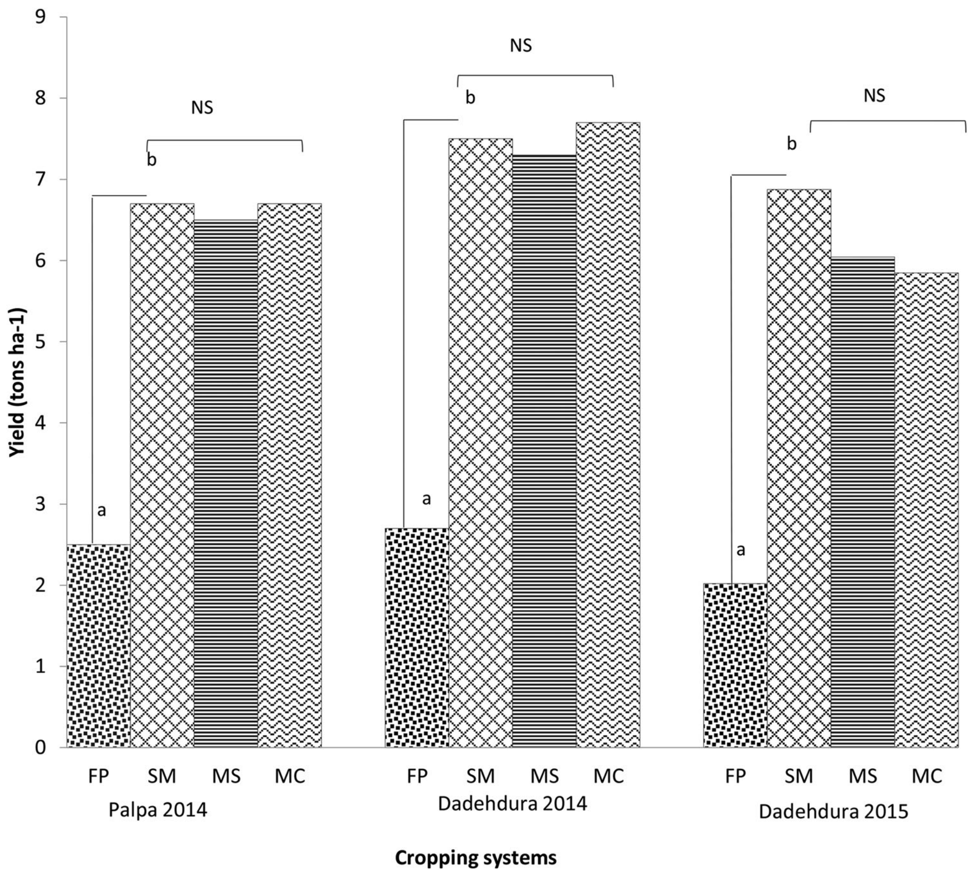

Figure 4. Maize grain yields for the four cropping systems where FP: farmer practice; SM: maize mono-crop; MS: maize and soybean intercrop; MC: maize and cowpea intercrop in Palpa and Dadeldhura. Different characters indicate significant different means ($p < .05$). NS represent no significant differences.

3.2. Impact assessment

3.2.1. Farmer perceptions

Within the two years, the standard deviation of perception scores was lower after the experiment than at the start of the season, which could indicate a convergence of opinion about comparisons of both line sowing vs. broadcasting, and mini-tiller vs. animal traction with oxen (Figures 4 and 5).

3.2.2. Seeding method

There were clear differences in perceptions of seed required and yields obtained when comparing seeding methods that persisted throughout the two-year project duration (Figure 4(a) and 5(a)). Farmers in both Palpa and Dadeldhura clearly perceived that more seeds were required when seeding by broadcasting than with line sowing (Figure 4(a) and 5(a)). Similarly, they expected yields to be higher after seeding in lines than by broadcasting. In addition, at the start of the project farmers in Dadeldhura expected that lower costs and labour inputs were needed for seeding by broadcasting, while in Palpa the costs of broadcasting were perceived higher than line sowing. The anticipated costs of line sowing were lower in Palpa after the first year of trials (Figure 5(a)). Some of the perceptions changed during the project. The perception of labour requirement of line sowing was lower after the two years of trials in Dadeldhura. The perceived differences between line seeding and broadcasting were smaller after the project (Figure 4(a) and 5(a)).

The number of farmers that had a positive change of perception towards line sowing increased after the second year of trials. Yield had the highest number of farmers with a positive change of perception, followed

