A FARM TYPOLOGY FOR THE ATLANTIC ZONE

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The Research Program on Sustainability in Agriculture (REPOSA) is a cooperation between Wageningen Agricultural University (WAU), the Center for Research and Education in Tropical Agriculture (CATIE), and the Costa Rican Ministry of Agriculture and Livestock (MAG). In addition, REPOSA has signed memoranda of understanding with numerous academic, governmental, international, and non-governmental organizations in Costa Rica.

The overall objective of REPOSA is the development of an interdisciplinary methodology for land use evaluation at various levels of aggregation. The methodology, based on a modular approach to the integration of different models and data bases, is denominated USTED (*Uso Sostenible de Tierras En el Desarrollo*; Sustainable Land Use in Development).

REPOSA provides research and practical training facilities for students from WAU as well as from other Dutch and regional educational institutions.

REPOSA's research results are actively disseminated through scientific publications, internal reports, students' thesis, and presentations at national and international conferences and symposia. Demonstrations are conducted regularly to familiarize interested researchers and organizations from both within and outside Costa Rica with the *USTED* methodology.

REPOSA is financed entirely by WAU under its Sustainable Land Use in the Tropics program, sub-program Sustainable Land Use in Central America. It operates mainly out of Guápiles where it is located on the experimental station *Los Diamantes* of MAG.

REPOSA (*Research Program on Sustainability in Agriculture*, o sea Programa de Investigación sobre la Sostenibilidad en la Agricultura) es una cooperación entre la Universidad Agrícola de Wageningen, Holanda (UAW), el Centro Agronómico Trópical de Investigación y Enseñanza (CATIE) y el Ministerio de Agricultura y Ganadería de Costa Rica (MAG). Además REPOSA ha firmado cartas de entendimiento con organizaciones académicas, gubernamentales, internacionales y non-gubernamentales en Costa Rica.

REPOSA ha desarrollado una metodología cuantitativa para el análisis del uso sostenible de la tierra para apoyar la toma de decisiones a nivel regional. Esta metodología, llamada USTED (Uso Sostenible de Tierras En el Desarollo) involucra dimensiones económicas y ecológicas, incluyendo aspectos edafológicos y agronómicos.

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REPOSA publica sus resultados en revistas científicas, tesis de grado, informes, y ponencias en conferencias y talleres. REPOSA regularmente organiza demostraciones para investigadores de Costa Rica y de otros países para familiarizarlos con la metodología USTED.

REPOSA es financiado por la UAW bajo su Programa del Uso Sostenible de la Tierra en los Areas Trópicos. La sede de REPOSA está ubicada en la Estación Experimental Los Diamantes del MAG en Guápiles.

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ACKNOWLEDGEMENTS

1 INTRODUCTION

This study is carried out as part of the Atlantic Zone Program in Costa Rica, which is the result of an agreement for technical cooperation between the Centre for Research and Education in Tropical Agriculture (CATIE), the Wageningen Agricultural University and the Costa Rican Ministry of Agriculture and Animal Production (MAG). The Program aims at the development of a methodology for the analysis of alternative land use scenarios. The methodology uses a linear programming model for the basic calculations, in combination with a geographical information system and simulation models (Stoorvogel, 1994a).

1.1 Problem definition

The methodology for the analysis and planning of land use, denominated USTED (Uso Sostenible de Tierras en El Desarrollo; Sustainable Land Use in Development), aims at the analysis of alternative land use scenarios and evaluates them in terms of e.g. productivity and sustainability (Alfaro et al, 1994). Although USTED focuses on the regional level, the individual farms are included as the final decision makers. Farms are grouped into a restrict number of farm groups, to deal with the relatively large number of farms (Stoorvogel, 1994a). In land use analysis it is often necessary to generalize individual farms into a number of farms types. Such a farm typology can be done on the basis of a wide range of criteria ranging from bio-physical characteristics like farm size to socio-economic criteria as farmer objectives. In the USTED methodology data availability excludes a number of socio-economic criteria. Other parameters like land use are excluded since it forms the output of the linear programming model. Therefore the farm typology is performed, based on the physical production possibilities represented by farm size and soil groups (Alfaro et al, 1994).

