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A CASE STUDY OF TRADITIONAL AGRO-FORESTRY PRACTICES IN A WET TROPICAL ZONE: THE "LA SUIZA" PROJECT

J. W. Beer, K. L. Clarkin, G. De las Salas, N. L. Glover

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SUMMARY

A case study of traditional agro-forestry practices in the wet tropics has been initiated in two small experimental watersheds (600-1200 m) situated in central Costa Rica.

This paper describes the structure as well as the species used in the agro-forestry combinations found in the area and the results of a survey are used to discuss the farmer's perception of these systems. In the case of the most important associations, which combine the valuable timber tree laurel (Cordia alliodora) with coffee (Coffea arabica) or sugargane (Saccharum officinarum) or pasture, standing basal areas and volumes are given together with estimates of annual increments. Moreover, initial results on crop yields with or without the tree overstory are presented.

The aims of this project include improving land use by encouraging tree planting with and without crops or pasture. A discussion with maps of the present land use, soils, and proposed land use classification is included and data on the two reforestation plots established to date is given.

RESUMEN

Se inició un estudio de caso sobre prácticas agro-forestales tradicionales en el trópico húmedo en dos cuencas experimentales situadas en La Suiza, Turrialba, Costa Rica, a elevaciones entre 600 y 1200 m.s.n.m.

Este trabajo describe la estructura y las especies de las combinaciones agroforesta Se utilizaron los resultados de una encuesta para discutir la percepción de los finqueros sobre estos sistemas. En el caso de las asociaciones más importantes, las cuales combinan un árbol de madera valiosa, laurel (Cordia alliodora) con café (Coffea arabica) o caña (Saccharum officinarum) o pastos, se dan las áreas basales y los volúmenes en pie junto con estimativos de los incrementos anuales. Se presentan además los resultados iniciales de rendimientos de cosecha con y sin el componente arbóreo.

Los objetivos de este proyecto incluyen el mejoramiento del uso de la tierra estimulando las plantaciones forestales con y sin cosechas o pastos. Se incluye una discusión, con mapas, sobre los suelos y el uso actual de la tierra; se propone una clasificación para el uso potencial de la misma. Se presentan datos sobre dos parcelas de reforestación establecidas hasta la fecha.

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INTRODUCTION

In October 1977 CATIE became the first "Associated Institution" in the "Programme on the Use and Management of Natural Resources" of the United Nations University (Figure 1). As part of the agreement then signed UNU pledged funding for the development of a multi-purpose research and demonstration area where traditional agro-forestry systems could be qualitatively and quantitatively studied.

THE RESEARCH - DEMONSTRATION AREA

After considering several possible sites two small adjacent watersheds (total area 830 ha) north of the Costa Rican town of "La Suiza., which is located 10 km southeast of Turrialba (Figure 2), were selected, chiefly for the following reasons:

1) The terrains and environments in the small owner-operated farms are typical of the tropical wet middle elevation zone (600 - 1200 m).

2) Examples of many of the traditional agro-forestry combinations used in this zone exist in the research area.

3) Erosion problems, attributable to inappropriate land use, are common and their correction (possibly through agro-forestry practices) would provide excellent demonstration sites.

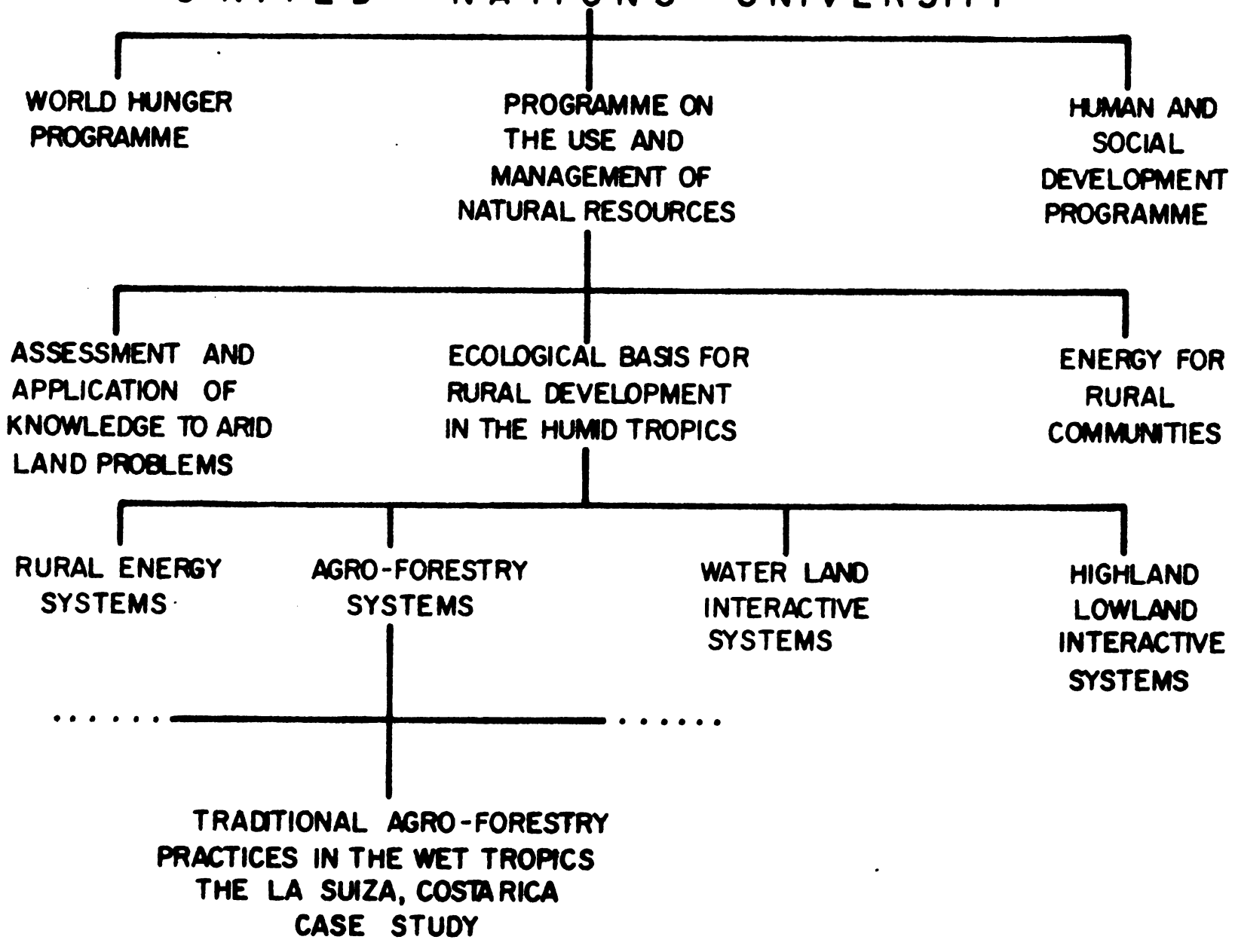
4) The farmers of the area appear to be very willing to cooperate in supporting research and to have demonstration plots (Figure 3), established by CATIE, on their land.

5) The proximity of the site to CATIE would permit the use of results from previous projects as well as making it a readily accessible demonstration/teaching facility.

BACKGROUND DATA

Annual rainfall (average of 6 years), recorded in La Suiza (616 m.a.s.l.) is 2,489 mm. Data from CATIE (602 m.a.s.l.) gives an average temperature of 22.3° (maximum 27°, minimum 17.6°) and a daily relative humidity of 87%. There is a drier period in February and March but still with some rainfall.

FIGURE 1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AGRO-FORESTRY SYSTEMS
WATER LAND INTERACTIVE SYSTEMS
HIGHLAND LOWLAND INTERACTIVE SYSTEMS
TRADITIONAL AGRO-FORESTRY PRACTICES IN THE WET TROPICS THE LA SUIZA, COSTA RICA CASE STUDY

Figure 2. Map of Costa Rica.

