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Cocoa pods. Photo: Johanna Rüegg

Dynamic cocoa agroforestry: 25 years of experience in Alto Beni, Bolivia

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"Agroforestry plots can produce a range of foods for consumption and sale, contributing to income diversification and long-term resilience, food security and food sovereignty."

Introduction

Cocoa is traditionally cultivated under agroforestry. This production system is still common on the Latin American continent, although today the largest producing countries are Côte d'Ivoire and Ghana in Africa, where most cocoa is grown in monocultures.

Cocoa agroforestry is gaining more and more interest globally for its benefits in providing some of the functions of tropical forests, such as biodiversity and regulation of the water cycle and temperature extremes, as well as carbon sequestration. Cocoa, similarly to coffee, is very suitable for production under agroforestry. It is a species originating in riparian forests in the Amazon and Central America, where it occupies the lower middle stratum and therefore tolerates shade. Cocoa yields in agroforestry tend to be lower than in monocultures, although total system yields, including companion crops, are higher (Niether et al. 2020).

In Alto Beni, Bolivia, in the foothills of the Bolivian Andes, there has been experience with organic cocoa production under agroforestry for several decades. The systems employed by the smallholders differ in their design and diversity, but in general they are characterized by relatively high density and diversity of companion trees compared to other producing regions in the world (Figure 1).

Figure 1: A typical mature dynamic agroforestry system in Bolivia; trees are not yet pruned

Some systems can be characterized as dynamic agroforestry (see Box 1), which may include timber, fruit and native trees as well as palms, banana and other crops in addition to the main cocoa crop. Often, the large canopies of the trees are not pruned, leading to highly shaded systems (Esche et al. 2023); this was the case for the nine producers described in this article at the time they were interviewed. Today, there are programmes in the region that offer shade tree pruning as a service, in order to better maintain these highly dense and diverse agroforestry systems.

In 2008–2009 the Farming Systems Comparison in the Tropics project (SysCom) initiated a long-term study in the region to compare the agronomic, economic and ecological performance of two different cocoa production systems: conventional and organic cocoa production in monocrop (full sun) and agroforestry (shaded) (Schneider et al. 2017). The SysCom trial also included a dynamic agroforestry system, in line with the longstanding experiences of farmers in the region. The project was established on land that was fallow for 20 years and covered with secondary forest. The companion trees in the SysCom dynamic agroforestry plots are pruned twice a year (see photo, next page) to increase the light input to the cocoa and companion crops and to increase nutrient cycling. The system operates without external inputs.

This article provides economic results from a case study of a mature model plot under dynamic agroforestry in the region, with data from 2017 and 2020. It compares these results with information obtained in 2017 from other smallholder plots in the region that combine cocoa with fruit trees in agroforestry systems and with results from the dynamic agroforestry and organic monoculture plots that are part of the long-term SysCom trial.

Box 1. Dynamic agroforestry

The principles of dynamic agroforestry were formulated by Ernst Götsch, a Swiss producer and researcher who developed this form of production in Brazil in the 1970s (Götsch 1995). In 1995 he was invited to visit El Ceibo in Alto Beni, an umbrella organization of cocoa producers cooperatives. His visit introduced this form of agroforestry in the region, which has since been promoted by Ecotop. Among the principles are the combination of species, according to their life cycles and the strata they occupy in natural forests, the use of natural regeneration of species, and the high density of trees, especially at the beginning, which are then constantly thinned over time, leading to irregular spacing between trees of different heights (Andres et al. 2016).

Aerial photo of a dynamic agroforestry plot that was part of the SysCom trial; shade trees are pruned twice a year. Photo: Erick Lohse, ECOTOP/FiBL

Methodology

From 2017 to 2020, nine agroforestry plots of smallholder farmers, who grow cocoa together with a diversity of fruit trees, were selected in Alto Beni for a study at the regional level, including the model plot of Walter and Asencia Yana, which is described in more detail below. Not all of these plots can be characterized as dynamic agroforestry, but they certainly include elements of it. All companion trees — forest species as well as fruit and palm species — were inventoried. Through interviews with the farmers, information was obtained on the year of establishment, cocoa yields, income and use of fruit trees. The areas of the plots were recorded using GPS.

