TROPICAL AGRICULTURAL RESEARCH AND TRAINING CENTER

(CATIE)

CHARACTERIZATION AND EVALUATION OF AGROFORESTRY SYSTEMS

The case of Acosta-Puriscal, Costa Rica

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1. Introduction

Small farm production, especially in Latin America, is carried out to a large extent under ecologically unstable conditions. Sloping landscape with few possibilities for mechanized production, erodable soils and erratic rainfall conditions are some of the environmental factors which strongly influence farm production and productivity. Especially during the last 5 years, input-output price relationships deteriorated, principally due to the rapid price increase for fertilizer and other chemical inputs. These changes had a negative effect on production on marginal lands due to relatively low fertilizer efficiency resulting from low absorption capacity and loss of nutrients by leaching and run off.

Under these ecological and socio-economic conditions, the development of stable land use systems seems to necessitate the incorporation of crops - trees and livestock components.

Based on this, the Tropical Agricultural Research and Training Center (CATIE) in collaboration with the German Agency for Technical Cooperation (GTZ) started research activities in mountainous regions of Central America with the following objectives:

- Analysis of traditional land use systems to identify major types of land use, production and productivity and to establish the degree of integration between crops - trees - and livestock production.
- Development and diffusion of agro-forestry production systems based on the results from the above mentioned analysis.

The purpose of this paper is to report on the methodological approach and on initial results from field work conducted in the region of Acosta-Puriscal, Costa Rica.

2. Study area, observed problems and hypothesis[1]

The study area is located 60 Kms southwest of San José, the capital of Costa Rica. Altitude varies between 800 and 1200 m; slopes are moderate (from

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1) Data from this section are extracted from: PLATEN, H. von and LAGEMANN, J.: (Eds.): Agricultural Production in Acosta-Puriscal, Costa Rica. CATIE, Technical Series Nª 13, Turrialba, 1981.

20-30%) to very steep (more than 100%).

Erodable latosolic soils predominate in the whole area and indicate the vulnerability of the region under inadequate land use.

The area has abundant seasonal rainfall. The average varies between 2000 and 2500 mm per year, which mainly falls between April and November. The rest of the year is relatively dry (6).

Deforestation during the last 100 years' period has been increased drastically. Only about 20% of the original forest is left, which results in erosion, excessive run off, and in parts of the year, in water deficits (3,16).

65% of the farm land is actually used for extensive cattle grazing with grasses of relatively low productivity. Erosion problems are particularly pronounced in overstocked natural pastures and under inadequate management. This is especially the case in the Puriscal area where farm sizes are larger compared to Acosta. 15% and 17% of the land is used by annual and perennial crops respectively.

The majority of the farms are considered "small holdings" less than 4 ha (48%), or between 4 and 10 ha (31%).

The topography is the major environmental factor effecting annual crops production and pasture land negatively. Lack of sufficient infrastructure makes marketing of products difficult. The relationship between input and output prices has deteriorated rapidly during the last years. Consequently, emigration in the study area has increased, especially among young people who leave for the industrial centers (2).

After description of the area and identification of major limitations, the following hypothesis was formulated:

Traditional agro-forestry systems can be used as starting point to increase production and productivity by using improved varieties and better management techniques without a decrease of their ecological stability.

3. Methodological approach[1]

The target group of the Research and Training Center is the small farmer with a low standard of living. Consequently, the first step was the selection of areas where a relatively large number of smallholdings are concentrated.

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1) Sections 3.1 and 3.2 in principle points are extracted from LAGEMANN, J.: Farming Systems Research as a Tool for Identifying and Conducting Research and Development Projects, in: Agricultural Administration (accepted for publication on February 1982).

This was followed by an area description and finally, by an analysis of existing agro-forestry systems.

3.1 Selection of areas

Area selection was based on principal land use, topography and agro-climatic conditions. Results from different regions thus are comparable to a certain extend. Direct extrapolation of results is limited because of great hetereogeneity of the physical and socio-economic environment in Central America[1]. Hence, under these prevailing conditions, special emphasis was given to the number of possible adopters within project areas.

For selection of the project areas the following criteria were used:

- Population density and number of small farmers
- Standard of living
- Regional priorities of national institutions
- Access to the area and infrastructure
- Production potential

Generally, it is not possible, in the time available, to quantify the values for all criteria. This is especially the case for the criterion "production potential". With information on environmental factors and after visiting and comparing potential study areas, the best subjective estimate of the research team and collaborating scientists was considered sufficient.