For small regions within the study area detailed soil maps are available, which typically contain few soil associations. According to the Soil Survey Staff (1992), soil associations are heterogeneous mapping units which on a more detailed map scale can be mapped into more homogeneous units. For these regions also maps with the locations of the farms are available. A farm typology can be based on the soil map and the farm map.   .
At regional level the location of farms is not known. In addition small scale soil maps contain more soil associations, which need a different approach for the farm typology. At regional level a farm typology is based on a less detailed map scale, implying that the farm typology will be more generalized due to data availability. In the farm typology the most prevailing soil group of the soil association will be utilized. A problem is although that not every farm will contain predominantly the most prevailing soil due to soil variability. On basis of the used soil map it is not possible to determine which soil group farms contain. Therefore new procedures have to be developed to perform farm typology.

This research tries to deal with these problems and presents a procedure to perform a farm typology at regional level. The procedure will be carried out for both a pilot area and the northern Atlantic Zone of Costa Rica. While the Atlantic Zone of Costa Rica is rather complex to perform the farm typology, first a small sub-region, the Guácimo canton, will be

studied. After a field check and adjustment of the performed farm typology, the procedure will be extended to the Atlantic Zone.

Additionally an indication will be given of soil variability within farms. Furthermore specific attention is given to functional soil grouping. Soil fertility and biocide leaching are considered the principal constraints on the sustainability of agriculture in the Atlantic Zone (Stoorvogel et al, 1995). With the aid of simple transfer functions biocide leaching and soil fertility are studied for the prevailing soils in the Atlantic Zone. The results of these transfer functions are added to the outcome of the costa rican land evaluation system (SEPSA, 1992) and used to determine a functional soil grouping.

1.2 Research area

Costa Rica is located in Central America between 8°02' to 11°13' N latitude and 82°33' to 85°57' W longitude (Herrera, 1985). At first sight Costa Rica can be divided into three morphologic main regions:

mountain ranges running from northwest to southeast

a northeastern Atlantic-Caribbean Lowland

a Pacific coastal region broken up by peninsulas and bays.

Costa Rica is dominated physiographically by the central mountain range, a sequential series running northwest southeast, the Guanacaste mountain range, the Central mountain range and the Talamanca mountain range. The northeastern Atlantic-Caribbean lowlands extend from the Guanacaste mountain range foothills to the Caribbean coast. The vast Caribbean lowlands cover about 20 % of the country. The Pacific coastline is extremely broken by peninsulas, bays and islands offshore with an mountainous country, the Nicoya complex, which often approaches right up to the sea. Between the Guanacaste mountain range and the Nicoya complex lies a broad depression called the Valley of the Tempisque, after de main river it contains (Hartshorn et al, 1982; Weyl, 1980).

Climate ranges from humid tropical via temperate mountain to semi-arid within a distance of about 120 km. This climatic diversity is related to the high central mountain range. Mountainous regions above 1000 m are generally cool and temperate, with abundant and moderate seasonal rainfall (2 - 5 m/yr). In the Atlantic and southern Pacific lowlands, rainfall is high (2 - 7 m/yr) and relatively aseasonal. The northern half of the Pacific coastal plain forms a distinct, markedly drier (1 - 2 m/yr) region, where precipitation is more seasonal than in the rest of the country (Herrera, 1985; Gómez, 1986).

The varied physiography and climate of Costa Rica support 12 ecological Life Zones, each with an impressively diverse biota. Two Life Zones, Tropical moist and Tropical wet, cover nearly half of the country (Holdridge, 1967).