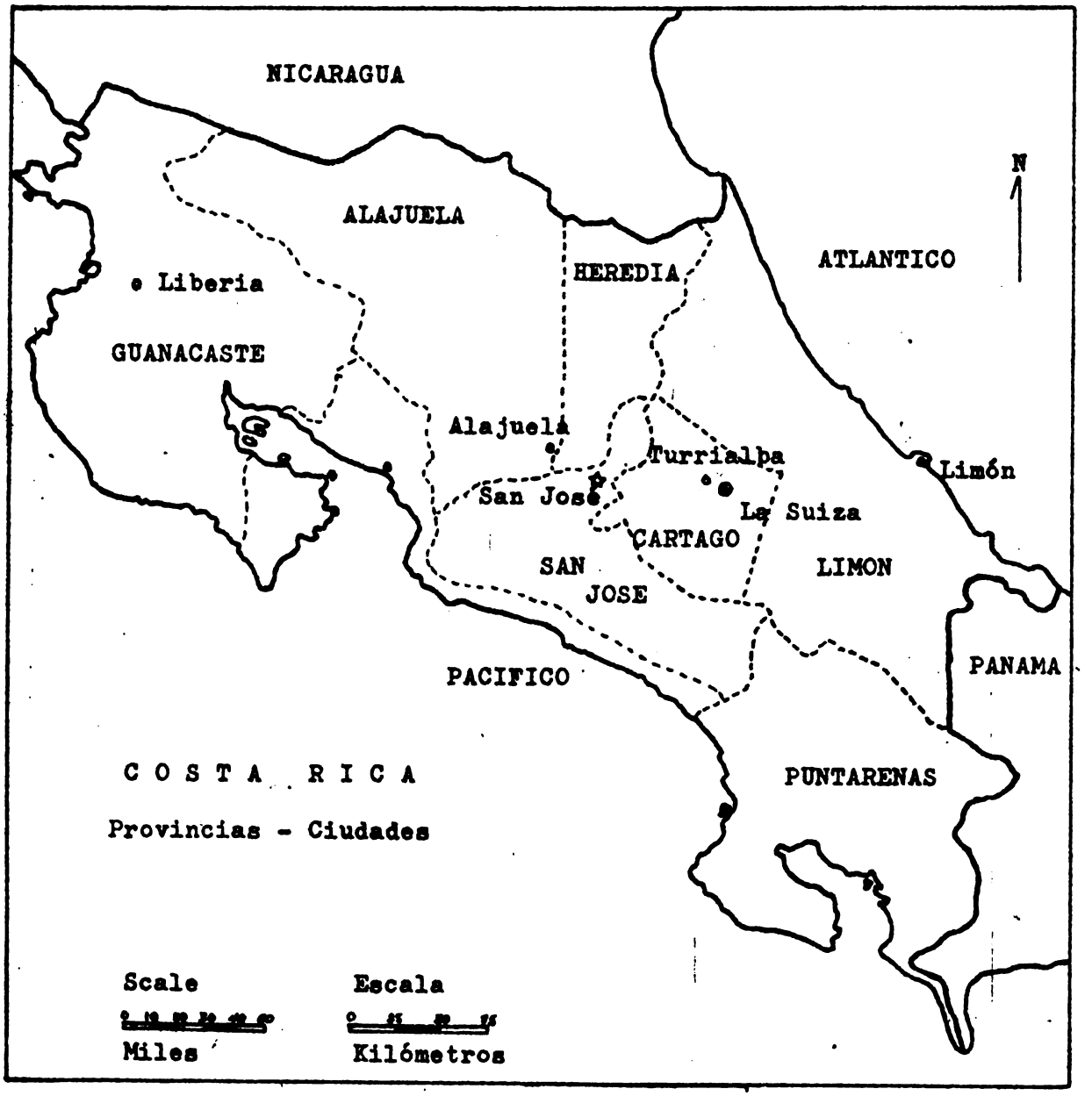
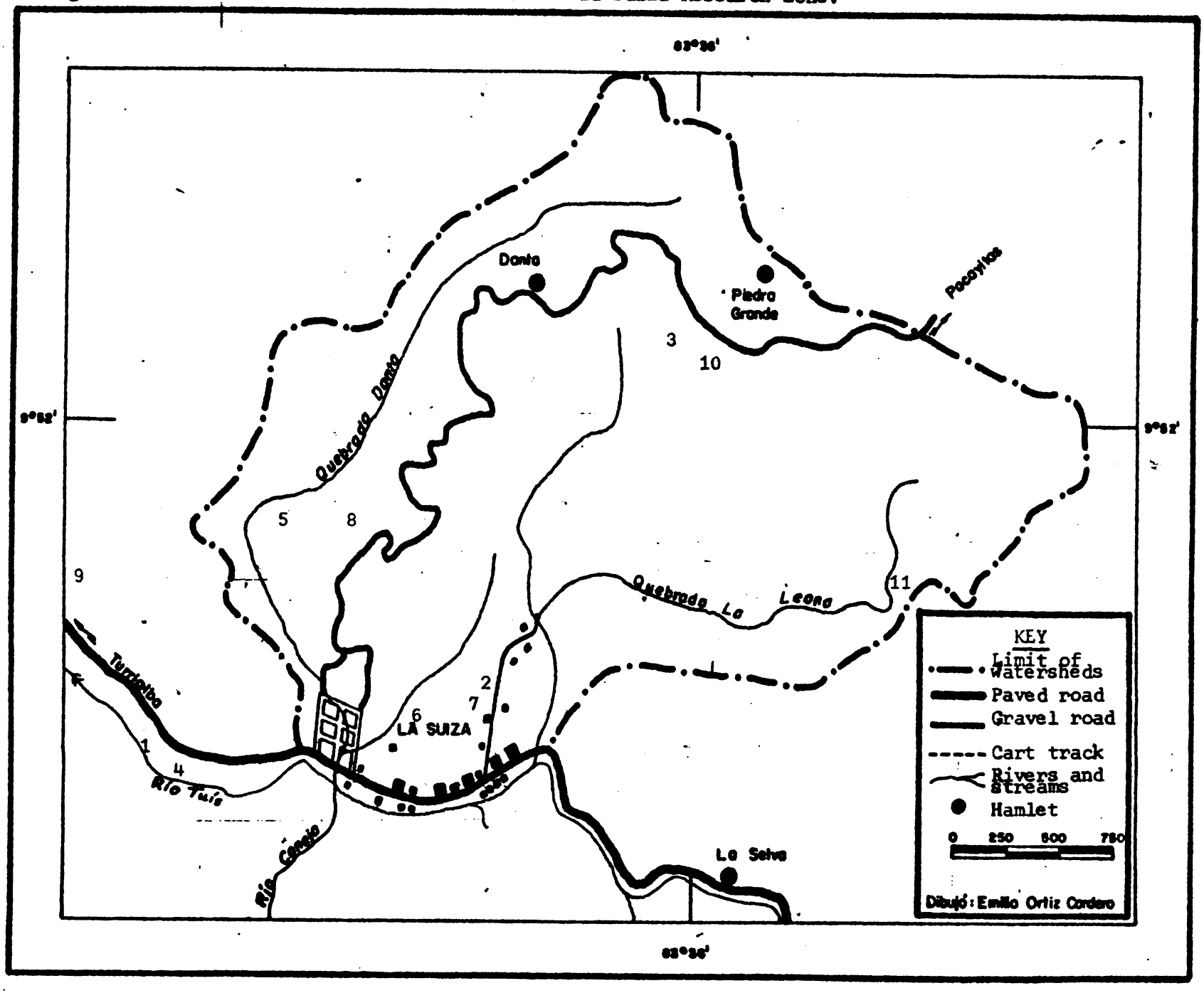


Figure 3. Permanent Demonstration Plots in the La Suiza Research Zone.



The research area occupies a representative south facing section of the valley wall above the "Tuis" river. The upper boundary lies within the "Tropical Premontane Rain Forest" but the majority of the area is situated within the "Tropical Premontane Wet Forest" of the Holdridge life zone classification system. (Holdridge 1967, Tosi 1969).

Present land cover varies from cane (Saccharum officinarum)/pasture/ secondary forest in the most inaccesible and highest areas through cane/ pasture/coffee (Coffea arabica, Coffea canephora) systems in the middle elevations to a predominantly cane-coffee culture in the valley bottom (Figure 4). Some other crops such as maize (Zea mays) and fruit are commonly cultivated but generally only on a small scale for home consumption. Crop rotation is not usually practiced and tends to occur only after long intervals as a result of biological (e.g. weeds) or financial (e.g. low crop value) pressures.

THE PROJECT

Six sub-projects were proposed for the first year (1979) of this study. The objectives of this phase are:

1) To generate basic data that will be needed to interpret results and permit use of the knowledge in other appropriate regions.