The following fruit tree species were found: *achachairú* (*Garcinia macrophylla*), *arasá* (*Eugenia stipitata*), *asaí* (*Euterpe precatoria*), banana (*Musa* sp.), starfruit (*Averrhoa carambola*), peach palm (*Bactris gasipaes*), *cherimoya* (*Annona cherimola*), citrus (*Citrus* sp.), *copoazú* (*Theobroma grandiflorum*), guava (*Psidium guajava*), *majo* (*Oenocarpus bataua*), mango (*Mangifera indica*), inga (*Inga* sp.), avocado (*Persea paradisiaca*), rambutan (*Nephelium lappaceum*) and jackfruit (*Artocarpus heterophyllus*). Among the inventoried trees, about 25 precious (i.e., high-value) timber species have a market in the region. Their standing value was estimated based on local prices, adjusting for the fact that 40% of the timber is lost during processing (Brönnimann 2017). The most common precious species were *Swietenia macrophylla, Amburana cearensis, Myroxilon balsamum* and *Hymeanea courbaril*.

Detailed data for the year 2020 from the model plot of Walter and Ascencia Yana, who recorded their labour and monetary investments, as well as their income from cocoa and companion crops, are included in this article. Expenses included equipment, maintenance, fuel and tools. Their 1.96-ha agroforestry system is one of the longest established examples in the region and also one of the most diverse and dense, including a high variety of fruit tree that are in the productive stage. Therefore, the plot is often visited in training sessions. The plot was established more than 25 years ago and was based on the principles of dynamic agroforestry (see Box 1).

Results

The model plot

In Walter and Ascencia Yana's model plot most of the companion trees were planted by seed, a common practice in dynamic agroforestry. Natural regeneration was respected and species of less interest or in competition with others were thinned and additional species were incorporated over time. Because of this type of management, which resembles natural forest processes, the layout of the plot is irregular, and there are places in the plot where companion trees are up to 1 metre apart. The cocoa density is 487 trees/ha.

An example of a dynamic agroforestry plot of a farmer in the region of Alto Beni, Bolivia. Photo: Johanna Rüegg

A total of 54 species were inventoried in the model plot, including 21 precious species and 13 fruit species. Including shrub and palm species whose fruits are not used brings the total number of species to 72.

From the fruit trees, six products were sold in 2017: *achachairú* (*Garcinia macrophylla*), starfruit (*Averrhoa carambola*), peach palm (*Bactris gasipaes*), *copoazú* (*Theobroma grandiflorum*), rambutan (*Nephelium lappaceum*) and *ocoró* (*Garcinia madruno*). Ginger (*Zingiber officinale*) was also harvested and sold. Rambutan, *achachairú* and *copoazú* are the most economically important crops and are sold every year. In addition, eight species were used for self-consumption.

In 2017 cocoa yields were 280 kg/ha, bringing an income of USD 1,116 per ha. Fruit trees contributed an income of USD 2,332 per ha, for a total income of USD 3,448 per ha. To date, no timber has been harvested; however, in 2017, the standing value of timber was estimated at USD 3,307 per ha, representing a long-term capital accumulation.

According to more recent (2020) data from the model plot (see Table 1), cocoa production has increased to approximately 430 kg/ha, with an income of USD 1,762 per ha. At the same time the sale of companion crops in 2020 was lower than in 2017, with a contribution of USD 1,174 per ha. With recorded costs of USD 294 per ha, and 54 working days/ha of labour invested, this results in a net income per working day of USD 49.