3.2 Description of areas

The second step of project activities was the description of the physico-biological and socio-economic environment and the identification of major types of land use.

3.2.1 Physico-biological conditions

The description of the physico-biological conditions included rainfall distribution (monthly averages, maximum and minimum), the monthly precipitation - evaporation differences (to estimate periods of moisture deficit), and temperature regime (monthly averages, maximum and minimum). In large areas of Central America the topography (altitude and slope) is important as are soil chemical

factors like in many parts of the tropics which usually show great variations even within small areas. The principal pests and diseases of the major crops as well as annual and perennial weeds were also identified.

3.2.2 Socio-economic conditions

The socio-economic conditions of the region exert strong influence on the type of farming systems in the area and will also influence the adoption of new technologies. Good information on infrastructure, markets and marketing channels, prices of agricultural inputs and products, availability of credit and service institutions, channels of communication, and local customs facilitated an understanding of the existing farm situation and will later help in the appraisal of those innovation considered for adoption by the target group.

The description of the farms includes identification of farm resources which are fixed in the short run, but modifiable in the long run. Resources of this kind are farm land, family labour, and fixed capital including energy resources. The actual use of external inputs indicated the importance of various input types and usage according to farm size and/or farms with specific crops. Existing peaks in demand for labour on the farms gave a rough estimate on possible labour bottlenecks.

Data on product sales were collected in order to estimate the extent of what farm families consume out of their own production and the relative importance of various products as a source of cash income.

3.2.3 Identification of major types of land use

During this phase randomly selected farms were asked for field sizes devoted to various annual and perennial crops as well as pastures. This allowed a rough estimate of the relative importance of major types of land use and was then supplemented by specific questions on utilization and importance of trees, species grown, products and management of trees and crops, and trees and pastures in combination as well as in different types of live fences.

3.2.4 Area stratification

Area stratification was done according to factors most strongly influencing the type of farming systems and probably the performance of various farm enterprises. These factors are topography and climate. Post-survey stratification

criteria could be: water availability, power source, or distance to major markets. Principal goals for stratification are to increase the variance of the main parameters between areas and to minimize them within areas. This enables researchers later to develop relevant technologies for specific conditions.

3.3 Analysis of traditional agro-forestry systems

There is a number of definitions for agroforestry, all rather similar but more or less comprehensive. CONSTANT (5) gives perhaps one of the best: "Agroforestry develops the concept of using trees as a component of the overall management of land resources to meet the needs of the people for food, fuel, shelter and income. The systems used need to be socially, culturally and economically acceptable to maximize total output at given input levels and to minimize damage to the total environment".

Small farms usually combine several production activities such as annual crops, trees and livestock. Consequently, the analysis of land use systems includes all major types of land uses, the resources devoted to them, production and productivity. In this paper we concentrate, however, on the analysis of combined agricultural and forestry production systems. Sequences of various land uses or combinations in time but not in space are not regarded as an agroforestry technique here.

3.3.1 Classification of agroforestry systems

Agroforestry systems are expected to enable sustained productivity under marginal site conditions whereby socio-economic as well as ecological aspects are taken into consideration. Due to tradition, infrastructure, soils and climates, there are different types of combination and management forms to be found in Central America. COMBE and BUDOWSKI (4) have e.g. distinguished between three main combination systems and some 20 different main techniques in regard to the function of the trees and the distribution of trees in time and space.

Preliminary surveys in the study area of Acosta-Puriscal showed that in almost all farms trees are used for economic reasons in live fences, by tradition partly in pasture lands and for shade in combination with coffee. As coffee also is the most important cash crop of the area, and pasture lands are causing most severe land slide problems these two systems together with live fences were

consequently selected as typical for the specific socio-economic and ecological situation of the study area. After identification of these main systems next classification factor was set to be that variable which has the highest influence on production and productivity. For coffee it was found to be the variety. Thus all farms are divided into coffee-shade tree combinations with improved varieties (caturra) and traditional varieties (typica e híbrido tico). Figure 1 shows the principal agroforestry systems classified according to the main combinations found in the study area.