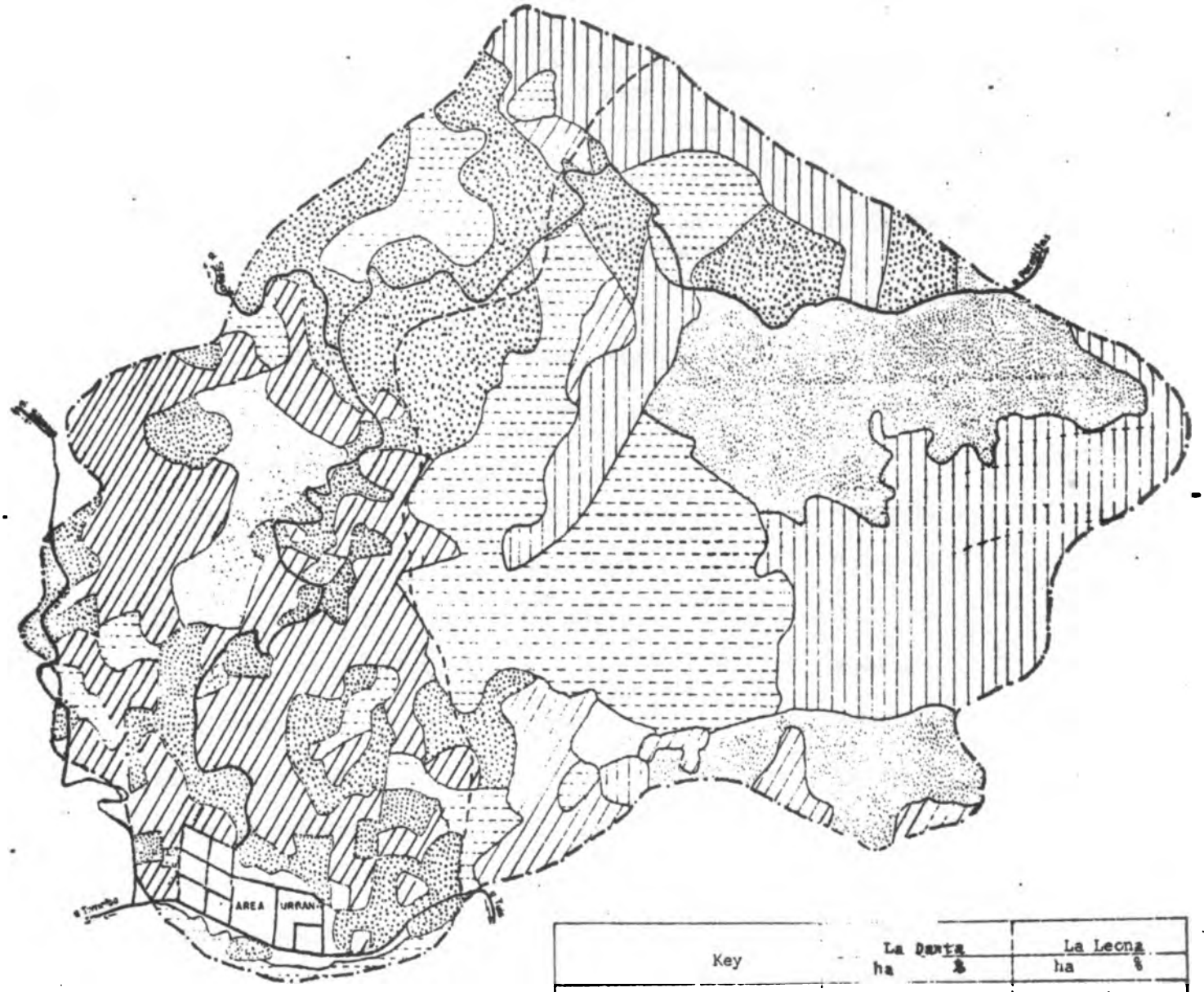
2) To quantify the most important tree-crop associations so that the ecological benefits and limitations can be realistically assessed.

3) To incorporate new practices into the farming systems in order to improve land use and thus reduce soil degradation and erosion.

THE SUB-PROJECTS

1. General survey of the research zone.

The purpose of this sub-project was to record, by means of a specially prepared form, socio-economic and land use data. This work was carried out by 5 CATIE graduate students who subsequently wrote reports on social influences (Apolo 1979), erosion problems (Bermúdez 1979), species of the secondary forest (Fierros 1979), reforestation possibilities (Marcôndes 1979) and agro-forestry practices (Ugalde 1979). The latter author prepared Tables 1 and 2 which give the local and scientific names of the arboreal species most commonly used in agro-forestry systems in La Suiza. Informal conversations with cooperating farmers, and the comments in the 29 questionnaires which were completed for this survey, have lead to the identification of a number of important factors which operate in agro-forestry systems:



Key	La Danta ha	La Danta %	La Leona ha	La Leona %
Urban Area	16.16	4.64	--	--
Secondary Forest	13.34	3.83	148.08	30.73
Coffee	134.05	38.47	33.13	6.88
Sugarcane	125.35	36.04	46.91	9.74
Shrubland	36.09	10.36	136.14	28.27
Pastureland	23.20	6.66	117.31	24.36
Total	348.37	100.00	481.57	100.00

Figure 4 *

Present Land Use

"La Leona" and "La Danta"

Watersheds

Draftsman: Emilo Ortiz C.

*Adapted from Figeroa 1979

Table 1. Trees found associated with crops in the La Suiza research area*.

Scientific name	Common name	Family
Cordia alliodora	Laurel	Boraginaceae
Erythrina poeppigiana	Poró gigante or Poró extranjero	Papilionaceae
Erythrina sp.	Poró	Papilionaceae
Gliricidia sepium	Madero negro	Papilionaceae
Citrus sinensis	Naranja	Rutaceae
Bactris gasipaes	Pejibaye	Palmae
Psidium guajava	Guayabo	Myrtaceae
Citrus limetta	Limón dulce	Rutaceae
Citrus nobilis	Mandarina	Rutaceae
Musa sapientium	Guineo	Musaceae
Musa paradisiaca	Plátano	Musaceae
Musa sapientium	Banano	Musaceae
Syzygium malaccensis	Manzana de agua	Myrtaceae
Persea americana	Aguacate	Lauraceae
Brosimum alicastrum	Ojoche	Moraceae
Vismia guianensis	Achiotillo	Guttiferae
Cocos nucifera	Coco	Palmae
Cedrela odorata	Cedro	Meliaceae
Mangifera indica	Mango	Anacardiaceae

* Adapted from Ugalde, 1979.

Table 2. The most common living fence post species found in the La Suiza research area*.

Scientific name	Common name	Family
Erythrina poeppigiana	Poró gigante or Poró extranjero	Papilionaceae
Erythrina sp.	Poró	Papilionaceae
Gliricidia sepium	Madero negro	Papilionaceae
Cordia alliodora	Laurel	Boraginaceae
Acnistus arborescens	Güitite	Solanaceae
Yucca elephantipes	Itabo	Agavaceae
Psidium guajava	Guayabo	Myrtaceae
Cordyline terminalis	Caña de indio	Liliaceae
Spondias purpurea	Jocote	Anacardiaceae
Miconia sp.		Melastomaceae
Vismia guianensis	Achiotillo	Guttiferae
Lippia torresii L. *oxiphyllaria*	Caragra	Verbenaceae
Croton niveus	Copalchi	Euphorbiaceae
Castilla elastica	Hule	Moraceae

* Adapted from Ugalde, 1979.

1) Although the management of some of the traditional Costa Rican tree-crop combinations is relatively advanced, natural regeneration is the usual origin of the timber species. This leads to uneven tree densities over the crop and consequent management problems, in particular manipulation of the unequal shade. Natural regeneration also produces tree plantations of highly variable form since the parent may well be a sub-standard example which was not cut when its more valuable neighbours were harvested. Moreover, the expanding practice of using herbicide sprays (Apolo 1979) in permanent crop areas, such as coffee and cacao (Theobroma cacao) plantations is adversely affecting the natural regeneration of the valuable tree species such as laurel (Cordia alliodora) and Cedro (Cedrela odorata). The preference of the La Suiza farmers for manual weeding, as opposed to the use of herbicides is presumably one of the reasons for the unusual concentration of agro-forestry associations in this area. The La Suiza farmers are also very receptive to the general idea of tree planting and have ample knowledge, gained from their experiences with coffee, of the establishment techniques. It is interesting that one farmer reported relocating some of the naturally regenerated laurel seedlings to promote a more regular shading of his coffee in the future. Hence, "extension" assistance in the form of improved tree stock and advice about tree pruning and optimum tree, as well as crop, spacing could lead to significant improvements in these traditional systems. With these needs in mind a provenance trial of laurel, initiated on CATIE land, has been repeated in La Suiza.