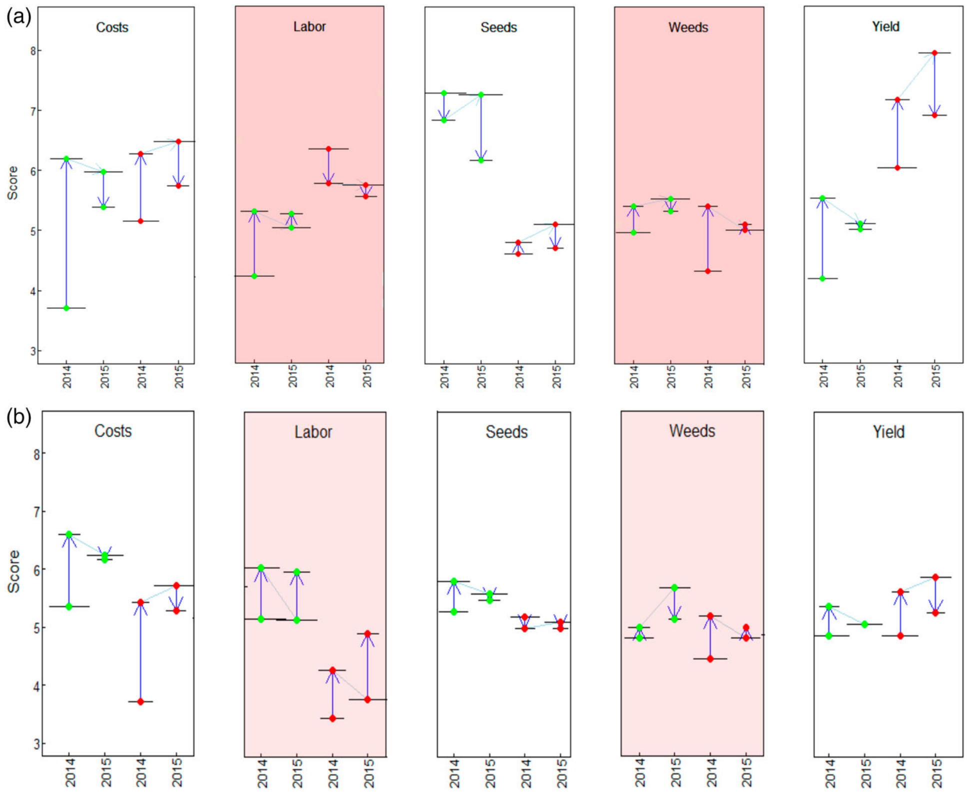

Figure 5. Scoring of the relative input requirements (costs, labour, seeds) and crop performance (weed pressure, yield) of (a) seeding by broadcasting (green) vs. in lines (red), and (b) tillage using a mini-tiller (red) vs. animal traction with oxen (green), in Dadeldhura on a scale of 0–10 in 2014 and 2015. The blue arrow represents the change in perceptions before and after experiments within a year, the grey lines connect the last scoring of 2014 with the first of 2015. Error bars indicate the standard deviations.

by labour required, the amount of seeds used, expected costs, and the incidence of weed. While in Palpa the number of farmers with positive perception in order of descending significance was: costs, labour, yield obtained, seed required, and weeds pressure (Figure 5).

3.2.3. Tillage

In Dadeldhura the differences in perceptions of different tillage methods (mechanized tillage with a mini-tiller and animal traction with oxen) were less pronounced than for the perceptions of the sowing method. The main difference between the two tillage methods was the lower perceived labour requirement for mechanized tillage with a mini-tiller (Figure 4(b)). Within both experimental years, the expectation of labour requirements was higher after the experiment than at the start of the season for both tillage methods. The initial farmer perception about the expected lower costs and labour inputs with a mini-tiller changed to a comparable score of ca. 5.5 for both tillage methods. In Palpa, the cost and labour required for the use of animal traction were perceived much higher than when using a mini-tiller (Figure 5(b)). However, the perception of the amount of labour required for the mini-tiller increased during the two years in Dadeldhura. Similarly, the cost of the mini-tiller was perceived higher at the end of the trials in comparison to the initial perception (Figure 4(b) and 5(b)).

In Dadeldhura yield scored the largest number of farmers with a positive change in perception of the mini-tiller, followed by seed requirement and weed incidence. Fewer farmers changed their perception about costs and labour requirements at the end of the second year (labour scored high only after the first year) (Figure 4(b)). In contrast, in Palpa the majority of farmers had a positive change in perceptions of expected costs, followed by labour needed, yields, weed incidence, and amount of seed (Figure 5(b)).

3.2.4. Perception by different types of farmers

In general, a larger proportion of medium resource endowment (MRE) to high resource endowment (HRE) farmers changed their perceptions in Palpa, while in Dadeldhura there was not a clear pattern but mostly low resource endowment (LRE) to MRE farmers had a positive change of perception. The farmers that had a positive change in perception of labour required for seeding in lines belonged to the low resource endowment type in Dadeldhura, while those that had the positive change of opinion in Palpa belonged to the medium and HRE types.

The farmers that had positive change of perception about the obtained yield and required seed in Dadeldhura belonged to the low resource endowment type. The positive change of perception of cost required for the use of mini-tiller in Palpa was indicated by low to MRE farmers.

3.3. Early adoption of the technologies and practices

3.3.1. Farmer's perceived constraints to adoption

The reasons for low adoption of innovations discussed with the farmers previous to the trials in 2014 and after one year of participatory on-farm trials are depicted in Table 6. The main reasons for non-adopting innovations in both sites were stated to mainly relate to the labour constraint, the low availability of the technology and farmer perception and preferences.

3.3.2. Try-out of practices and technologies

The try-out of the practices and technologies was based on the farmers that indicated that they started to use the technologies since 2015 (Table 7). All of the farmers experimented only partially and only in plots close to the homestead.

Table 7. Percentage of technology and practice innovation users in 2015.

Innovation	Palpa (%) (#)[b]	Dadeldhura (%) (#)
Line sowing	5 (2)	20 (7)
Mini-tiller	15 (6)	0
Hybrid seed	5 (2)	17 (6)
Improved OPV[a] seeds	20 (8)	20 (7)
Mineral fertilizers	10 (4)	3 (1)

[a]Open pollinated varieties.
[b]Number of farmers.

3.3.3. Type of farmers

Most of the farmers that used the practice of sowing in lines and mineral fertilizers in 2015 belonged to the HRE type and to a high social cast level. The only farmers that bought hybrid seeds belonged to the HRE type; additional farmers that used the hybrid seeds obtained the seed from development projects.

In Palpa, only HRE farmers used hybrid seed before the start of our study. However, in 2015, MRE and LRE started using hybrid seed. It is important to note that these farmers had our trials in their fields and were active in the development of the experiments. Predominantly MRE farmers used the improved OPV *Manakamana*, line seeding and mineral fertilizer. Only one HRE farmer practiced seeding in lines in all the fields of his farm. Farmers from all endowment types started using a mini-tiller in Palpa.