### 3.3.1.1 Coffee in combination with trees

The combination of coffee with trees has both a traditional and a commercial aspect. Modern techniques with high-yielding coffee varieties, intercropped with mostly one commercially useful shade species are to be found more frequently in the Puriscal region where farms are relatively big ($\bar{X}$ = 13 ha). The traditional techniques, characterized by older coffee varieties, a higher diversified mixture of timber and fruit trees are concentrated more in the region of Acosta, where average farm size is about 7 ha. Although coffee, in general, yields higher annual productions in pure plantations, under intensive management and this is well-known by the farmers in the project region, in nearly 95% of all surveyed farms, coffee is mixed with at least one shade tree species. Also, new plantations are usually established in this form. A typical vertical structure of a mixed coffee-shade species system consist of three layers (Figure 2).

- first layer is coffee
- second layer is a shade tree such as _Erythrina poeppigiana_ or fruit production species like _Citrus_ spp., _Musa_ spp. _Mangifera indica_, or fruit and timber producing species like _Inga_ spp., height between 5 and 8 m.
- third layer is mainly a timber tree layer with _Cedrela odorata, Diphysa robinioides,_ but also fruit trees like _Spondias purpurea, Persea americana_ or palms like _Guilielma gasipaes_.

The horizontal distribution is usually very regular and the number of associated species is low under modern management techniques. Traditional techniques are easily recognized by a high diversity and irregularity. After distinguishing between new and old coffee varieties we subdivide combinations of crops and trees found into three groups described below for final ecological and economic evaluation.