2) The management of traditional associations is going through a slow empirical process of refinement (Johnson 1972), which has been occurring ever since farmers first planted shade-adapted species within a partially cleared forest (Fuentes 1979). In terms of the number of species and strata a simplification has often resulted. However, the combinations still exhibit a multi-strata aspect and they presumably utilize the available natural resources more completely than a monoculture does. The best developed examples are those associations where the crowns of the timber producing species form the upper layer, leguminous shade trees, Musa spp. and fruit trees occupy the central layer; and a permanent agricultural crop such as coffee or cacao is grown at or near ground level.

3) A possible disadvantage of permitting tall arboreal species with crops is that coalesced rain drops falling from the lofty tree crowns may be more damaging to the flowers, fruit and soil surface than the rain itself (Suarez de Castro 1952). For this reason the central foliage layers, which can intercept these high velocity drops, can provide an extremely important protective shield. Moreover, in the case of the coffee-Erythrina poeppigiana-laurel association, the choice of coffee variety and pruning schedule for the tree species may influence the importance of this problem. In fact, the heaviest pruning, of the Erythrina poeppigiana which drastically reduces the central foliage strata, is usually carried out at the beginning of the dry season when rain drip is at a minimum and root competition for water is increasing.

4) The people are aware of the ecological benefits from associated tree species such as, in the case of Erythrina poeppigiana, the provision of nitrogen and organic material. However, they do not reflect upon the potential financial benefits from the timber species. The annual per hectare increment of laurel growing in cacao on the Atlantic lowlands of Costa Rica could be worth $1,000 at 1979 prices (Gewald and Rosero 1979). Estimates for the laurel growing over coffee in Turrialba give a figure of $654/ha/yr (Combe and Gewald 1979). At present, timber harvesting is usually dictated by the material needs of the family and hence it is far commoner to find that only three or four mature trees have been removed from a stand rather than all merchantable stems. This promotes sustained yield management and means that once established the upper strata may be continously maintained. In this respect it is noteworthy that coppice management of laurel is being independently developed in many areas of Costa Rica including La Suiza (trees with original diameters of up to 40 cm).

5) The production of food by multi-purpose trees growing amongst agricultural crops can be limited by a wide variety of social and practical considerations. The physical danger, to field workers, from spines in the leaf litter of most varieties of the pejibaye palm (Bactris gasipaes) is probably the major reason why associations containing this cash crop species are rarely seen. The availability of spineless pejibaye seedlings would greatly assist the promotion of this potential component for a variety of agro-forestry combinations. Some farmers dislike having fruit trees in their coffee plantations and the edible flower producing "itabo" in their fences because of the damage, to the crop and fence wire respectively, caused by people collecting the fruits and flowers.

II. Benefits and limitations of guava (Psidium guajava) as a pasture shade tree.

Guava is the most common tree in the La Suiza pastures. It is naturally spread by seed passing through the alimentary tract of cattle, and it is tolerated by the farmers because it provides excellent firewood, shade and edible fruit for both farm animals and humans. However, local opinions about the tree's influence upon forage yields and forage moisture content are inconsistent. In order to study this interaction, and to determine growth rates of established trees, two permanent plots of fifty trees each have been delimited (Table 3). Note that the trees utilized for Trial 3 are representative of the oldest guava found and although their age is not known these dimensions are indicative of the size this species will attain in the Turrialba area. In both pastures dimensional measurements were also taken from ten of the remaining trees. These were then felled (early 1979) so that resprounting vigour, and hence continous firewood production capacity, can be related to parent tree size.

Table 3. *Psidium guajava* in pastures.

	Trial 2 (Sra. Smith)	Trial 3 (Sr. Thiele)
Plot area (ha)	0.15	0.16
n	50	47
N (per ha)	340	300
Average number of stems at breast height per root stock	2.6	2.3
$\bar{d}$ of dominant stem (cm)	6.8	10.9
$\bar{h}$ (m)	5.0	6.8
Average crown area (m^2)	19.6	29.3
Portion of plot beneath guava foliage (%)	67	88
Animal density[a] (Cattle - horses per ha)	1	1.8
Major forage species	*Paspalum conjugatum* *P. notatum* *Axonopus compressus*	*Axonopus compressus* *Paspalum conjugatum*

a. Owner's estimate

III. Relative soil stabilization provided by three living fence post species.

An agroforestry practice that is evident throughout Costa Rica is the use of woody plants as living fence posts. Many benefits, both aesthetic and material, result from this practice. Possibly one of the most valuable and least acknowledged properties of these living fence posts is their ability to retard soil bank erosion by means of the mechanical barrier and fine mat of surface roots which they produce. The publication of information on the uses and relative soil stabilizing properties of these fence post species could promote their employment in a wide variety of agro-forestry combinations. For example, they could be interplanted in lines between cropping strips to form living barriers for the control of laminar erosion on steep hillsides. The as yet unrealized objective of this sub-project is to study the traditional establishment techniques, and the potential for erosion control, of the four species most commonly used in La Suiza fences: güitite (Acnistus arborescens), itabo (Yucca elephantipes), madero negro (Gliricidia sepium) and poró (Erythrina berteroana).

IV. Culture of Cordia alliodora with perennial crops

Since associations containing laurel are common, and of greater economic importance than any other agro-forestry combination in La Suiza, this sub-project has been given much greater emphasis than the other five.

Laurel is eminently suitable for the upper component of traditional agro-forestry associations because it readily regenerates on exposed soil surfaces, it is a very fast growing pioneer species, it is self-pruning even in an open grown environment, it naturally forms a straight cylindrical trunk and narrow open crown, it is deciduous in the dry season, it supplies a surprising amount of organic material to the soil (Molleapaza 1979) and it provides one of the best known building woods whose price is rapidly rising (see also Johnson and Morales, 1972). Potential disadvantages are: a) it is susceptible to a number of insect pests (Wheeler 1942) though it appears they rarely cause mortality; b) large cankers may drastically reduce the value of the wood especially in very humid climates (Marshall 1939); c) its large lateral surface feeding roots presumably compete with associated plants; d) the problem of foliage drip mentioned earlier.

Laurel with pasture (frequently in a mixture with other trees such as Erythrina spp.), laurel with sugarcane and, most important, laurel with coffee (usually with E. peoppigiana as well) are three common combinations. Permanent plots have been established within these associations in order to determine wood yields and the tree's influence upon the productive capacity of the associated pasture or crop.

In coffee plantations (Table 4) standing merchantable wood volumes (of laurel) of 128 and 123 m^3/ha, corresponding to basal areas of 10.4 and 13.2 m^2/ha respectively, were found in 2 of the sample plots. The optimal density appears to be between 100 and 200 laurel/ha, the extremes applying to the mature and sapling stages respectively. An equivalent or higher

Table 4. Dimensions of Cordia alliodora, Erythrina poeppigiana and Coffea arabica when associated.

	Trial 1 Sr. Delgado	Trial 6 Srs. Esquivel	Trial 7 Sr. Galván
Plot area (ha)	0.25	0.57	0.24
n	60	61	66
Cordia alliodora			
$\bar{d}$ (cm)	16.9	33.5	23.1
$\bar{h}$ (m)		24.7	Not measured
N (ha)	242	117	275
G (m^2/ha)	5.8	10.4	13.2
V[a] (m^3/ha)	41	128	123c
t[b] (yr)	3-7	7-15	5-15
i_v[b] (m^3/ha/yr)	5.9-13.7	8.5-18.3	8.2-24.6
Pruned (%)	80	0	0
Average height of pruning (m)	7.6	0	0
Erythrina poeppigiana			
$\bar{h}$ (m)	4.9	3.25	--
N (ha)	215	228	0
t[b] (yr)	12	20	--
Coffea arabica			
N (ha)	3760	2750	7300
t[b] (yr)	12	1-20	1-40
Varieties	Caturra	Borbón, Arabica	Borbón
Yield[b] (fanegas[c]/ha)	40	18	21

a. Summation of individual tree volumes calculated with a form factor of 0.5

b. Based on owner's estimate

c. The volume unit 'fanega' is approximately equal to 700 lb. when used for coffee beans.

d. Estimated by calculating heights with the linear regression $h = 0.464d + 5.2$ ($r^2 = 0.72$) derived from Trial 1.

density of E. poeppigiana is only feasible because of the regular lopping. Pruning of the laurel was only observed in a young stand, as one would expect from the responses in the questionnaire forms (sub-project 1). The stratification commonly seen in agro-forestry combinations is illustrated by the height data in Table 4. Laurel forms the upper layer at greater than 12 meters, E. poeppigiana the central layer at 3 to 5 meters and coffee, which is usually allowed to reach 2 meters, the lowest strata. Note that the variations in coffee yields shown in this table are more closely related to the unrecorded factors such as the intensity and type of management than to tree density etc.