3.3.4. Relation between try-outs and perceptions

Early adopter farmers demonstrated a positive change of perception at least in one of the factors evaluated. The farmers that tried line sowing in Palpa had also a positive change of perception about the required costs and labour. Only one had a positive change in perception about yield (Figure 6(a)). While in Dadeldhura, the farmers that tried out had a positive change of perception for at least one of the variables tested. Thirty-three percent of those farmers had a positive change of perception of labour needed, 29% about money required, 24% about yield obtained, 22% about the amount of seed needed, and 8% about weed infestation (Figure 6(b)).

Concerning the use of mini-tiller, in Palpa most of the farmers had a positive perception of costs (46%) and labour (33%). Yield and weed population (28%) and only 23% had a positive change of perception about required seed (Figure 6(c)). None of the farmers adopted the use of a mini-tiller in Dadeldhura.

4. Discussion

Through the participatory approach in our study, farmers were informed about experimenting with new practices and technologies by providing training and experiential learning on their fields, and had the chance to reflect upon their previous perceptions, while the researchers were able to improve their understanding of the factors that constrain farmers adoption of innovations. In addition, the project gave

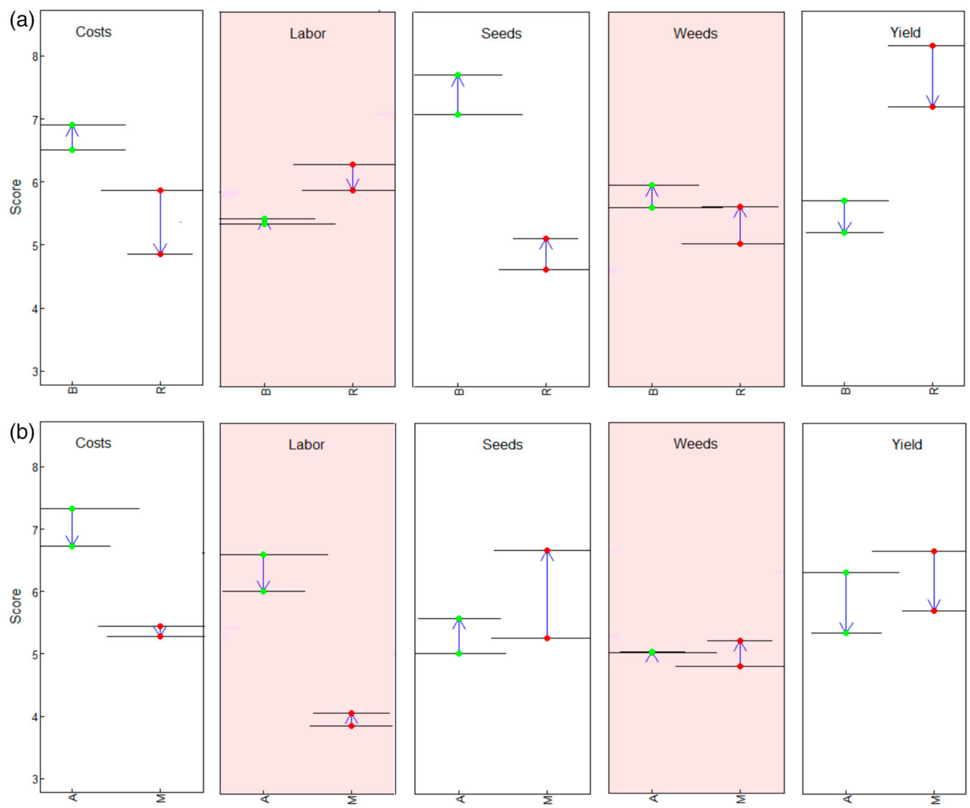

Figure 6. Scoring of the relative input requirements (costs, labour, seeds) and crop performance (weed pressure, yield) of (a) seeding by broadcasting (B) in green vs. in lines (R) in red, and (b) tillage using animal traction with oxen (A) in green vs. mini-tiller (M) in red in Palpa on a scale of 0–10 in 2014. The blue lines represent the change in perceptions before and after experiments within a year, the grey lines connect the scoring before and after the trials in 2014. Error bars indicate the standard deviations.

insights of how participatory approaches can have an impact on the perceptions of farmers towards innovations and their potential adoption. According to Tiwari et al. (2004), participatory methods provide a way to assess and inform farmer perceptions that cannot be captured in on-station trials. Similarly, Pircher, Almekinders, and Kamanga (2013) indicated that social analysis is crucial to understand the effectiveness of participatory technology evaluations. In particular women, household members are difficult to reach, while they play an important role in farming in the mid-hills of Nepal. Through the participatory method, it was feasible to involve women, to compile their reasons for adoption or non-adoption and to understand their perceptions. This study contributed to the evidence that considerably higher yields (Devkota et al., 2015) can be obtained in farmer fields in our case study areas, and it enriched the knowledge on the performance of maize-legumes intercrops. Furthermore, with the FFD and the perception assessment, we demonstrated that farmers are aware of the advantages that sowing in lines can bring in terms of yield and seed saving, and the use of a mini-tiller in terms of labour and costs. However, farmer decisions to use those practices and technologies were affected by a multitude of bio-physical, social (including cultural), and institutional factors.

4.1. On-farm participatory learning

The effect of our project and in particular of the experiments was shown by the convergence of opinion that occurred during the two growing seasons, and was observed for the comparisons of both line sowing vs. broadcasting and mini-tiller vs. animal traction with oxen (Figures 3 and 7). Also, Kraaijvanger et al. (2016) showed that attitudes and congruency of opinion of farmers towards agricultural innovations were affected by participatory experimentation.