FIGURE 1: AGROFORESTRY SYSTEMS IN ACOSTA-PURISCAL
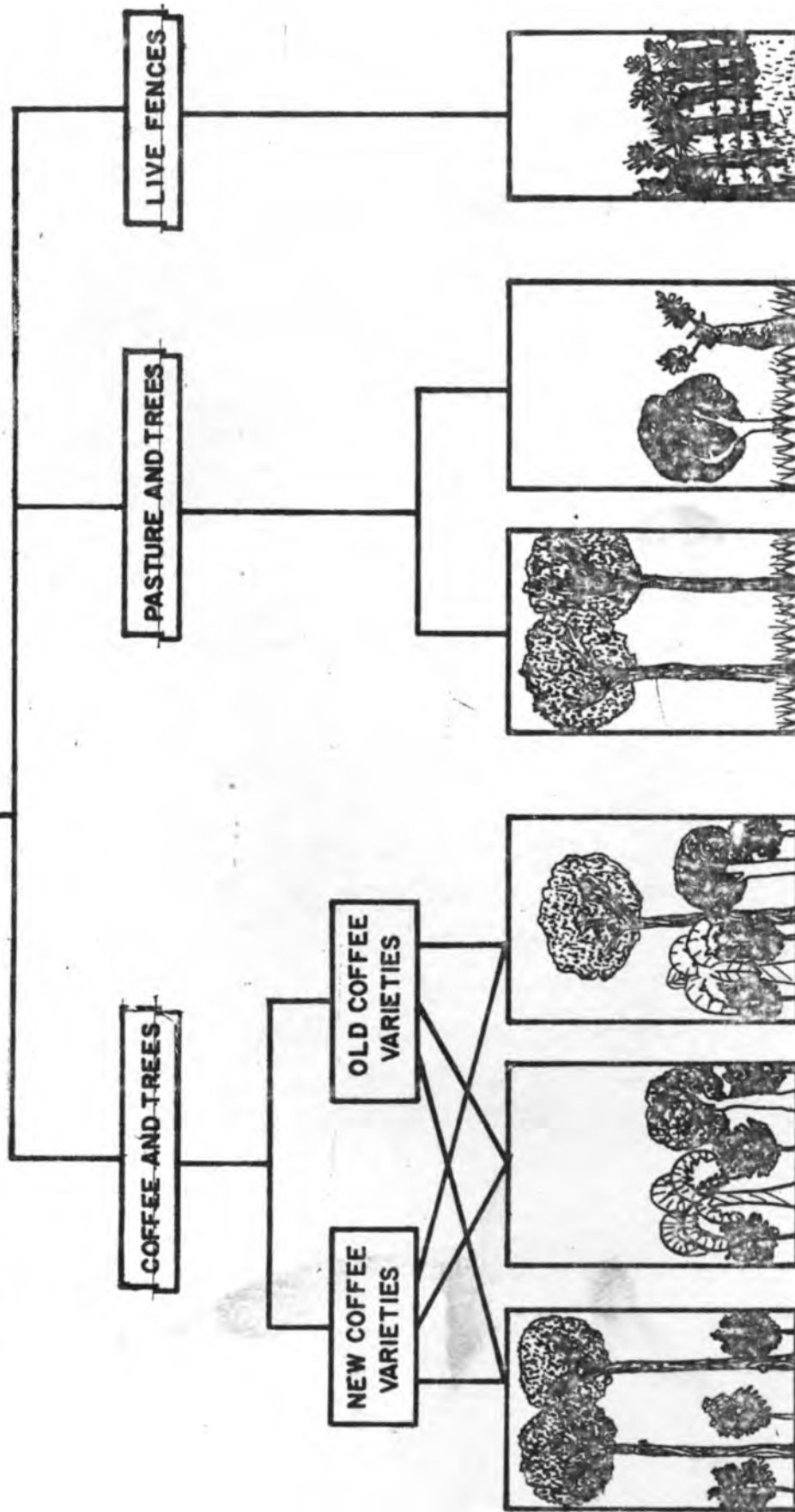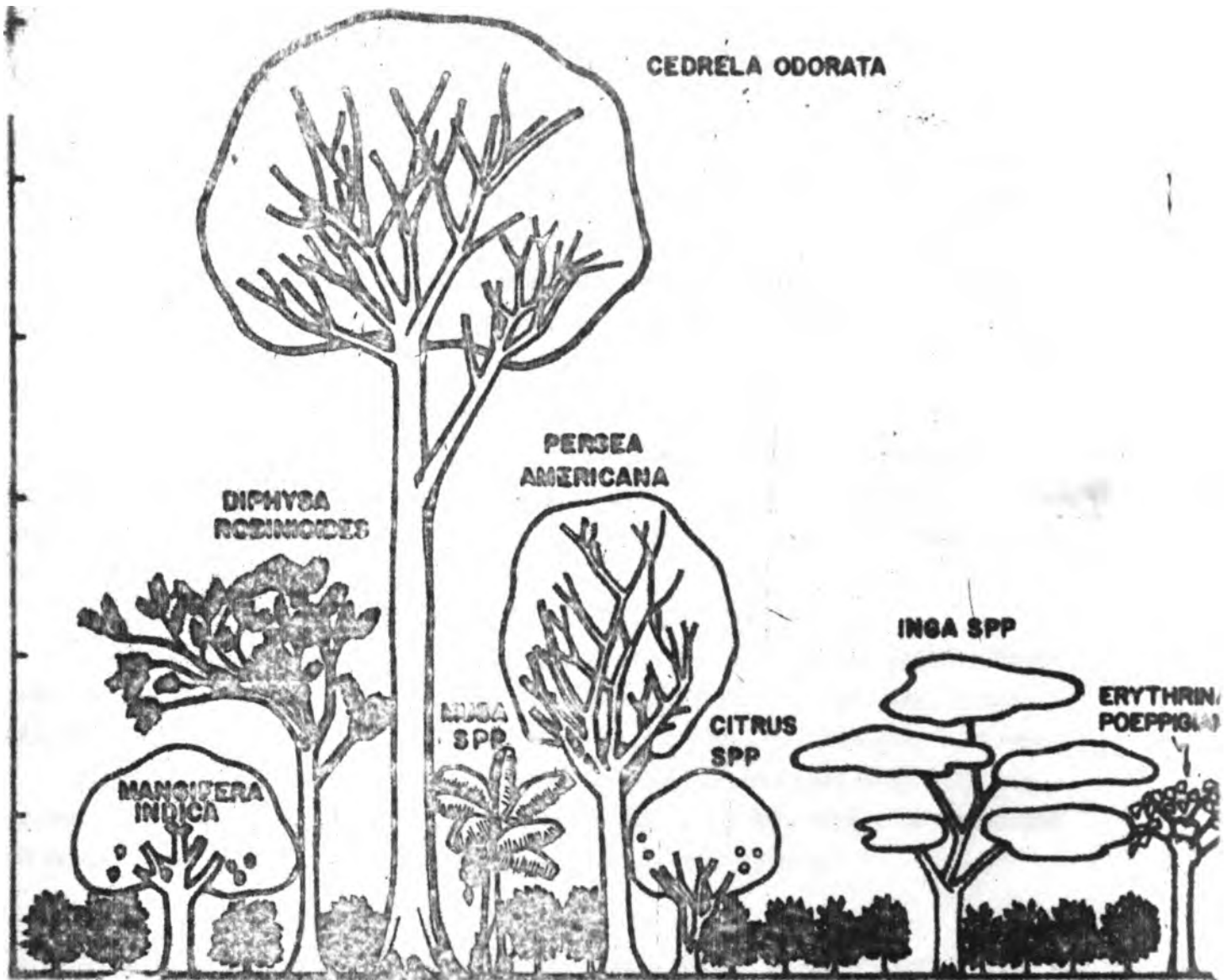
SCALE 1:200