Measurement of crop yields from a coffee-E. poeppigiana association (Table 4, Trial 1), with and without a laurel overstory, began only July 13th 1979. Two areas containing approximately 100 coffee bushes were selected and the positions of all trees as well as the bushes were carefully mapped (Table 5). Numbered metal tags were nailed to the stems of the representative bushes so that yields could be determined, over the five month harvest period, on an individual plant basis. Varieties other than Caturra, bushes established after the original planting and bushes that are spaced at less than 1 m intervals, within the rows, were considered non-representative. Border rows were also included in the experimental plots. Harvesting will continue at approximately fifteen day intervals until December when a reliable comparison of yields, beneath and removed from the influence of laurel, will be carried out.

Investigation of the interactions in the laurel-sugarcane association are being deliberately carried out in areas with a high tree density in order to determine the maximum adverse effects which should be expected (Table 6). The first comparative study of the sugarcane yield beneath a stand of laurel, and in an open adjacent area, has been completed. The yields of 5 x 5 m plots beneath mature trees, with a stand density equivalent to 161 stems/ha, were on the average 85% of the control yields (Table 7). This difference was significant, but owing to the inherent variability both in the soils and in the mixture of varieties (table 6) found in the cane fields of cooperating farmers, a much larger sample is essential before attempting any economic comparison of the reduced profit from cane versus the additional wood value resulting from annual tree growth.

Measurements recorded in two pastures containing laurel are summarized in Table 8. As in the case of the laurel - sugarcane trials tree density, basal area, and standing volume were determined from the highest density stands. One of a series of planned studies, related to cattle grazing in tree plantations, has been initiated as part of Trial 8. Cattle have been excluded from plots containing 28 laurel which were paired on the basis of diameters with 28 others that remain in the adjacent grazing areas. The intention is to see if an increase in growth rate occurs after eliminating the cattle which are thougth to be an adverse influence because they cause soil compaction around the shallow lateral laurel roots.

It is interesting to compare the averaged values of the minimum annual volume increments (i) given in Tables 4, 6 and 8. In coffee plantations, sugarcane fields and pasture this is respectively 7.5, 5.1 and 2.9 m^3/ha/yr. This difference could be due to a variety of influences amongst which the following are probably significant: the better soil management in coffee plantations versus sugarcane and pasture land, the physical damage to the

Table 5. Plant densities in the coffee yield plots, Trial 1.

	Coffea arabica plus *Erythrina poeppigiana*	*C. arabica* plus *E. poeppigiana* plus *Cordia alliodora*
Plot area (ha)	0.0212	0.0308
C. alliodora		
n	---	12
E. poeppigiana		
n	8	7
C. arabica		
n	93	115
N (ha)	4387	3734
Average yield[1] (kg/bush)	0.97	0.82

1. Accumulated total from the first 5 pickings (July 15th - September 27 1979).

Table 6. Dimensions of Cordia alliodora and Saccharum officinarum when associated.

	Trial 4 Sr. Delgado	Trial 5 Sr. Salas
Plot area (ha)	0.12[c]	0.056[d]
N	58	34
Cordia alliodora		
$\bar{d}$	21.5	30.7
$\bar{h}$	Not measured	25.3
N (ha)	204[c]	161[d]
G (m^2/ha)	6.8[c]	12.3[d]
V[a] (m^3/ha)	56[c, e]	159[d]
t[b] (yr)	5 - 15	20 -25
i_v[b]	3.7 - 11.2	6.4 - 8.0
Saccharum officinarum		
Yield (tonnes/ha)	60[b]	See Table 7
Varieties[b]	50 - 135	47
	44-30-98	50
		Hawaii

a) Summation of individual tree volumes calculated with a form factor of 0.5

b) Based on owner's estimate

c) For the maximum density stand (25 trees)

d) For the maximum density stand (9 trees)

e) Estimated by calculating heights with the linear regression $h = 0.464d + 5.2$ ($r^2 = 0.72$) derived from Trial 1.

Table 7. Sugarcane yields beneath (Cordia alliodora) and in an adjacent monoculture.

	Replications	Mean plot yield (kg)	Standard deviation of plot yields	Yield (tonnes/ha)
Laurel[a]	8	164[b]	28	66
Control plots	8	193[b]	23	77

a) including one mature laurel tree which forms part of a stand (N=161/ha)

b) significantly different at the 5% probability level by Student's 't' test.

trees in sugarcane fields (machete cuts) and in pasture (soil compaction), the lower density of mature laurel which is generally observed in sugarcane and pasture areas compared to coffee plantations.

Another important consideration in the assessment of agroforestry associations is to determine how the trees influence run-off and erosion. These two characteristics are presently being measured for clay soils in a pasture, and in a coffee plantation, with and without laurel or E. poeppigiana. Table 9 gives the averaged results (3 replications per treatment for the period July to September (inc. 1979). Unfortunately the collection tanks have overflowed on several occasions so the measuring system is now being improved. As a result this preliminary data does not include the rainfall and run-off attributable to 4 of the largest storms that occured during the recording period. Obviously these few unmeasured events would have had a disproportionate influence upon run-off and erosion. Thus, it would be premature to attempta detailed analysis of the information in Table 9. The only conclusion which can be made is that during a typical rainstorm E. poeppigiana or the litter layer it produces, protects the soil of this coffee plantation from surface erosion.

Table 8. Dimensionsof Cordia alliodora associated with pasture.

	Trial 8 (Sr. Fuentes)	Trial 9 (Sr. Muñoz)
Plot area (ha)	0.29[c]	0.29[d]
n	56	65
Cordia alliodora		
$\bar{d}$ (cm)	22.7	24.9
$\bar{h}$ (m)	17.1	19.2
N (ha)	114[c]	67[d]
G (m^2/ha)	5.9[c]	3.7[d]
V[a] (m^3/ha)	60[c]	42[d]
t[b] (yr)	15	5 - 25
i_v[b] (m^3/ha/yr)	4	1.7 - 8.4
Pasture		
Species	Axonopus compressus Homolepsis aturensis Paspalum conjugatum	Axonopus compressus Paspalum conjugatum Homolepsis aturensis Setaria geniculata
Animal density (cattle-horses/ha)	0.5	1.8

a) Summation of individual tree volumes calculated with a form factor of 0.5

b) Based on owner's estimate

c) For the maximum density stand (33 trees)

d) For the maximum density stand (19 trees).

Table 9. Run-off and erosion in a coffee plantation and a pasture with or without a tree overstory (July - September inc. 1979).

	Slope (%)	Run-off (%)	Erosion (kg/ha)	Sediment yield (g/l)
Coffea arabica	30	1.01	313[b]	4.9
C. arabica- *Erythrina poeppigiana*-	30	0.91	41b	0.6
C. arabica - *E. poeppigiana* - *Cordia alliodora*	30	1.50	67[b]	0.9
Pasture[a]	44	5.39	18[c]	17.7[c]
Pasture[a] *E. poeppigiana*	46	8.40	22[c]	25.0[b]
Pasture[a] *C. alliodora*	46	7.19	22[c]	22.5[c]

a. Dominant species *Axonopus compressus*, *Homolepsis aturensis*, *Paspalum conjugatum*.

b. Total for June-September inclusive.

c. Total for two storms only (that produced 30 and 14 mm of precipitation).

V. Delineation of critical erosion areas

A land management scheme for the La Suiza research area is needed to plan the continued development of this case study. Figures 4, 5 and 6, which were prepared by Figueroa*, show present land use, soils, and land use capability respectively. They are based on aerial photographs, enlarged to a scale of approximately 1:90000, and a series of field surveys.