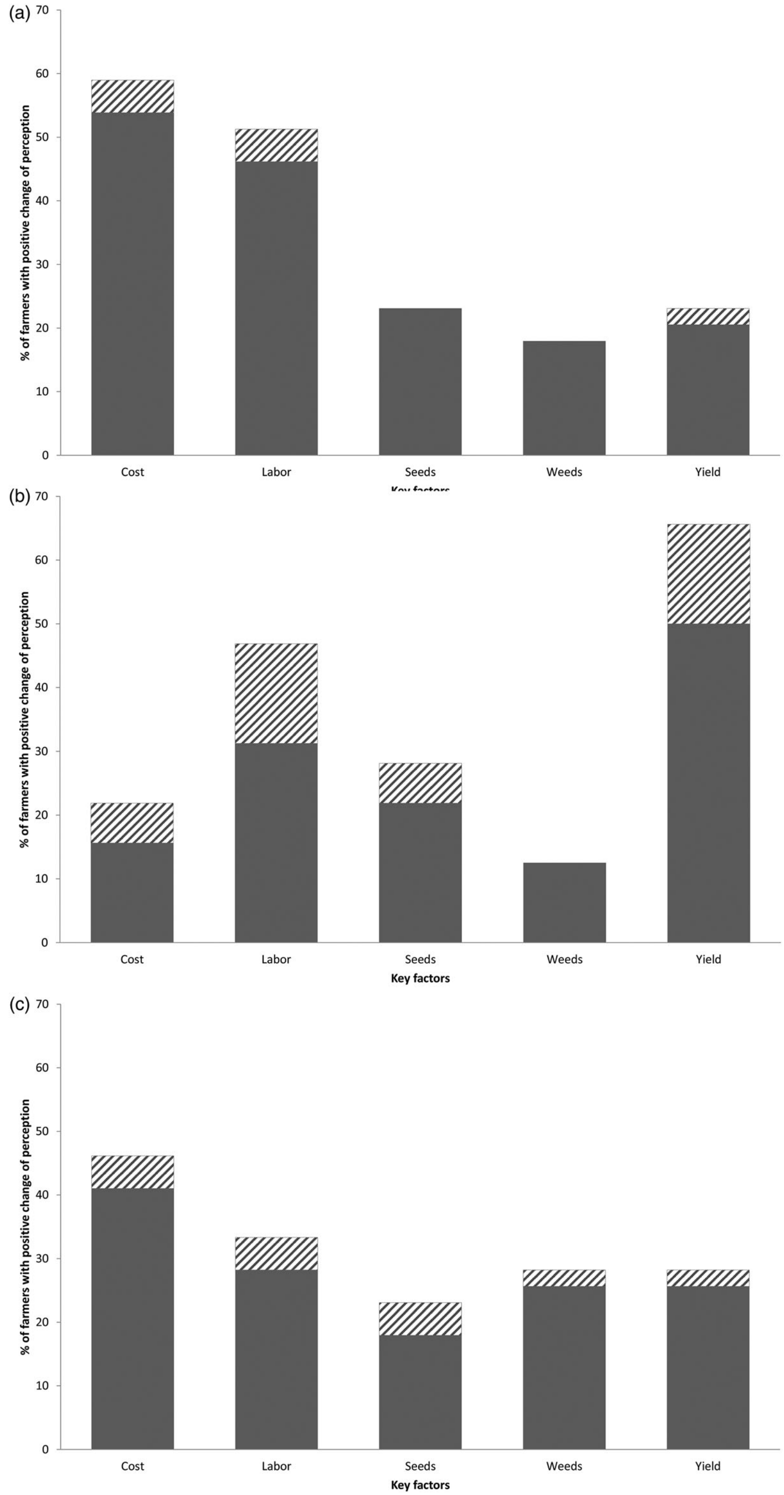

Figure 7. Percentage of farmers with positive change of perception of the key factor and the percentage of early adopters in dotted font for (a) line sowing in Palpa, (b) line sowing in Dadeldhura, and (c) mini-tiller in Palpa. There were not early adopters of mini-tiller in Dadeldhura.

The scoring procedure applied allowed to assess the changes in farmer perceptions. Farmers partially trying out one of the technologies or practices after the first year of the project had a positive change in perception. At least in one of the factors used in the perception assessment. Hence, not all assessed factors (labour, costs, yield, seeds, and weeds) needed to be changed positively to allow an adjustment in behaviour. There were less positive changes in the perceptions of the mini-tiller than about line sowing. Farmers' perceptions of both line sowing in comparison to broadcasting, and mini-tiller as opposed to animal showed that yield is not the only decisive factor affecting adoption of the practices.

Through the reasons given by farmers and the assessment of their change of perceptions, we could explore a broad range of farmers' reasons of reluctance to 'innovate' in the mid-hills agro-ecosystems. Many of the stated constraints to try-out new practices and technologies were related to timely labour availability, supply of inputs (by costs or availability), and cultural preferences (including socio factors). Similar factors affecting adoption have been described previously in small farming systems (Andersson & D'Souza, 2014; Awan et al., 2015; Brown, Nuberg, & Llewellyn, 2017; D'Souza, Cyphers, & Phipps, 1993; Kotu, Alene, Manyong, Hoeschle-Zeledon, & Larbi, 2017; Mbosso et al., 2015; Ransom et al., 2003; Toth, Nair, Duffy, & Franzel, 2017).