The Atlantic Zone Program aims at the northern part of the Atlantic Zone, situated in the north-east of Costa Rica (Figure 1.2.1). It covers the cantons Siquirres, Guácimo and Pococi and part of Limón and Matina, which all lie in the Limón province. The Atlantic Zone is characterized by rapid land use changes. During the last 50 years, a large part has been deforested and colonized (Sader & Joyce, 1988; Veldkamp et al, 1992).
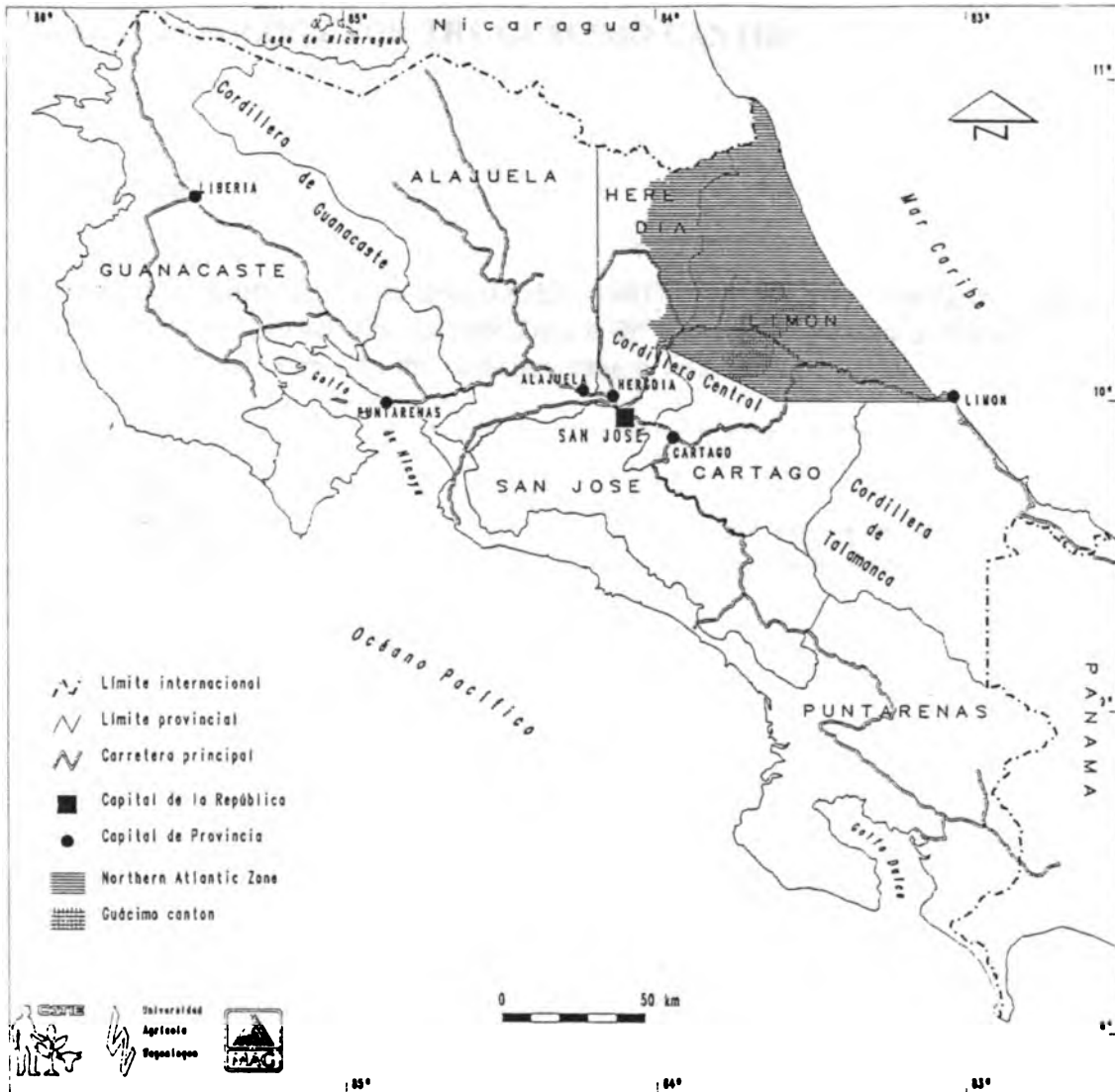
Figure 1.2.1 The location of Costa Rica with the Atlantic Zone and pilot area Guácimo.