Present land use (Figure 4) consists of a complex mixture of the major crops (sugar cane, coffee, pasture) with areas of abandoned pasture or "charral" The "charral" as well as much of the existing pastureland, is often encountered on steep slopes which are crisscrossed by cattle paths. The secondary forest is not managed and is only utilized as a sourse of a few useful wild plants, such as the vine "bejuco" (Serjania ruficepala) from which baskets are made, and to supply firewood (in particular Lippia torresii).

According to Krushensky (1976) all the land east of the western branch of the "Leona" and the sections of the "Leona" and "Danta" watersheds above 1100 m are underlain by the "Doan" geomorphic formation, a conglomerate-breccia with andesite and basalt fragments. The soils in the remaining section have developed from the "Aguacate" formation, which is composed of air-fall and ash-flow tuff together with mudflows ("Lahares"). Both these formations, which were created by volcanic activity, are underlain by marine sediments.

The terrain between the "Danta" and the western branch of the "Leona" is extremely broken, and a large proportion of the soils are gravelly and/or stoney (Figure 5). These and other topographic features suggest that a large scale mass movement once occurred in this area and that the soil is continuing to creep downhill because the parent material is still not well seated. The consequences of this intermittent movement during the rainy season are cracks and ridges in the roads, broken municipal water pipes and the interesting legal question of who owns a crop that has slid across a farm boundary. Another striking erosion problem is the frequent occurrence of "bombas de agua", small landslides that occur in an explosive fashion after heavy rain.

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* Reprinted by permission of Ing. C. Figueroa from "Contribuciones para un plan de manejo de dos cuencas modelo en La Suiza, Costa Rica". Tesis Mag. Agr. Turrialba, Costa Rica, CATIE. (In preparation).

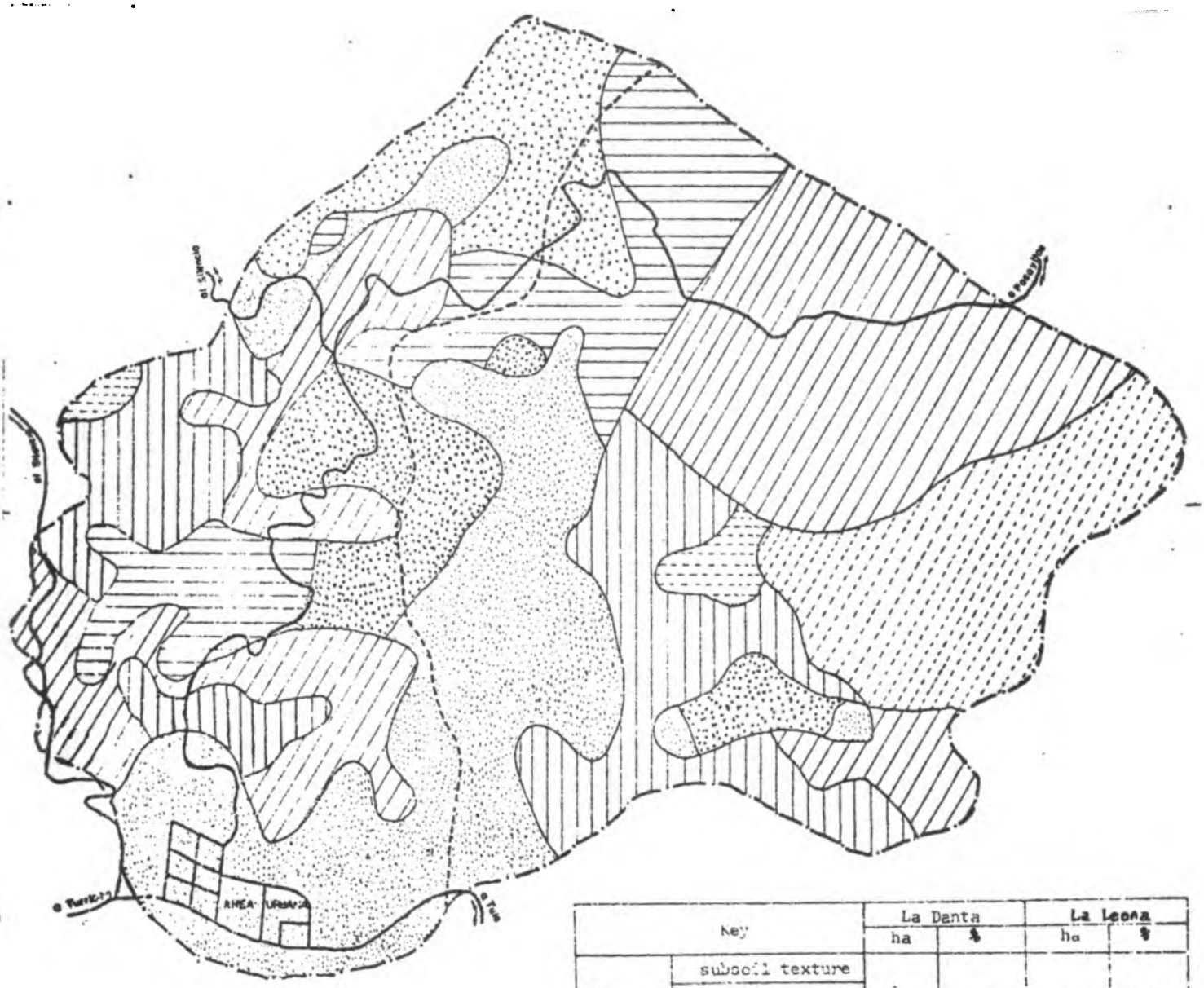


Figure 5

Soils *

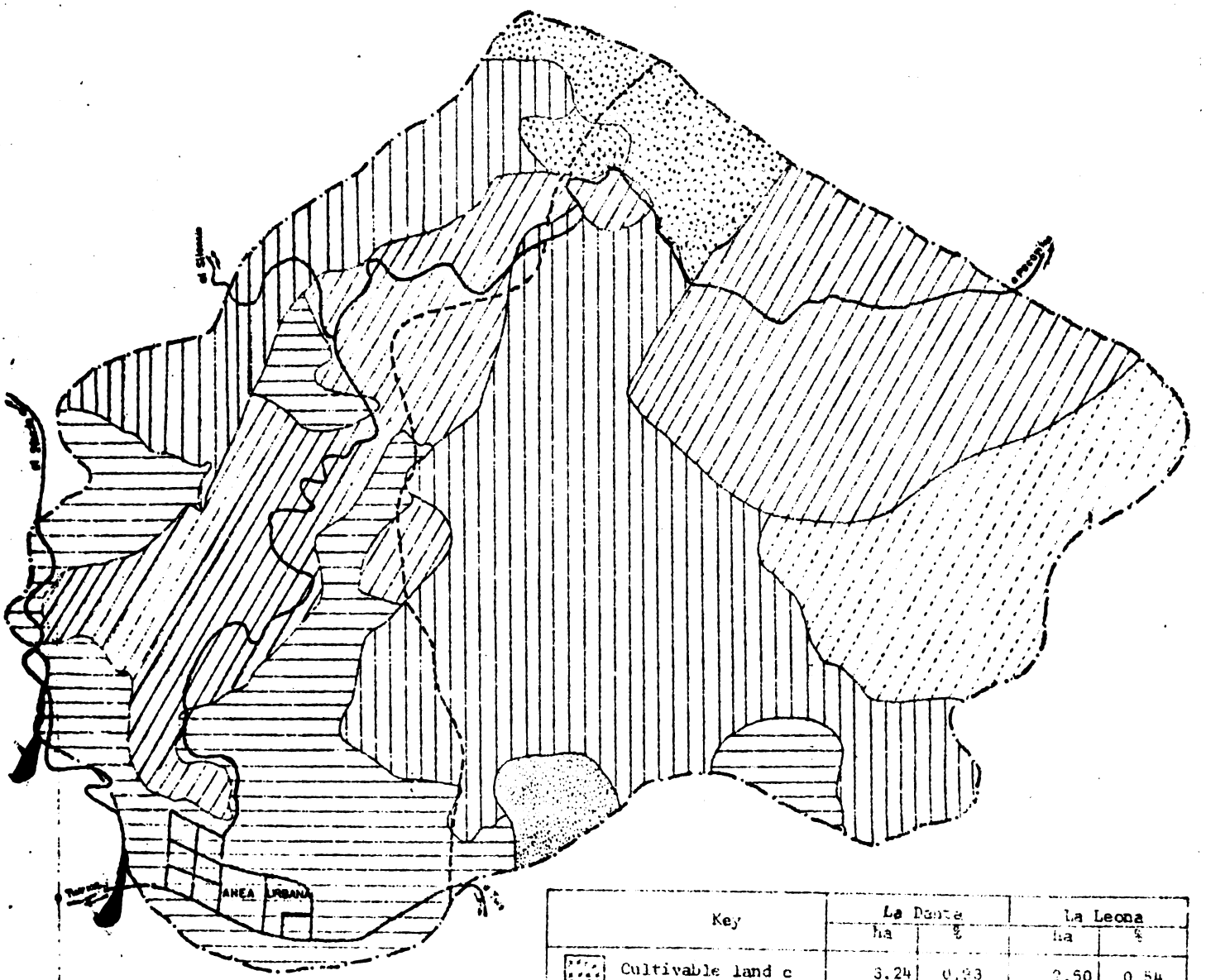
"La Leona" and "La Danta"

Watersheds

Draftsman: Emilio Ortiz C.