Aw-Hassan (2008) argued that farmers involvement (through participatory approaches) in the design and implementation, enhance the impact of agricultural research. Yet, these approaches have been also criticized as impractical to scale-out technologies, especially because of the high cost involved. We argue that the stage in which farmers are involved is key. The initial phases of the project are the most important to involve farmers. As mentioned by other studies, farmers should be involved in early stage of the design of innovations and the practices and technologies should be built or adjusted on existing local knowledge traditional practices, and livelihood goals (Millar & Connell, 2010; Pretty, 2002). In addition the farmers sample should represent the heterogeneity in the zone.

4.2. Timely labour availability

Labour availability has been mentioned as one of the main causes of low agricultural productivity in the mid-hill regions in Nepal (Tiwari et al., 2004). This was also observed in our study, as a mismatch between the demand for labour to carry out farm activities in a timely manner and the availability of labour was identified as one of the main reasons for not using the proposed practices. For example, in Palpa the main constraint for not practising sowing in lines mentioned by farmers was the narrow time window for sowing after the onset of rains and the limited availability of oxen-ploughing or tractor to rent during that period. The farmers in both Palpa and Dadeldhura were constrained by limited availability of labour due to migration of young male household members and low involvement of the youth. Especially in Palpa farmers repeatedly stated that 'young people don't want to work in agriculture, it is difficult to find people to hire in this area'. As a result, there is a large labour constraint at moments with peaks in labour demand, such as sowing time.

The proposed technologies were evaluated for the expected demand of labour. Farmers initially expected benefits of reducing the labour demand by mechanisation of tillage with a mini-tiller, but that perception was adjusted when they experienced the difficulty of taking the mini-tiller to remote plots located on steep slopes with difficult access (Figure 3(b)). For the proposed practice of sowing in lines farmers initially thought it would require more labour input than the traditional practice of broadcasting the seed (Figure 3(a)). Although this perceived higher labour demand for line sowing declined during the project, timely availability of labour was still mentioned as the main reason for low try-out of this practice. As a consequence, the try-out of line sowing was low in Palpa (5%) but relatively high in Dadeldhura (20%) where farm activities are mostly performed by family members, in contrast to Palpa were hired labour is more common. Furthermore, line sowing is a relative easy practice to implement, with low input requirement, low risks, and high returns. These simple technologies are more likely to have a shorter adoption and are more likely to be scaled out (Millar & Connell, 2010; Rogers, 2003).

4.3. Access to inputs (cost and availability)

The lower try-out of mini-tillers, and mineral fertilizers in Dadeldhura than in Palpa was probably related to lower levels of village connectivity, supply of technology information and connections to markets in

Dadeldhura. As stated by previous studies in small farming systems (Kotu et al., 2017; Millar & Connell, 2010; Ransom et al., 2003; Reed, Chan-Halbrendt, Tamang, & Chaudhary, 2014). Palpa has a better connection to markets to the more developed lowlands of the Terai, which might have influenced access to inputs. This reflects the findings of Andersson and D'Souza (2014) and Reed et al. (2014) that indicated that smallholders with some market access, maybe be primed for adoption of conservation agriculture practices. The adoption of mineral fertilizer in the mid-hills has been conditioned by the timely availability and the quality of the fertilizers in local markets.

In general, the expected costs for use of mini-tillers were lower than for oxen use, but the difference in perceived costs between the two technologies decreased in both case study areas (Figure 3(b) and 7(b)). During the project, farmers realized that acquiring the mini-tiller will imply additional costs due to the cost of fuel, maintenance and skilled labour to operate. On the other hand, farmers in Dadeldhura seemed to underestimate the costs of ploughing with oxen (owned or shared with neighbours), because they do not necessarily consider their own labour as an extra financial cost. In contrast, farmers in Palpa were able to compare these costs with the cost of renting oxen or tractor and perceived lower cost associated with using a mini-tiller. The highest try-out rates of mini-tillers could be anticipated in Palpa, since machinery ownership is positively associated with household assets, credit availability, electrification, and road density (Mottaleb, Krupnik, & Erenstein, 2016).

The try-out of hybrid and improved OPV varieties after the first year of our project was relatively high considering only one growing season of participatory trials when comparing to the reported average nine years required to adopt hybrid maize as reported by (Rogers, 2003). In both project sites, the improved varieties were sowed in plots close to the homestead as farmers perceived non-local seeds as requiring more inputs and better soils, as also observed in other tropical smallholder farming systems (Andersson & D'Souza, 2014; Tittonell et al., 2010). Furthermore cultivation of improved varieties was preferred in fields close to the homestead to prevent the attack from wild animals in both regions. We found that mainly high resource-endowed farmers started experimenting with improved or hybrid varieties. Ransom et al. (2003) had similar findings.

4.4. Cultural preferences

The feminization of agriculture may have limited the mini-tiller try-out in both regions. In the villages studied in Dadeldhura, farming is predominantly done by women, due to out-migration of men. Many of the female farmers here, stated not to be confident to operate machinery. Moreover, ploughing is traditionally seen as a male activity in both mid-hill regions. Similarly, in Palpa men operate and provide service of the mini-tiller, none of the women recalled to have ever used mini-tiller or any other machinery. Moreover, taking over these activities from men would increase their already large labour burden further, while they are already responsible for many tasks (Halbrendt et al., 2014). These cultural reasons are often overlooked by development projects, but already provide a valid explanation of why women are not willing to adopt mechanized technologies in the household as they associated it with an increase in labour specially in Dadeldhura that ploughing services are done by family members in contrast to Palpa that it is a purchased service.