FIGURE 2: MOST COMMON VERTICAL STRUCTURES IN COFFEE-SHADE TREE COMBINATIONS FOUND IN THE STUDY AREA.

a) <u>Coffee with timber producing tree species</u>

The most important timber tree species found among investigated farms are listed in order below:

Inga spp. Gliricidia sepium, Diphysa robinioides, Nectandra spp., Tabebuia rosea, Cordia alliodora and M yroxylum balsamum.

There are high variations in coffee-timber tree combination forms (density, distribution, abundance, number of species), in management forms (regeneration, harvesting methods, pruning, fertilization) or in farmer's objectives (financial reserve, increase of income, home consumption). Local conditions determine the importance of these parameters. These combinations are usually found in larger farms where the owners do not rely on immediate returns from their investments.

b) <u>Coffee with tree species providing other products</u>

Important products other than timber are shade, firewood, fruits and honey production. A number of farmers also are aware of soil stabilization, nutrient balance and wind shelter. Rarely drugs or medicine production are found in the investigated region.

The most frequently found multiple use species are:

Erythrina spp., Citrus spp., Inga spp. Musa spp. Gliricidia sepium, Mangifera indica, Persea americana, Spondias purpurea, Guilielma gasipaes, Yucca elephantipes, Psidium guajava, Annona muricata, Annona spp. Vantanea barbouri.

Fields with improved coffee varieties are mostly combined with only one or two of the above-mentioned species. Traditional coffee varieties are found in combination with a higher number of different tree species.

c) <u>Coffee with all types of trees</u>

These highly diversified production systems belong to the "traditional" type. They are most frequent in the smallest units in infrastructurally and economically less developed parts of the study area. The majority of products of the intercropped species are consumed by the farmers or sold locally at irregular intervals. This refers principally to bananas and oranges.

3.3.1.2 <u>Pastures in combination with trees</u>

Except for *Citrus spp.*, most species found in the pastures of the study area, seem to originate from natural regeneration. These species are: *Croton*

gossypiifolius, G liricidia sepium, Diphysa robinioides, Cedrela odorata, Psidium guayava, M iconia argentea, G uazuma ulmifolia, Rapanea ferruginea, Hymenaea courbaril, Tabebuia rosea, Inga spp., Eugenia jambos, Enterolobium cyclocarpum, Samanea saman, Cassia spectabilis.

Pastures area mostly used in extensive form with low productive grasses and a stocking rate of less than 1 head per ha. Usually single trees are to be found in the pastures as remnants of the original vegetation or in secondary growth. The smaller farmers especially, tend to eliminate remaining trees, whereas among the bigger or richer farms, a tendency of conservation or even plantation of trees is recognized. These differences are due to limited resources of small farmers with no or insufficient financial resources for purchasing fire and construction wood. Consequently, they are obliged to harvest their own trees. Also, as grass productivity is low, and competition between trees and pastures for water especially during the dry season is expected, trees in pasture lands are regarded as inconvenient by a number of the investigated farmers. On the other hand, as erosion problems increase rapidly in the area, some farmers show certain interest in planting trees. Pines and eucalyptus are frequently used as far as support is given. However, plantations still are rare. Among the trees found in the farms, we distinguish as before mentioned, between timber producing species and species providing "other products".

a) <u>Pastures with timber producing tree species</u>

Intensive pasture management usually implies a change from local grasses to higher productive imported species, fertilizing, and weeding. In many cases it also means a combination with timber producing tree species.

A tradition for silvo-pastoril management techniques obviously does not exist, and hence there is no great number of combinations.

Frequently found timber producing trees are *Cedrela odorata* and *Tabebuia rosea*. But also *Hymenea courbaril, Enterolobium cyclocarpum* and *Samanea saman* were found to produce excellent timber as well as edible fruits or fodder.

b) <u>Pastures with tree species providing other products</u>

The most important product provided by the species found in combination with pastures in the investigational area is firewood. Principle species used are: *Croton gossypiifolius, G liricidia sepium, Diphysa robinioides, Psidium guajava, M iconia argentea, G uazuma ulmifolia, Inga spp., Eugenia jambos* and

Cassia spectabilis.