The climate is characterized by abundant rainfall during the whole year (3000-6000 mm/y), and high temperatures with an annual average of 26°C. As a consequence the relative humidity is high with an average of 87% (Herrera, 1985).

Soils in the area are of volcanic origin and predominantly classified as Andosols, Inceptisols (Soil Survey Staff, 1992). Their fertility status depends largely on the age of soil formation. The volcano slopes are dominated by lava- and mudflows in which infertile soils developed. On the alluvial fan, near present or past riverflows, young deposits can be found (Histosols and Entisols). The alluvial plain is dominated by well to poorly drained fertile deposits (Wielemaker & Vogel, 1993).

2 A FARM TYPOLOGY FOR THE GUÁCIMO CANTON

2.1 Introduction

Due to the availability of census data (DGEC, 1987) at canton level, the farm typology has to be carried out per canton. The Atlantic Zone is divided into five cantons (Figure 2.1.1). For the setup of the procedure first the Guácimo canton was used.
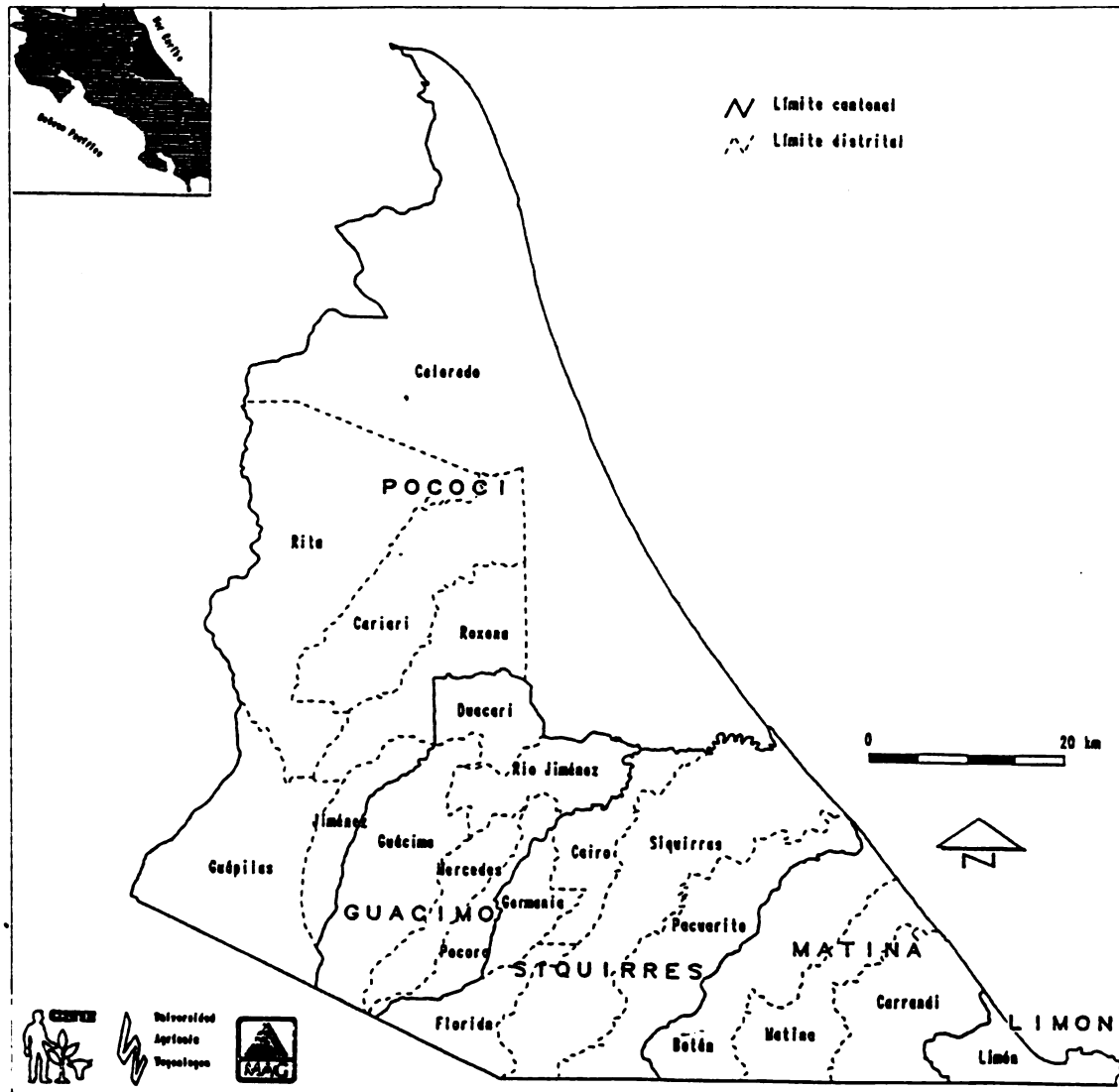
Figure 2.1.1 The cantons of the Atlantic Zone.