Similarly, in Palpa, traditionally preferred grain colours and flavours were a strong reason for not using improved seed varieties before and after the participatory trials. In addition, the growth duration until crop maturity of the hybrid cultivars was mentioned as a cause of low adoption. The hybrids used during the first year of participatory trials took 15 days longer to mature than the local variety. This is a reason of farmers' concern since the delay in maize maturity and harvest could cause planting delays of the subsequent winter crop (Karki et al., 2015). In addition, in general farmers preferred white varieties (local) in participatory varietal selection Tiwari, Virk, and Sinclair (2009), because these are considered to be compatible with their farming systems. This is specially the case in Dadeldhura where maize use is mostly used for home consumption, while in Palpa it is used mainly for livestock feed.

Moreover, farmers have the perception that low rainfall availability leads to hard soils when using mineral fertilizers. This was mentioned in both sites repeatedly, and goes in line with earlier conducted studies about perceptions in the mid-hills where farmers expressed awareness that the physical properties of 'soil were damaged by the continuous use of only mineral fertilizers, with soils becoming more difficult to plough and clods more difficult to break' (Tiwari et al., 2004). Cultural preferences and priorities also influence farmers' decisions for crops and activities in other ways. For instance, when asking a farmer why she didn't use line sowing the answer was: 'I wanted to plant all the field in lines, but I had to go to the temple so I just broadcasted the rest'.

4.5. Farmer diversity

In addition, the perceptions and the experimentation varied among the different type of farmers. As stated by Tiwari et al. (2004) it is unlikely that one combination of traits, will suite all conditions of all farmers population. In both mid-hill regions, the main adopters were the HRE farmers. This is in line with Rogers (2003) who stated that first innovators are usually characterized by a higher social status. LRE farmers have often been found to be limited in development and adoption of innovations. They are grid-locked in so-called poverty traps (Tittonell, 2014) and are less willing and able to take risks (Millar & Connell, 2010).

4.6. Sustainable intensification and implications

The changes in perception of farmers throughout the two-year project showed that communication with farmers could influence their opinions. These opinions will eventually inform their decision-making regarding experimentation and subsequent adoption of sustainable intensification practices or technologies. However, the sustainability of the use of combination of external inputs to increase yields requires careful consideration in the farming systems of the mid-hills of Nepal. In the regions characterized by high male migration where women are overloaded, practices that require additional labour (such as line sowing) may be unsustainable (Halbrendt et al., 2014). In addition, most of the farmers in the studied communities have low investment capacity which will limit their possibilities to purchase inputs such as hybrid seeds and mineral fertilizers every year, even if these inputs are available on the local market.

The importance of adopting innovations in mid-hill farming systems depends on the household objectives. Although, the main goal for the farms studied is to safeguard food security, farmers desire to intensify is associated with the wish to move to market orientation. However, crop intensification has been criticized as a pathway to reduce poverty in rain-fed small farming systems due to its limited profitability (Harris & Orr, 2014). Three scenarios were suggested by Harris and Orr (2014) under which crop production may function as a direct pathway to move out from poverty: (1) extensification, (2) commercialization, and (3) income diversification. Farming systems in the mid-hills regions of Nepal are highly constrained by their size (less than half hectare) so extensification is hardly a promising option. Commercialization is restricted to farmers that have invested capacity and connection to markets, who usually commercialize vegetables. Income diversification has actually been the strategy that most of the farmers in the Dadeldhura and Palpa are using in order to cope with poverty. Further special attention shall be given to the trajectories of different types of farms in the mid-hills agro-ecosystems in order to identify farmers whose interest and livelihoods strategies align with (sustainable) intensification.

Different alternatives need to be studied to improve livelihoods of the rural population. All the different components of the farming systems should be assessed to find better options for sustainable intensification. As stated by Blackstock et al. (2007) sustainability requires an integrated and holistic systems approach, where biophysical processes have to be considered in the context of their social-economic drivers and responses.

4.7. Limitations

We argue that there were relative differences in perception and relative high try-out rate by the studied farmers after two years of participation. However, farmers' change of perception and try-out could be influenced by other factors. For instance, the farmers may have been influenced by the presence of other (humanitarian) projects in the case study areas. Moreover, farmers might align their answers to expectations about our study, as stated in similar studies (Andersson & D'Souza, 2014). In fact, when farmers were asked about what their practices will be in the future, some responded that their decision will be made depending on the projects available in the future, for example, 'Only if a project comes next year I will change my practices, otherwise I will keep on doing the same'. Projects often provide incentives such as 'free subsidized fertilizers, seeds, and herbicides', which results in questions about the nature of the adoption claimed (Andersson & D'Souza, 2014). Long-term adoption – or abandonment – would be only visible sometime after the project has ended.

5. Conclusions

A multitude of biophysical, social, and institutional factors constrain the productivity in small-scale farming systems in marginalized areas such as the mid-hills of Nepal. Sustainable intensification is increasingly proposed as a tool to improve the productivity of these systems and subsequently improve the livelihoods of small-scale farmers. However, empirical evidence of successful adoption of sustainable intensification methods by small-scale farmers is still scarce. In this study, we argue that the active participation of famers in identifying context-appropriate innovations is essential in the adoption process. Through a two-year farmer-oriented participatory research project, we showed that: (1) substantial productivity improvements can be achieved through intensification methods, (2) the active involvement of farmers in on-farm trials increased understanding of underlying decision-making factors to adopt or non-adopt improved practices, and (3) the engagement of farmers positively influenced farmer perceptions towards the adoption of innovations. Even though, productivity increased significantly through the explored improved methods, social and cultural factors limited its fast adoption. Especially, labour scarcity and limited economic capital formed major considerations to in particular low and medium resource-endowed farmers. There is a need to work to integrate all the components of the farming system to develop context-appropriate innovations. This study informs the agricultural development sector that to introduce appropriate agricultural innovations and attain sustainable productivity improvements, it is necessary to design context-specific projects and policies with active farmer participation.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Adesina, A. A., & Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: Evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics*, *13*, 1–9.