A number of these species, well-known by the farmers, also produce fodder or fruits for cattle. These species regenerate naturally, and very rarely are they planted. Also these additional products are scarcely or never used.

3.3.1.3 Trees in live fences

Fencing with living trees instead of fence posts is used by 95% of the farmers because of the advantages in terms of establishment and maintainance costs as well as possible uses. In general two different ways for establishment are to be found.

- preparation by usually 2 m long stakes on which the barbed wire is fixed directly.
- and, in minor cases, plants or smaller stakes in combination with fence posts supporting the wire until the propagated or planted trees have reached suitable stability.

Both tendencies are found all over the area. Commercial and uncommercial products provided by live fences comprises pruning material for new live fences, firewood, edible fruits, fodder, honey, wind shelter and soil stabilization.

The most frequent species identified are: G *Liricidia sepium, Diphysa robinioides, Bursera simaruba, Yucca elephantipes, Tabebuia rosea, Miconia argentea, Eugenia jambos,* and *Spondias purpurea.*

A typical management form is to cut back branches of the live fence posts at certain time intervals to about 2 m hights. Distances between stakes along the line vary between 0.5 and 4 m. Additional uses or multiple purposes are rare (14).

3.3.2 Systems approach to analyse agroforestry systems

The systems approach is based on the assumption that an understanding of the interactions between elements of a system will facilitate understanding of the performance of the system as a whole (1).

The analysis of agroforestry production systems recognizes five consecutive steps:

- identification of farmers' production objectives
- identification of the elements in the system

- study of relationships between elements
- analysis of the performance of the system inclusive its stability
- analysis of production incentives

3.3.2.1 Identification of objectives

It is generally taken for granted that small farmers' primary goals are production for food and shelter, followed by cash income to buy products not produced by the farm (13). There are, however, specific local differences, according to food preferences, social customs, risk adversion and distance to product markets. In addition to informal discussions with farmers during the field work, data on production objectives were sought through formal questionnaires. It was evident that food security and risk distribution came first in the reasons mentioned for diversified production systems. These production objectives combined with the goal of sustained increase of labour - and land productivity will be used as the principal criteria for evaluation.

3.3.2.2 Identification of elements

The first chore of the research team was to establish a list of elements which constitute a specific production system. The elements to include depend on the objectives of the analysis. In this study the final goal is to evaluate the performance of agroforestry systems compared to agricultural systems according to farmers production objectives. Hence, those essential elements which influence soil fertility (long term production potential) production and productivity have to be included.

Taking a coffee and shade trees system as an example, the input-output elements included in the analysis were climate (rainfall and temperature pattern); soils (type, structure, nutrient status), labour (work-hours), crops (species, variety, density, cropping pattern, production), trees (species, density, age, shade effects), production, pest, diseases and weeds.

Data on climate were taken from published information. The first mentioned input-output variables were quantified in the fields by direct measurements, whereas data on pests, diseases and weeds were collected by observation in order to estimate their relative importance in various production systems.

3.3.2.3 Study of relationships between elements

In this comparative study we concentrate on interactions between trees and

crops. Important relationships under study are: a) Effect of various trees on soil fertility (Org. matter, N,P,K, Ca) and waterholding capacity of the soil, b) Effects of shade on diseases and pests[1] and c) Effects of trees on growth and yields of crops.

For the Acosta-Puriscal region it is hypothesized that under marginal conditions (especially on steep slopes) soil fertility and yield level will decline over time when no counteractive measures are undertaken. The cuantification of this relationship seems to be necessary in order to identify which measures (type and number of trees, or other erosion control method) are adequate to garantee sustained yields and income. Relationships between these elements are analysed using correlations and regression models. Prior stratification of the study area and classification of agroforestry systems served as means to decrease - within one system - the variation of those parameters not included in the regression models.

