Integrating biological, economic and farmer evaluation of plantation intercropping in Costa Rica

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Introduction

Agroforestry technologies consist of an almost infinite number of variations of different potential tree-crop combinations, spacings and managements. The complexity of on-farm agroforestry research has been recognised as a challenge in terms of research methodology (Scherr 1991). Furthermore, when a technology is adopted it will be modified by each farmer to meet their needs and capacity. The resilience of an agroforestry technology to perform under these varied conditions must be evaluated if broad recommendations of viable agroforestry technologies are to be made. This study uses a method that attempts to maintain a simple experimental structure while testing a wide range of variants and giving farmers maximum liberty in the management of the system.

Methods

The following multidisciplinary set of objectives were defined by the team of a forest economist, an agroecologist, and a forestry extensionist working in Sarapiquí, Costa Rica.

1) Evaluate if intercroping plantations can offset the opportunity costs of tree production.
2) Maximise the production from a plantation through long-term intercropping.
3) Determine if biophysical design criteria translate into economic benefits for farmers.

An array of different agroforestry options were defined to reflect different production objectives and environmental conditions in the region (Table 1).

Table 1. Agroforestry options defined in consultation with the Sarapiqui Agricultural Centre

	No intercrop	Annual intercrop	Perennial intercrop
Good soils (Eutropepts)			
Cordia alliodora	Pure plantation	Maize or Cassava	Plantain
Vochysia guatemalensis	Pure plantation	Maize or Cassava	Plantain
Mediocre soils (Dystropepts)			
Terminalia amazonica	Pure plantation	Cassava	Heart of Palm
Vochysia guatemalensis	Pure plantation	Cassava	Heart of Palm
Poor soils (Ultisols)			
Dipteryx panamensis	Pure plantation		Pineapple
Vochysia guatemalensis	Pure plantation		Pineapple

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Single plots of each of the agroforestry combinations were established in abandoned pasture at the La Selva Biological Station. Although there was no replication of any one combination of trees and crops, the plots can be conceived of as an experiment. The main treatments are two types of tree species per site. Trees were either open canopy suitable for intercropping (species varied between sites), or dense canopy providing good weed control potential (*Vochysia guatemalensis*). The subtreaments were no intercrop, annual intercrop, or perennial intercrop, and the species of crop varied according to soil type.

Ten farmers in six communities of central Sarapiquí who were reforesting and interested intercropping part of the plantation agreed to collaborate. Farmers were requested to maintain a simple contrast between an intercropped area and a pure plantation choosing from the trees and crops previously defined. Previous land-use varied between abandoned pasture, cleared secondary forest, and agricultural land. Soils varied from some of the richest in the tropics (Entisols) to some of the poorest (Ultisols).

Height and diameter of 50 trees per treatment were measured on-station and on-farm at 12 and 24 months after planting. Total height was analysed using a General Linear Model programme and applying contrasts to compare between types of intercropping. Records were kept of all labour activities, inputs, and crop production for the on-station plots for a period of 39 months. Farmers were asked to estimate the number of days spent in establishment and maintenance of the plots, and the yields obtained during the first 2 years. An estimate of maintenance of on-farm sites was made by scoring weed incidence during visits 0, 3, 6, 12 and 22 mo after planting. Opinions of the farmers were sought through informal interviews at the start of the project and evaluation workshops one-year and two years into the project.

Results

Tree growth on-farm after one year was significantly greater in the presence of all crops, but on-station only after two years and with perennials (Table 2). Combining on-station and on-farm data, *Cordia alliodora* had significantly greater height and diameter when grown with plantains than with cassava or no crop (height 4.4 vs 3.2 m, $p<0.05$; diameter 7.6 vs 5.8 cm, $p=0.10$), while trees grown with cassava were not different from trees grown withour crops (height 3.5 vs 2.9 m; diameter 5.9 vs 5.7 cm). In contrast *V. guatemalensis* grew significantly better (height 4.4 vs 3.4 m $p<0.05$, diameter 8.9 vs 7.0 cm, $p<0.05$) when intercropped with cassava than when grown without crops.

Labour inputs and crop yields on-station were generally within the range reported by farmers. Weed incidence was lower in intercropped plots than pure plantations on-farms. Intercropping in plantations increased the costs of the plantations by between 2 to 6 fold (Table 3). Only in the case of plantains was the investment recovered in production, and then only at production levels obtained on good agricultural soils. Returns on the additional labour to intercrop the plantation varied widely, only the plantain intercrop provided a return greater than the daily wage of 1,700 colones.