Almekinders, C. J. M., & Elings, A. (2001). Collaboration of farmers and breeders: Participatory crop improvement in perspective. *Euphytica*, *122*, 425–438.

Andersson, J. A., & D'Souza, S. (2014). From adoption claims to understanding farmers and contexts: A literature review of conservation agriculture (CA) adoption among smallholder farmers in Southern Africa. *Agriculture, Ecosystems & Environment*, *187*, 116–132.

Awan, S. A., Ashfaq, M., Naqvi, S. A. A., Hassan, S., Kamran, M. A., Imran, A., & Makhdum, A. H. (2015). Profitability analysis of sustainable cotton production: A case study of cotton – wheat farming system in Bahawalpur District of Punjab. *Bulgarian Journal of Agricultural Science*, *21*, 251–256.

Aw-Hassan, A. A. (2008). Strategies for out-scaling participatory research approaches for sustaining agricultural research impacts. *Development in Practice*, *18*, 564–575.

Becerril, J., & Abdulai, A. (2010). The impact of improved maize varieties on poverty in Mexico: A propensity score-matching approach. *World Development*, *38*, 1024–1035.

Blackstock, K. L., Kelly, G. J., & Horsey, B. L. (2007). Developing and applying a framework to evaluate participatory research for sustainability. *Ecological Economics*, *60*, 726–742.

Braun, A. R., Thiele, G., & Fernández, M. (2000). *Farmer field schools and local agricultural research committees: Complementary platforms for integrated decision-making in sustainable agriculture* (Network Paper No.105). London: Overseas Development Institute.

Brown, B., Nuberg, I., & Llewellyn, R. (2017). Negative evaluation of conservation agriculture: Perspectives from African smallholder farmers. *International Journal of Agricultural Sustainability*, *15*, 467–481.

Central Bureau of Statistics. (2014). *National Population and Housing Census 2011 (Village Development Committee/ Municpality)* (Vol. 6, pp. 9–80). Kathmandu,Nepal: National Planning Comission Secretariat Governement of Nepal.

Choudhary, A. K., & Suri, V. K. (2013). On-farm participatory technology development effects on resource conservation technologies in Rainfed Upland Paddy in Himachal Pradesh, India. *Communications in Soil Science and Plant Analysis*, *44*, 2605–2617.

Dahal, B. M., Nyborg, I., Sitaula, B. K., & Bajracharya, R. M. (2009). Agricultural intensification: Food insecurity to income security in a mid-hill watershed of Nepal. *International Journal of Agricultural Sustainability*, *7*, 249–260.

Department of Hydrology and Meteorology of Nepal. (2015). *Climatological and agrometeorological records of Nepal* June 2015 ed. Kathmandu : Ministry of Population and Environment, Department of Hydrology and Meteorology.

Devkota, K. P., McDonald, A. J., Khadka, A., Khadka, L., Paudel, G., & Devkota, M. (2015). Decomposing maize yield gaps differentiates entry points for intensification in the rainfed mid-hills of Nepal. *Field Crops Research*, *179*, 81–94.

Dijkshoorn, J., & Huting, J. (2009). *Soil and terrain database for Nepal* (Report 2009/01). In Information, I.-W.S. (Ed.), 2009/01 ed, Wageningen, p. 29.

D'Souza, G., Cyphers, D., & Phipps, T. (1993). Factors affecting the adoption of sustainable agricultural practices. *Agricultural and Resource Economics Review*, *22*, 159–165.

Garnett, T., Appleby, M., Balmford, A., Bateman, I., Benton, T., Bloomer, P., … Fraser, D. (2013). Sustainable intensification in agriculture: Premises and policies. *Science*, *341*, 33–34.

Ghimire, R., & Huang, W.-C. (2015). Household wealth and adoption of improved maize varieties in Nepal: A double-hurdle approach. *Food Security*, *7*, 1321–1335.

Halbrendt, J., Kimura, A. H., Gray, S. A., Radovich, T., Reed, B., & Tamang, B. B. (2014). Implications of conservation agriculture for men's and women's workloads among marginalized farmers in the central middle hills of Nepal. *Mountain Research and Development*, *34*, 214–222.

Harris, D., & Orr, A. (2014). Is rainfed agriculture really a pathway from poverty? *Agricultural Systems*, *123*, 84–96.

Hellin, J., Bellon, M. R., Badstue, L., Dixon, J., & La Rovere, R. (2008). Increasing the impacts of participatory research. *Experimental Agriculture*, *44*, 81–95.

Hoffmann, V., Probst, K., & Christinck, A. (2007). Farmers and researchers: How can collaborative advantages be created in participatory research and technology development? *Agriculture and Human Values*, *24*, 355–368.

Hunter, M. C., Smith, R. G., Schipanski, M. E., Artwood, L. W., & Mortensen, D. A. (2017). Agriculture in 2050: Recalibrating targets for sustainable intensification. *BioScience*, *67*(4), 386–391. http://dx.doi.org/10.1093/biosci/bix010

Karki, T. B., Sah, S. K., Thapa, R. B., McDonald, A. J., & Davis, A. S. (2015). Identifying pathways for improving household food self-sufficiency outcomes in the Hills of Nepal. *PLoS ONE 10*, e0127513.

Kotu, B. H., Alene, A., Manyong, V., Hoeschle-Zeledon, I., & Larbi, A. (2017). Adoption and impacts of sustainable intensification practices in Ghana. *International Journal of Agricultural Sustainability*, *15*(5), 539–554. https://doi.org/10.1080/14735903.2017.1369619

Kraaijvanger, R., Veldkamp, T., & Almekinders, C. (2016). Considering change: Evaluating four years of participatory experimentation with farmers in Tigray (Ethiopia) highlighting both functional and human-social aspects. *Agricultural Systems*, *147*, 38–50.