Table 1. Economic data (USD per ha) recorded on Walter and Ascencia Yana's model plot, 2020

Cocoa dry bean yield (approximate; kg/ha)	430
Income, cocoa	1,762
Income, companion crops	1,174
Total income	2,936
Costs	294
Labour time (days/ha)	54
Net income per working day	49

The results show that income from companion crops can vary from year to year due to fluctuations in yields or demand. In addition, fruit species come into production only after several years, and the market changes over the years. One of the challenges of agroforestry is to foresee and plan for long-term market developments. In the case of the Amazonian fruits *copoazú* and *asaí*, for example, there was not much interest in these crops when the model plot was planted in 1997. Since then, however, a very strong market for them has developed, contributing significantly to the family's economy.

Recently, companion trees in the model plot and in the region have been pruned, especially the high-stratum timber trees and the middle-stratum fruit trees, as too little light was reaching the cocoa stratum. This resulted in an increase in a mean cocoa yield from 138 to 506 kg/h, measured as part of a trial in farmers' fields (Esche et al. 2023). An estimated increase in fruit tree production of about 30% was also recorded in Walter and Ascencia Yana's model plot. The organic material from the pruning also serves to recycle nutrients. Currently, local advisory services recommended that producers have their trees pruned by a specialist every three years.

Together with the improvement of genetic material, the pruning of companion trees has increased dry bean cocoa yields in the model plot from approximately 280 kg/ha in 2017 to approximately 430 kg/ha in 2020 (Table 1) to approximately 480 kg/ha in 2022. The yields of companion crops were also increased by pruning and thinning. And as the cocoa grafts mature, a further increase in production is expected.

Comparison with other producers

Table 2 shows the characteristics of smallholder plots in the region as assessed in 2017; all were focussed on organic cocoa production in agroforestry with timber and fruit species. Half of the plots had an area less than 0.98 ha. However, this does not always represent the area cultivated with cocoa, but refers to the total size of the inventoried plot. The plots were between 10 and 20 years old, representing mature systems in terms of cocoa, but young in terms of timber, which isn't harvested before 25–50 years of age. Densities of companion trees between 84 and 517 trees/ha could be observed, which shows that these plots are quite complex and dense systems. Fruit species, including banana, are of high importance as additional crops, with an average of 125 individuals/ha. In the region, there are also plots focused on timber that do not include fruit trees (these were not included in the selection of plots for this study).

Table 2. Characteristics of plots producing cocoa together with fruit and timber species in 2017

	Area (ha)	Age (years)	Density, cocoa/ ha	Density, timber trees/ha	Density fruit trees and others/ha	Density companion trees/ha	Total number of tree species	Number of timber trees
Minimum	0.54	10	455	79	39	150	27	14
Maximum	4.38	21	543	333	280	517	67	25
Mean	1.51	16	483	188	125	313	40	18
Median	1.00	17	483	184	87	271	36	18

Cocoa yields vary between 190 and 1,015 kg/ha, with a mean of 514 kg/ha (Table 3).

The two agroforestry components — timber as well as fruit trees and other crops (such as ginger) — contribute substantially to the economic performance of the plots. Farmers mentioned selling between one and seven companion crops, with half of the farmers marketing more than three additional products. These sales contribute between 3 and 68% of farmers' income, with a mean of USD 899 per ha per year. In comparison, cocoa contributes a mean of 68% of income, with a mean of USD 2,089 per ha per year.

The timber component represents a substantial capital accumulation, with a mean standing value of USD 5,565 per ha in 2017. Given that the plots can probably remain productive for up to 25–50 years, this can make a strong contribution to the income of the families if the timber is sold in the future.

Table 3. Cocoa yields, income, species for self-consumption and capital accumulation from the plots in 2017

	Cocoa dry bean yield kg/ha	Cocoa income USD/ha	Income sale fruit USD/ha	Number of crops for sale	Number of crops for self-consumption	% cocoa income	Total income USD/ha	Standing value USD/ha (60%)*
Minimum	190	773	148	1.00	2.00	32	998	2,955
Maximum	1015	4,126	2,389	7.00	10.00	97	4,274	8,682
Mean	514	2,089	899	3.44	5.78	68	2,988	5,565
Median	437	1,778	945	3.00	5.00	67	3,533	5,129

*Note: As mentioned on page 59, 40% of the timber is lost during processing (Brönnimann 2017).