Concerning the highly diversified combinations of coffee with all tree species, it is intended to estimate the relationships between total yields and the complexity of the production system. For this reason, the complexity index formula by HOLDRIDGE (9) will be applied:

$$C = \frac{H \cdot B \cdot D \cdot S}{1000}$$

Where:
C = complexity index
H = height of the 3 highest trees/1000 m^2
B = basal area for all trees with dbh (at 1.3 m) more than 10 cm/1000 m^2.
D = number of trees with more than 10 cm dbh/1000 m^2
S = number of tree species with more than 10 cm dbh/1000 m^2

3.3.2.4 Analysis of systems performance

The degree of "goal - fulfillment" is estimated by comparing all types of inputs and outputs. Data on external and farm internal inputs[2] as well as output in form of crop yields, fruit production, timber and firewood as well as forage leaves and fruits are collected by a multi-visit survey with weekly visits to the farms throughout a whole production cycle. Total yields in physical and monetary units as well as net income are related to production resources, like land, labour and capital investment. This productivity analysis

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1) These effects are analysed under controlled experiments.
2) This includes also investment costs for coffee and trees.

combined with a risk analysis, which shows the probability of getting low or high yields or returns, is conducted with data based on a one year production cycle. This limitation can partly be overcome by a sensitivity analysis during which major production coefficients are varied and compared with the effect on production and net income.

3.3.2.5 Analysis of production incentives

Let's assume that prior analysis indicated that the farmers' principal goals were reached at a higher level with agro-forestry systems compared to alternative land use systems. Does this lead to the conclusion that farmers' incentives to adopt this "improved technology" are sufficiently high ? The establishment of agro-forestry systems is usually an investment and - with the inclusion of trees - a long term investment. Investment incentives are normally expressed by the Internal Rate of Return[1] (IRR). For small farmers the calculation of the increase in net income is a more useful parameter compared to the IRR, because capital investment is usually low under smallholders' conditions (15).

The increase in net income is calculated by comparing the net income over time of agro-forestry systems with alternative uses. Increments in net benefits as well as net benefits of the alternative use are discounted in order to receive the net present worth. The incremental net present worth is then divided by the net present worth of the alternative production system (15).

A direct comparison of two production systems is sufficient only under the condition that demands on farm resources are similar. In case of higher labour input for agro-forestry systems, the decrease in production and net income on other fields or other activities has to be taken into account.

4. First results of field work on coffee with fruit species and shade trees

During the period of March 81 - February 82 detailed input-output data were collected from 68 farms (randomly selected) by weekly visits. Major agro-forestry activities were identified and essential data collected. However, the first results presented in this paper concentrate on coffee fields only.

Before analysing the data they were classified into various groups according to the variables: coffee variety, tree species and fertilizer application. We found five major production techniques. The one with the lowest net income/ha (15.312 ₡) was the group with traditional coffee varieties, shade and fruit trees and the absence of mineral fertilizer. The data on the other 4 groups with

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.) It is the interest rate which equalizes discounted net benefits and investment costs.

a higher production and net income are presented in Tables 1 and 2.

The characteristics of agro-forestry systems with traditional varieties in Table 1 show the differences between the systems "coffee + shade trees (A)" and "coffee + shade + fruit trees (B). Besides, about 3500 coffee plants, system A has about 70 -'100 shade trees of various species, and system B 30 - 60 trees and on average 135 fruit trees, like bananas and oranges. System B is more traditional with a higher complexity, and most commonly found in the project area. The major difference is the age of the coffee plants with an average of 13.7 and 9.0 years for system B and A respectively. This has probably a negative effect on coffee production, however, there was no significant relationship between coffee yields and age of coffee plants.

The total fertilizer application differed slightly and herbicide + fungicide application was higher (although not significantly different) in the case of system B. Coffee yields were on average 27% lower in the traditional system B, however, the difference was not significant.

The difference in total value of production is decreased by the products of fruit trees. After deducting the variables and fixed costs the estimated net income of "coffee + shade + trees" · was about 5.000 ¢/ha higher compared to the system with fruit trees.

Table 2 presents the same systems but with an improved coffee variety (caturra). The input figures are higher for the "coffee + shade tree system (C)", although not significantly. Coffee yields are generally much higher compared to the traditional varieties (compare with Table 1); system D (with fruit trees) has a 14% lower yield compared to system C. The incremental yield from fruit trees and the lower variable costs for system D equalize the net income of both production system.

These results are interesting in several respects:

1) They indicate the high production potential of the newly introduced caturra coffee variety together with mineral fertilizer,

2) There are some indications that production costs for external inputs can be decreased with more complex systems,

3) The introduction of fruit trees (up to a certain extent) does not negatively effect net income from the whole field.