*Adapted from Figeroa 1979

Key		La Danta		La Leona	
		ha	%	ha	%
	subsoil texture				
Non-gravelly soils	loamy sand-sandy loam	3.27	0.94	7.42	1.54
	loam	52.05	14.94	71.80	14.91
	clay loam clay	88.83	25.50	140.43	29.16
Gravelly soils	loamy sand-sandy loam	92.81	26.64	86.25	17.91
	loam	70.62	20.27	38.58	8.00
	clay loam-clay	40.79	11.71	56.05	11.64
Unmapped area		--	--	81.09	16.84
Total		348.37	110.00	481.57	100.00



Key	La Danta		La Leona	
	ha	%	ha	%
Cultivable land c	3.24	0.93	2.60	0.54
Cultivable land d	--	--	11.27	2.34
Cultivable land e	150.46	43.19	15.22	3.16
Permanent crop land	104.30	29.94	149.19	30.98
Forest Uses	79.67	22.37	196.57	40.82
Protected Lands	10.70	3.07	24.85	5.16
Un-mapped area	--	--	81.87	17.00
Total	348.37	100.00	481.57	100.00

Figure 6

Land Use Capability*

"La Leona" and "La Danta"

Watersheds

Draftsman: Emilo Ortiz C.

*Adapted from Figeroa 1978

Interestingly a small stream, which may cut a definite channel, often flows from the head of the slide for at least a short time after the original failure. It is suspected that the location of "bombas de agua" may be related to local fracture zones and ground water concentration in soft deeply weathered parent material (tuff, mudflow and ash). A build up of hydrostatic pressure may explain the dramatic characteristics of this process which is distinguishable from the surface slips that are also found in the research area. An attemp will be made to correlate physical land characteristics and soil with the location of the "bombas de agua" and the other small landslides.

The soils of this area have been broadly classified by Perez, Alvarado and Ramírez (1978) using the "USDA 7th Approximation", as "Typic Tropohumults"" associated with "Typic Humitropepts". The soil map (Figure 5) presented here is based on 130 sample points, either auger holes or road cuts. It was drawn up for the classification of potential land uses and hence the aim was to group soils with similar physical characteristics that determine agronomic potential. The divisions are primarily based upon the presence of gravel, cobbles or stones in quantities which would affect drainage, infiltration and workability of the soil. The secondary separation was based upon soil textures which were determined in the field by feel. However, recent laboratory tests indicate some discrepancies in this latter assessment in that many areas mapped as loams may be well-structured clay loams or clays. A classification system developed by Tablas (1973) for El Salvador was used to delimit land use capabilities (Figure 6). It takes into account percent slope, microrelief, soil texture, rockiness, effective depth, drainage, degree of existing erosion, pH and salinity. In the case of the La Suiza watersheds the most common limiting factors were slope, stoniness (at or near the surface) and in one area microrelief.

VI. Reforestation of degraded pastures on hillsides

The establishment of small tree plantations within crop or pasture areas is a case of a non-traditional agro-forestry association. In the La Suiza area there are many examples of degraded pastures undergoing various processes of erosion, in particular on the steep hillsides where cattle produce numerous denuded paths floowing the contours. In such areas productivity is very low and there are good economic arguments, as well as ecological reasons, for converting precipitous pastures into forest plantations.

The aim of this sub-project is to investigate the control of these erosion processes, initially by studying changes in the physical properties of the soil, by comparing the existing animal husbandry system with coniferous or natural reforestation schemes. Opportunity is also being taken to study species and provenances suitability for these degraded pastures. Cupressus lusitanica, Pinus caribaea and P. oocarpa (14 provenances)have been planted in the poorest sections (approximately 1.3 ha per trial) of the pastures in two La Suiza farms. The tree parameters that will be annually measured are height and survival. The soil study involves a yearly comparison of soil characteristics that influence erosion, such as bulk density and organic material content.

A rough calculation of the establishment costs for one plantation showed an investment of $651/ha. However, the complications arising from the experimental requirements led to excessive labour requirements and hence an inflated cost. The main benefit of such an accounting is for comparing costs in equivalent trials when techniques or materials are changed. In the above example, the material costs for the encompassing fence amounted to 37% of the $651 total. If the same number of living fence post stakes, locally purchased at 23 cents each, had been used instead of buying chemically treated fence posts the total cost would have been reduced to $531/ha.

CONCLUSIONS

The initial phase of this case study on agro-forestry practices in a wet tropical zone has illustrated the complex network of factors which operate in these traditional systems. The early results support the contention that these combinations are economically and ecologically sound. However, a number of limitations have also come to light amongst which the most important that need further study are:

a) the relationship between the overall "architecture" of combination of foliage drip damage to the lower story.

b) the social restrictions on the location of multi-purpose trees such as the heavily spined pejibaye palm.

c) the poor quality and uneven distribution of the timber trees component.

Data on crop and tree yields, and environmental factors are beginning to accumulate. For example, the early results from one experiment show that erosion in coffee plantations can be greatly reduced by the inclusion of a leguminous tree Erythrina poeppigiana. A comprehensive assessment of these traditional agro-forestry practices is not yet possible but the study to date suggests that laurel is an excellent choice for tree-crop combinations. Although this tree can affect crop yields (significantly, at densities above 100 mature trees per hectare) the estimated value of the timber in typical associations more than offsets this limitation. Moreover, for the small farmers, who are the best proponents of these systems, the diverse mixtures of species found in the traditional combinations provide a range of materials for home use and an important economic safeguard.

The localized variation in apparently similar tree-crop combinations, and the inconsistant perception of the combinations benefits and limitations, point to the need for some simple guidelines for their management. As well as continuing with the scientific quantification of the existing associations the emphasis of this case study should gradually shift to include the testing of hypotheses formulated on: a) optimal tree and crop densities, b) management techniques (e.g. thinning and pruning), c) the potential of genetically improved tree stock.

