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Yerba mate field, Argentina. Photo: Marcelo Javier Beltran

The Argentinian experience with yerba mate in agroforestry

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Introduction

Climate change mitigation and food security are two of the main challenges in today's societies. Agroforestry — defined as the presence of trees on cropland, as external and internal boundaries and on any other available niche of farmland — can provide both food and climate change mitigation. As an agroecosystem that combines trees with farming practices, agroforestry has the potential to increase both biomass and soil carbon while maintaining agricultural production (Cardinael et al. 2017). There are several types of agroforestry systems, with different rates of above-ground and soil carbon sequestration (Corbeels et al. 2019). Agroforestry also contributes to water quality improvement, biodiversity enhancement, erosion control and nutrient cycling and availability (Dordel 2009; Varah et al. 2013).

Left: Yerba mate nursery; right: Yerba mate adult plants in production. Photos: Marcelo Javier Beltran

Due to this multitude of positive environmental and ecosystem services, agroforestry practices may directly contribute to the achievement of a number of United Nations Sustainable Development Goals (SDGs): 2 (no hunger), 7 (renewable energy), 11 (sustainable cities and communities), 12 (responsible consumption), 13 (climate action), 15 (life on land), and — often neglected — 17 (partnerships for the goals). It may also benefit other SDGs indirectly (Hübner et al. 2021).

Yerba mate

Yerba mate, or YM (*Ilex paraguarensis*) is a tree species approximately 15 metres (m) tall native to South America. It occupies the medium stratum of the continent's Atlantic Forest. The tree is endemic to eastern Paraguay, Misiones Province in Argentina and the southern Brazilian states of Rio Grande do Sul, Santa Catarina and Paraná (Giberti 2011). It is found in natural association with *Araucaria angustifolia* and *Ocotea* sp. The soils in the region are acidic (pH 5–6) old oxisols, and actual fertility depends greatly on the availability of organic matter.

The dried YM leaves are used for a traditional infusion that is sipped with a straw; this goes back to pre-Hispanic times. Jesuit priests learned how to grow the trees and planted them in plantations as far back as 1704. The infusion can be drunk with hot water (*mate*) or cold water (*terere*). The infusion can also be prepared as a tea.

During the last decades, new products have emerged, such as dehydrated powder to prepare "instant mate."

The small branches and leaves of YM are traditionally harvested during the southern hemisphere's fall and winter, between April and August. The drying process typically involves two stages. The first consists of passing the leaves and small branches (less than 10-mm diameter) through direct flames. This stage, known as "cracking," decreases moisture to 33% and sterilizes the leaves. The second stage consists of conventional drying at temperatures between 90 and 120°C for 2.5 to 4.5 hours under direct heat (hot air with smoke) or indirect heat (heated air through a heat exchanger). This is followed by maturation and finally by grinding and packaging. In Brazil, most YM is ground, packaged and marketed immediately after drying and must be consumed within two months. In Paraguay and Argentina, the leaves are matured in a dry dark building for a minimum of six months and, ideally, 12 to 18 months. During this period an oxidation process occurs, adding a golden yellow colour to the leaves and resulting in a less strong taste, which consumers in these countries especially appreciate.

There are two main strategies for YM production: a) large-scale farms based on the use of fertilizers and economies of scale (mechanical harvest, intensive management); and b) niche markets involving diverse special tastes, blends, sustainability and agroforestry landscapes.

Traditionally, YM was harvested by climbing the trees every two to three years in forest stands with naturally high proportions of trees and cutting the ends of branches with leaves. Cultivation of the trees increased during the 19th century in agroforestry arrangements that included *Araucaria* trees, and in association with cattle-raising in the Santa Catarina, Río Grande do Sul and Misiones highlands. In 1924, seeking higher productivity and easier ways to harvest the leaves, large-scale "open sky" monoculture plantations were established. Managing 1.5 m–2.5 m bushes instead of the native trees, which are approximately 15 m tall, eliminated the need to climb the trees to harvest the leaves, which could be dangerous. And by observing leaf-sprouting patterns, researchers and farmers have also found ways to increase the proportion of thin branches and leaves to be harvested. Initially, 600–1,200 bushes per ha were recommended. During the late 1970s and 80s, however, the recommended density increased to 2,200 bushes per ha. The last two decades have seen a slowly increasing interest in mechanized harvesting, with a recommended density of 2,700–4,000 trees per ha to facilitate a very high proportion of leaves in the harvest.

During the last two and a half decades, there has been increasing interest in high-quality YM grown in more natural, sustainable and shaded conditions, and in developing energizing beverages. Today, in Misiones Province, 16,000 farmers cultivate 182,000 ha of YM yielding 276,000 tonnes of dry leaves yearly; this is their main source of income. Of the farmers, 85% are smallholder who manage only 10% of the total crop volume. Of the dried YM, 10% is exported to a growing market in Europe, the USA and the Middle East. In the first two markets, consumption is boosted by South American expatriates and by the growing interest in healthy drinks. In the Middle East, where the culture of sipping mate is surprisingly blending in, Syria is the country with the highest YM imports.