Table 2. Mean tree height of all species combined after 2 years on-station and on-farm in the presence and absence of crops. "p" is the probability that values with and without a crop are different, n.s. = not significant.

	On-station Cropping		p	On-farm Cropping		p
	Annual	**None**		**Annual**	**None**	
Height m	2.4	2.2	n.s.	4.9	4.0	<0.05
Diameter cm	4.8	4.0	n.s.	8.8	7.1	<0.10
	Perennial	None		Perennial	None	
Height m	3.3	2.2	n.s.	5.2	3.5	<0.01
Diameter cm	6.4	4.0	<0.05	7.2	5.2	<0.05
	Annual	Perennial				
Height m	2.4	3.3	<0.01			
Diameter cm	4.8	6.4	<0.05			

Table 3. Economic evaluation of intercropping options over three years using best case scenarios of crop production and on-station levels of inputs and labour. Return to intercropping, is the additional income from the intercrop over the pure plantation divided by the additional labour to practice intercropping. All costs are in colones (c) at 1996. Prices; costs and returns were discounted at 10% per annum.

	Pure plantation	Cassava intercrop	Plantain intercrop	Heart-of-palm intercrop	Pineapple intercrop
Inputs (c)	19,090	62,580	66,915	91,370	292,614
Labour (days)	106	284	231	263	543
Total cost (c)	189,492	518,843	427,766	501,460	1,109,002
Subsidy (c)	81,600	81,600	81,600	81,600	81,600
Production (c)	0	69,544	352,810	150,122	397,928
Costs less Returns (c)	-107,893	-367,699	6,644	-269,738	-629,474
Returns to intercropping (c/day)		146	2440	496	285

Farmers initial stated reasons for intercropping were that they wanted to gain more for their labour and make full use of the productive potential of the site. In workshops during the course of the research farmers presented the following opinions.

1) Intercropping provides benefits and motivation to maintain the trees.
2) There was universal agreement that the trees grew better when combined with crops.
3) There was a need to look for markets for the agricultural and forestry products
4) Cassava intercropping had not provided much benefit as prices were very low.
5) Plantains were considered the best alternative, primarily because of the good price.
6) Heart-of-palm was also considered interesting as there was high demand for the product.
7) Pineapple production had high costs of establishment and uncertain market.

Discussion

Despite the wide range of trees, crops, soils and managements incorporated into this study a widespread effect was found that the presence of crops in the early stages of plantations does improve tree growth. The better tree growth with crops was probably due to better weed control in those areas. However, the effects of intercropping did vary with trees species. Species that maintain a high density of foliage and roots e.g. *Vochysia* spp. have slower initial growth than species that have greater rate of height, crown, and root system expansion but maintain lower leaf and root densities, e.g *C. alliodora*. Species of the former group have little interaction with intercrops in the first year due to their slower development, but after canopy closure they dominate resources competing strongly with associated species. Species of the latter group are likely to be more sensitive to competition from aggressive intercrops (e.g. cassava), but even after canopy closure they leave sufficient free resources for associated crops to be grown (Haggar and Ewel 1997).

The farmers stated their objectives as increasing returns on labour and making full use of the productive potential of the site. The production gained rarely compensated the investment and then only on fertile soils. The labour inputs in the current study were 3-4 times higher than that reported for taunya systems in Central America and similar to systems classified as "trees with crops" (Scherr and Current 1997). However, in most cases crops grown within the plantations would have been planted anyway, thus using labour that was to be invested in crops to establish the trees too. On non-agricultural sites 10-50% of reforested area was intercropped, mostly for home-production, while on agricultural sites 70-90% of the plantation was intercropped, mainly for commercial production. Nevertheless, under most conditions intercropping did not subsidise reforestation and some external subsidy would be needed maintain economic viability.

We believe that the method employed permitted an integrated evaluation of the biophysical, economic and social interactions that determined which production alternatives were viable and under what range of conditions. Dense canopy tree species that benefit from a single annual intercrop are most appropriate for farmers who wish to reforest abandoned pastures. As intercropping is not economically viable only a small part of the plantation should be intercropped to meet household needs. Maximising the productive potential of the site through the combination of trees and perennial crops is only economically viable on agriculture quality soils with crops that have good market prices. In this case, open canopy trees can be planted that benefit from the presence of perennial crops, and probably also permit longer-term intercropping.

References

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