Li, C.-J., Li, Y.-Y., Yu, C.-B., Sun, J.-H., Christie, P., An, M., … Li, L. (2011). Crop nitrogen use and soil mineral nitrogen accumulation under different crop combinations and patterns of strip intercropping in Northwest China. *Plant and Soil*, *342*, 221–231.

Lilja, N., & Ashby, J. A. (1999). *Types of participatory research based on locus of decision-making* (PRGA Working Document No. 9). CGIAR Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation. Cali: CGIAR.

Mancini, F., Termorshuizen, A. J., & Bruggen van, H. C. (2006). *Impact of integrated pest management farmer field schools on health, farming systems, the environment, and livelihoods of cotton growers in Southern India*. Wageningen: Biological Farming systems Wageningen University.

Mapfumo, P., Adjei-Nsiah, S., Mtambanengwe, F., Chikowo, R., & Giller, K. E. (2013). Participatory action research (PAR) as an entry point for supporting climate change adaptation by smallholder farmers in Africa. *Environmental Development*, *5*, 6–22.

Mbosso, C., Degrande, A., Villamor, G. B., Van Damme, P., Tchoundjeu, Z., & Tsafack, S. (2015). Factors affecting the adoption of agricultural innovation: The case of a *Ricinodendron heudelotii* kernel extraction machine in Southern Cameroon. *Agroforestry Systems*, *89*, 799–811.

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in Sub-Saharan Africa. *International Journal of Agricultural Sustainability*, *13*, 40–54.

Millar, J., & Connell, J. (2010). Strategies for scaling out impacts from agricultural systems change: The case of forages and livestock production in Laos. *Agriculture and Human Values*, *27*, 213–225.

Misiko, M. (2009). Collective experimentation: Lessons from the field. *The Journal of Agricultural Education and Extension*, *15*, 401–416.

MoAD. (2014). *Statistical information on Nepalese agriculture*. December 2014 ed. Kathmandu: Ministry of Agricultural Development, Government of Nepal, Agribusiness Promotion and Statistics Division. p. 222.

Mottaleb, K. A., Krupnik, T. J., & Erenstein, O. (2016). Factors associated with small-scale agricultural machinery adoption in Bangladesh: Census findings. *Journal of Rural Studies*, *46*, 155–168.

Paudel, P., & Matsuoka, A. (2008). Factors influencing adoption of improved maize varieties in Nepal: A case study of Chitwan District. *Australian Journal of Basic and Applied Sciences*, *2*, 823–834.

Pircher, T., Almekinders, C. J. M., & Kamanga, B. C. G. (2013). Participatory trials and farmers' social realities: Understanding the adoption of legume technologies in a Malawian farmer community. *International Journal of Agricultural Sustainability*, *11*, 252–263.

Pretty, J. (2002). *Agriculture: Reconnecting people, land and nature*. London: Earthscan Publication Limited.

Pretty, J., & Bharucha, Z. P. (2014). Sustainable intensification in agricultural systems. *Annals of Botany*, *114*, 1571–1596.

Ransom, J. K., Paudyal, K., & Adhikari, K. (2003). Adoption of improved maize varieties in the hills of Nepal. *Agricultural Economics*, *29*, 299–305.

Raut, N., Sitaula, B. K., Aune, J. B., & Bajracharya, R. M. (2011). Evolution and future direction of intensified agriculture in the central mid-hills of Nepal. *International Journal of Agricultural Sustainability*, *9*, 537–550.

Reed, B., Chan-Halbrendt, C., Tamang, B. B., & Chaudhary, N. (2014). Analysis of conservation agriculture preferences for researchers, extension agents, and tribal farmers in Nepal using analytic hierarchy process. *Agricultural Systems*, *127*, 90–96.

Rockström, J., Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., … Smith, J. (2017). Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio*, *46*, 4–17.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed). New York: The Free Press, Simone & Schuster.

Tittonell, P. (2014). Livelihood strategies, resilience and transformability in African agroecosystems. *Agricultural Systems*, *126*, 3–14.

Tittonell, P., Muriuki, A., Shepherd, K. D., Mugendi, D., Kaizzi, K. C., Okeyo, J., … Vanlauwe, B. (2010). The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa – a typology of smallholder farms. *Agricultural Systems*, *103*, 83–97.

Tiwari, T. P., Brook, R. M., & Sinclair, F. L. (2004). Implications of hill farmers' agronomic practices in Nepal for crop improvement in maize. *Experimental Agriculture*, *40*, 397–417.

Tiwari, K. R., Nyborg, I. L. P., Sitaula, B. K., & Paudel, G. S. (2008). Analysis of the sustainability of upland farming systems in the middle mountains region of Nepal. *International Journal of Agricultural Sustainability*, *6*, 289–306.

Tiwari, T. P., Virk, D. S., & Sinclair, F. L. (2009). Rapid gains in yield and adoption of new maize varieties for complex hillside environments through farmer participation: I. Improving options through participatory varietal selection (PVS). *Field Crops Research*, *111*, 137–143.

Toth, G. G., Nair, P. K. R., Duffy, C. P., & Franzel, S. C. (2017). Constraints to the adoption of fodder tree technology in Malawi. *Sustainability Science*, *12*(5), 641–656. 10.1007/s11625-017-0460-2

Zabala, A., Garcia-Barrios, L., & Pascual, U. (2013). *Understanding the role of livelihoods in the adoption of Silvopasture in the tropical forest frontier*. Cambridge: BIOECON Conference University of Cambridge.