Yerba mate agroforestry in Argentina's Misiones Province

Back in the 1930s, the immigrant farmer Alberto Roth, who admired the Swiss naturalist Moisés Bertoni (who had emigrated to the Upper Paraná river region in Paraguay,) observed that YM under naturally occurring *Araucaria angustifolia* trees grew better than under open-sky conditions. This was the start of promoting an agroforestry practice for YM. Later, in the 1980s, Juan Kozarik, Santiago Lacorte, Florencia Montagnini and other researchers working in the region noted the contribution of trees in agroforestry and silvopastoral arrangements to maintaining soil fertility and carbon sequestration, and even to sustaining and increasing crop and animal yields, when properly managed. Later, other researchers (Fernández et al. 1997) demonstrated that the level of some soil nutrients in YM plantations can be higher under trees than under conventional open-sky plantations. Julia Dordel (2009), working with nurse (shelter) trees in mixed tree plantations, demonstrated that *Grevillea robusta* doubles the availability of phos-

Left: Mate *bombilla* (drinking straw), package of dried Yerba mate leaves and ready-made drink; right: Argentinian woman sipping mate. Photos: Marcelo Javier Beltran



Left and right: Santo Pipó agroforestry trial; centre: views and farmers' visit. Photos: P. Gonzalez

phorus in the soil and in the leaves of the sheltered species *Toona ciliata*. A silvopastoral demonstration plot in Tres Capones, Misiones, also showed a 50% increase in forage from *Axonopus catarinensis* grown under *Grevillea robusta* trees compared to traditional open-sky pastures (Colcombet et al. 2019).

The effect of shading on YM yield and quality was studied in a trial growing YM under the trees *Grevillea robusta, Fraxinus* sp. and *Peltophorum dubium* (Prat Kricun and Kuzdra 2011). Results showed a 15% higher YM yield under *Grevillea robusta* after seven years. This seems to reject an initial hypothesis that YM needs to be grown under deciduous trees, since *Grevillea robusta* is an evergreen species. The trial also pinpoints the possibility that YM is benefiting from the *Grevillea robusta* effect on soil phosphorous, which may offset the depressive yield effect from possible excess shading.

A YM trial plantation simulating 0, 30, 50 and 70% shading indicated a tendency to reduced yield under increased shading. However, no clear statistical relationship between shading and YM yield was found in a YM trial under the tree species *Peltophorum dubium, Cordia trichotoma, Parapiptadenia rigida, Balfourodendron riedelianum, Handroanthus heptaphyllus, Grevillea robusta, Toona ciliata, Araucaria angustifolia* or *Paulownia tomentosa* on the farm of Luis Comoli, Santo Pipó, Misiones Province (Munaretto et al. 2019).

Shading could also influence YM leaf quality. As a rule, plants tend to intensify the production of secondary metabolites and essential oils when subject to shading; this can affect flavour. Although a few YM processors affirm that shaded YM has a preferred taste that consumers recognize by paying a higher price, chemical analyses have not revealed any clear tendency.

Tree shading is also said to facilitate fungi development in situations where ventilation is poor, resulting in high relative humidity. However, the years 2021 and 2022 provided climatic conditions that tell a different story. From February 2021 to January 2022, rainfall was less than 900 mm in the Misiones area; it is normally about 1,900 mm. These dry conditions were exacerbated during the November 2021 to February 2022 period by record high temperatures combined with record low (under 30%) relative humidity. During this period, up to 70% plant mortality associated with leaf burn was reported in open-sky YM plantations under eight years of age, while there was next to no mortality in YM under agroforestry (Colcombet et al. 2019).

Conclusions

According to the experiences in Misiones Province, no significant negative effects of shading were observed, either direct or indirect (i.e., leading to a greater proliferation of diseases) in YM yield. Moreover, in some cases, a positive effect of the shade trees was observed, in

protecting the YM from extreme hot and dry conditions, and generating up to a 15% yield increase compared to full-sun conditions. This is likely due to the sheltering effect of the trees in the integrated environment of the YM-trees agroforestry association. This supports the argument that YM can grow sustainably in agroforestry systems. Nevertheless, a good understanding of these interactions is still necessary to support YM sustainable management in agroforestry. This could also lead to innovative marketing strategies, in a market valued at USD 270 million per year in Misiones Province alone.

The I 049 Agroforestry project from the National Institute of Agricultural Technology (INTA), which started in July 2023, will include a statistical trial with four repetitions to study the effect of trees on soil fertility and YM yield, sanitary status and leaf properties and taste, in paired agroforestry arrangements with or without *Araucaria angustifolia* shading trees. This should allow the institute to build capacities and generate better recommendations for YM agroforestry farming in Argentina and the region.

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