However, the results have to be treated with caution because these figures

Table 1: Comparison of production in coffee fields, with and without fruit trees, traditional varieties (typica and hibrido tico) all fields with fertilizer application.

	Coffee with shade trees (A)	Coffee with shade and fruit trees (B)	t - value
Number of observations	12	38	-
Coffee plants/ha	3548	3840	-0.70
Number of shade trees[a]	70 - 100	30 - 60	-
N$^{\underline{o}}$ of orange trees + bananas	0	135	-
Age of coffee (Yrs)	9.0	13.7	2.85**
Labour input per ha (in man-days)	188	191	-0.08
Fertilizer input			
N-P-K (kg/ha) (18-8-13)	391	567	-0.61
N (kg/ha) (33% N)	357	196	0.66
Value of fertilizer (¢/ha)	2887	3168	-0.52
Value of herbicides + fungicides (¢/ha)	146	306	-1.21
Coffee yield (kg/ha) (dried coffee)	1148	836	1.53
Value of coffee production [b]	39,924	29,030	1.53
Value of tree production [c]	0	3,830	-
Total value	39,924	32,860	0.93
Gross margin [d]	32,318	27,460	0.72
Net income	31,676	26,772	0.73

SOURCE: (12)

a) Estimated figures, inventory in process.
b) Prices are average on-farm prices during 1981-82.
c) Includes only value from fruit trees, estimation of value from other trees is in process.
d) Gross margin = Gross return - variable costs.

Table 2: Comparison of production in coffee fields, with and without fruit trees, variety: caturra, all fields with fertilizer application.

	Coffee with shade trees (C)	Coffee with shade and fruit trees (D)	t-value
Number of observations	12	15	-
Coffee plants/ha	4465	4175	0.54
Number of shade trees[a]	60 - 90	20 - 50	-
N^a of orange trees + bananas	0	104	-
Age of coffee (Yrs)	4.4	6.7	1.91
Labour input per ha (in man-days)	217	212	0.18
Fertilizer input			
N-P-K (kg/ha) (18-8-13)	737	620	0.69
N (kg/ha) (33% N)	389	263	0.80
Value of fertilizer input (¢/ha)	4780	3356	0.75
Value of herbicides + fungicides (¢/ha)	691	581	0.34
Coffee yield (in kg/ha) (dried coffee)	1690	1452	0.41
Value of coffee production[b]	58,820	50,520	0.41
Value of tree production[c]	0	2,300	-
Total value	58,820	52,820	0.37
Gross margin	49,050	47,860	0.07
Net income	47,670	46,960	0.04

SOURCE: (12)

a) Estimated figures, inventory in process.
b) Prices are average on-farm prices during 1981-82.
c) Includes only value from fruit trees, estimation of value from other trees is in process.
d) Gross margin = gross return - variable costs.

rely only on one production cycle. More important would be to observe production and productivity over time. Apart from this, production figures of timber and firewood will be included in the final evaluation.

5. Conclusions

The analysis of the data supports the assumption that the project area can be regarded as an emergency area typical for densely populated and eroded landscapes in Central America. However, farmers in the Acosta area have since a long time adapted (invented) their land use systems to the ecological conditions and their small farm sizes. Production systems here consists of agro-forestry components in coffee-production and small fields of annual crops with a kind of minimum tillage technique. In comparison to these ecologically rather stable practices, farmers in Puriscal started the cultivation of tobacco, and this in rotation with maize, which aparently requires a completely cleaned field with a drastically increase in soil erosion.

Even more eroded are the increasing pasture lands where production decreased rapidly over time.

We found that the classification of agro-forestry systems has to concentrate on the principal combination forms and, therefore, is always very location specific. However, the methodological approach used to analyse agroforestry systems can be applied independently.

First results of the analysis on coffee in combination with trees indicates that a significant improvement of the traditional techniques is possible. As principal components we found: improved varieties and fertilizer application. The amount of fertilizer and other chemical products aparently can be reduced by increasing the complexity of the systems. With an increased density of trees coffee yields were decreased. Incremental yields of other crops and reduced costs of external inputs off-sets the loss in coffee production.

The exact influence of various tree densities on total production per field has to be studied further, as coffee production is and will remain the principal income source of the small farmers in the Acosta-Puriscal area. Additionally, coffee in combination with trees is ecologically the best adapted production system under the prevailing conditions.

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