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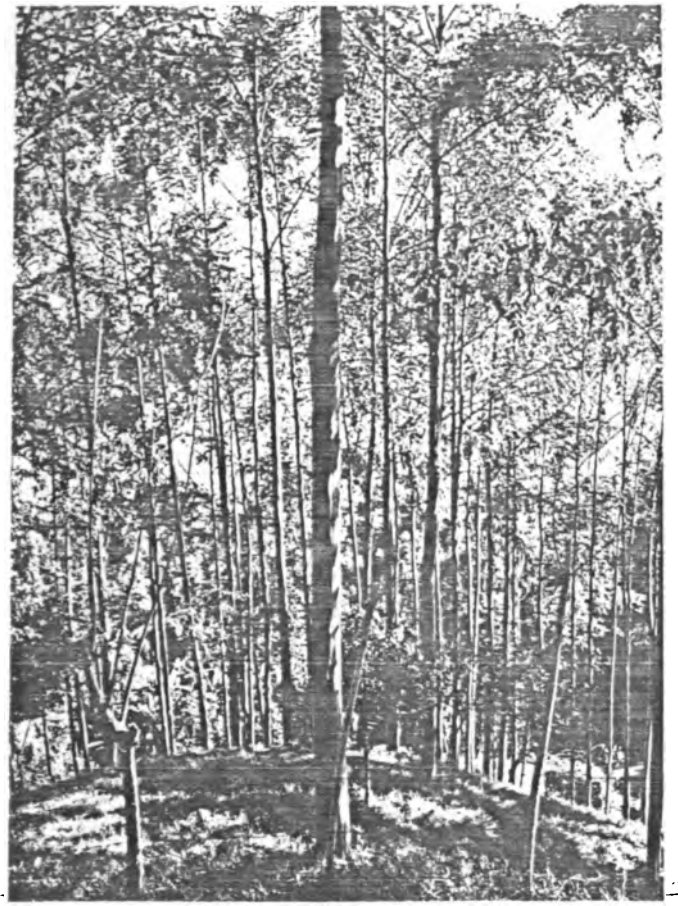
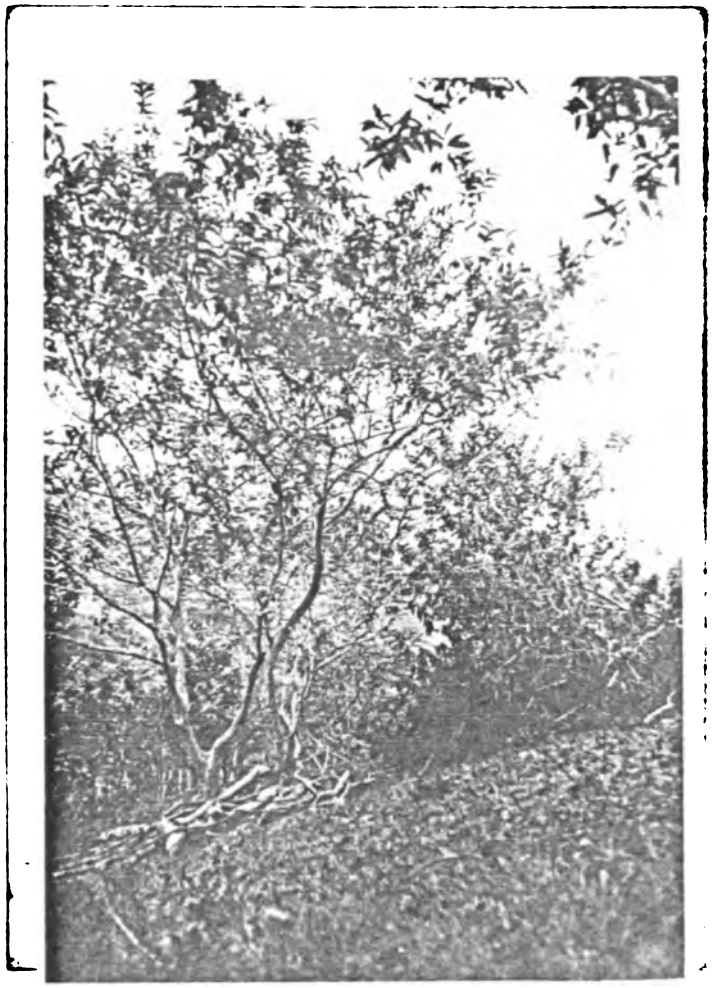
APPENDIX

PHOTOGRAPHS OF AGROFORESTRY PRACTICES IN THE VICINITY OF LA SUIZA, TURRIALBA, COSTA RICA



PHOTOGRAPH 1.

Eucalyptus deglupta with pasture (Cynodon nlemfuensis) in Turrialba.



PHOTOGRAPH 2.

Psidium guajava in pasture. The cut wood is being dried for firewood.
Trial 2. La Suiza.

PHOTOGRAPH 3.

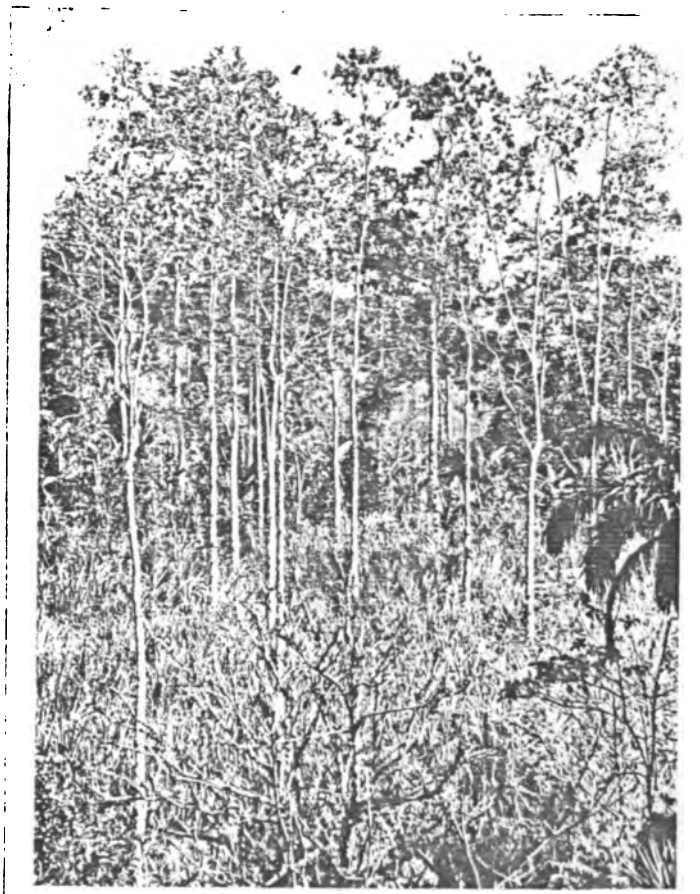
Erythrina poeppigiana in a pasture. Cattle eat the leaves and horses the leaves and bark.
Trial 8. La Suiza.

PHOTOGRAPH 4.

Itabo (Yucca elephantipes) as a living fence post. The cow is eating entire banana plants (Musa spp.).
La Suiza.

PHOTOGRAPH 5.

Yucca elephantipes planted to reduce roadside erosion.
Turrialba.



PHOTOGRAPH 6.

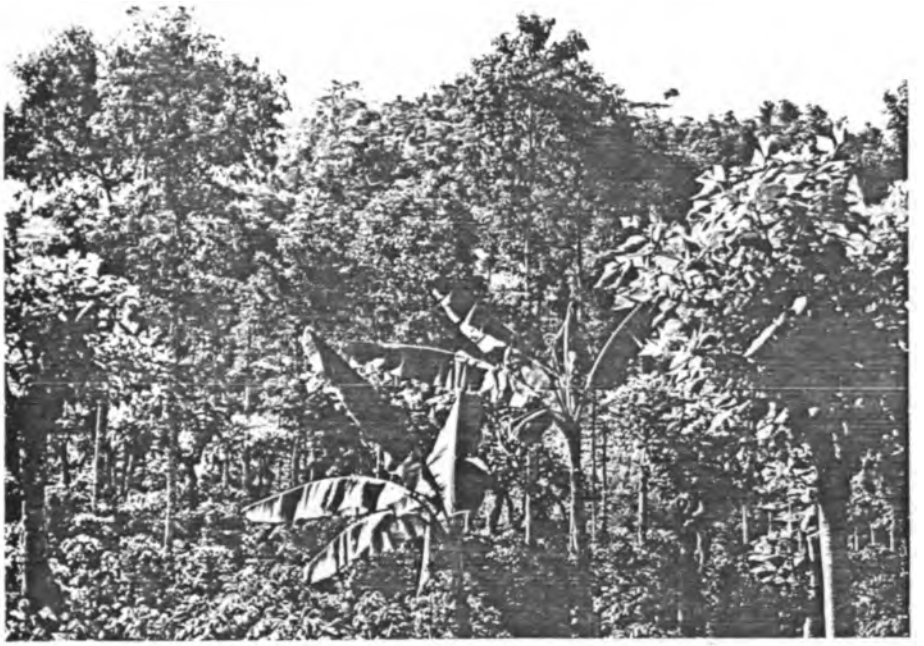
Laurel (Cordia alliodora) over sugar cane (Saccharum officinarum).
Trial 5. Table 7.

PHOTOGRAPH 7.

Students from the "Colegio Agropecuario de La Suiza" measuring coppice shoots of Cordia alliodora.
La Suiza.

PHOTOGRAPH 8.

A coppice of Cordia alliodora that is near merchantable size.
La Suiza.



PHOTOGRAPH 9.

Multistrata system of Cordia alliodora (upper), Erythrina poeppigiana (central) and Coffea arabica var. caturra (lower).
Trial 1. La Suiza.

PHOTOGRAPH 10.

The same site as is shown in photograph 9 after the July pruning of the Erythrina poeppigiana.
Trial 1. La Suiza.

PHOTOGPAPH 11.

Erosion and run-off measurements in a pasture that contains harvestable Cordia alliodora.
Trial 8. La Suiza.