Comparison of smallholder plots with results of the 2017–2019 SysCom long-term trial

The SysCom Bolivia trial in 2017–2019 compared the production and economic performance of two cocoa production systems: organic monoculture and dynamic agroforestry at the age of 9 to 11 years. In both systems, the cocoa density was 625 trees/ha. The dynamic agroforestry systems had a density of approximately 800 companion trees/ha during this time, substantially higher than in all the smallholder plots inventoried above. One of the reasons for this is that the farmers' plots in the 2017 study were older; thus, density has reduced over time. The companion crops that were harvested and sold were banana, coffee, *chima*, *copoazú*, ginger, *palillo* (*Curcuma longa*) and avocado.

Table 4 shows mean labour time and yields from the SysCom trial collected for the years 2017–2019. Income was calculated using local prices. Costs were estimated based on tools and inputs purchased during that time. All values were converted from BOB (boliviano) to USD with an exchange rate of 6.95125 BOB/USD (average exchange rate in 2017).

Table 4: Average cocoa yields (kg/ha) and economic data (USD/ha) for the SysCom project, Alto Beni region, 2017–2019

	Organic monoculture	Dynamic agroforestry
Cocoa dry bean yield	1,170	590
Income, cocoa	3,670	1,857
Income, companion crops	0	1,498
Total income	3,670	3,355
Costs	456	147
Labour costs (day/ha)	113	145
Net income per working day	28	22

The dynamic agroforestry system forming part of the SysCom trial is 2.8 times more labour intensive than that of Walter and Asencia Yana, and income is also higher in the SysCom trial. This is due to intensive management; for instance, the accompanying trees are pruned twice a year, so productivity is higher. With this more intensive management, yields of 590 kg/ha can be achieved in dynamic agroforestry, a promising yield but far from the 1,170 kg/ha of dry beans that were achieved in organic monoculture during the same time (Table 4). However, total productivity has to be considered. In agroforestry systems almost 45% of total income comes from companion crops, in the SysCom trial and in the model plot. However, the return on labour (net income per working day) recorded in the model plot (USD 49; see Table 1) was considerably higher than either the monoculture (USD 28) or the dynamic agroforestry system (USD 22) of the SysCom trial (Table 4), indicating that although income is lower, the farmers have found efficient ways to manage their plots.

Conclusions

Although there was a high return on labour in the model plot, there was high variability in cocoa yields. A few farmers achieved similar yields as monocultures in the region, while others showed a considerable share of income from crops, indicating the potential of dynamic and multipurpose agroforestry systems. Agroforestry plots can produce a range of foods for consumption and sale, contributing to income diversification and long-term resilience, food security and food sovereignty. A whole range of possible combinations is possible — each system has to be adapted to the specific circumstances, market opportunities and preferences of those who work on it.

Achieving economic profitability — while maintaining a high diversity of timber trees and native species for biodiversity conservation, efficient micro and macro climate regulation, water cycle regulation and carbon sequestration — is a great achievement. In addition, the "happiness" — the well-being and satisfaction — of working on a diversified plot of land in harmony with life is often mentioned by farmers. The importance of agroforestry systems in resilience to climate change, and its positive perception by farmers in the region, has also been shown (Jacobi et al. 2015).

Furthermore, the results show the importance of good practices such as the improvement of genetic material and the pruning of companion trees, and demonstrate that there is potential to further improve efficiency in the management of dynamic agroforestry systems. Actors in the Alto Beni region are contributing effectively to this process, offering pruning services and technical assistance such as providing seeds and seedlings of companion species and locally selected cocoa, as well as investing in long-term research and training.

Finally, for research and to evaluate the economic performance of agroforestry systems, it is important to obtain multiyear and long-term data, as agroforestry systems are also an investment for future generations.

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