Guácimo has a total area of 58,000 ha and 1,887 farms. The altitude of cultivated areas is between 10 and 500 m above sea level in a region with is classified as humid tropical, without dry months. The average annual rainfall is 3,600 mm with an average daily air temperature of about 25°C (Herrera, 1985).

The farm typology will be carried out on the basis of the criteria soil groups and farm sizes. These criteria are classified before the results are combined and the farm typology can be carried out. On the basis of expert knowledge admittedly arbitrary classes for farm size are defined (Table 2.1.1).

Table 2.1.1 Farm size classes.

Farm size	Area (Ha)
1	≤15
2	>15 and ≤30
3	>30

The location of the farm sizes will be combined with the soil map (1:150,000) in an overlay procedure. The original soil survey identified 75 different soil series, although part of these soil series are classified on the basis of soil genesis and are similar in their management (Wielemaker & Vogel, 1993). To keep the number of farm types limited, three main soil groups are identified on the basis of drainage and inherent soil fertility (Table 2.1.2).

Table 2.1.2 Description of the soil groups for the Guácimo canton.

Group	Description
1	Fertile and well drained soils; Andisols, Inceptisols, Dystropepts
2	Fertile and poorly drained soils; Entisols, Aqui subgroup of Inceptisols, Aquepts, Aquents.
3	Infertile and well drained soils; Oxic subgroup of Inceptisols, Oxisols

The soil map describes for each mapping unit the distribution of soil groups in percentages. In this chapter only the prevailing soil group is utilized, assuming that each farm in a mapping unit contains the described combination of soil groups. This assumption will be examined in Chapter 3.

Different sources of information have provided for the necessary data to establish the farm typology. The Atlantic Zone Program developed a GIS database including both physiographic and socio-economic data (Stoorvogel & Eppink, 1995). The data from the GIS are used and combined to carry out the farm typology. Chapter 2.2 will explain this procedure.

2.2 Methods

A procedure has been developed to carry out a farm typology for the Guácimo canton (Figure 2.1.1). First a screening took place to select agriculturally used areas. Large parts of Guácimo (27 %) are protected by law, Figure 2.2.1. Protected areas contain the zones proposed by the International Union for the Conservation of Nature, the Indian Reservations and a political buffer zone along the border with Nicaragua. It is assumed that there are no farms in protected or forest areas. The total area of the districts, minus the area with protected and forest areas is the area which is agriculturally used and for which the farm typology will be carried out. When the total area is known, the number of farms have to be calculated.
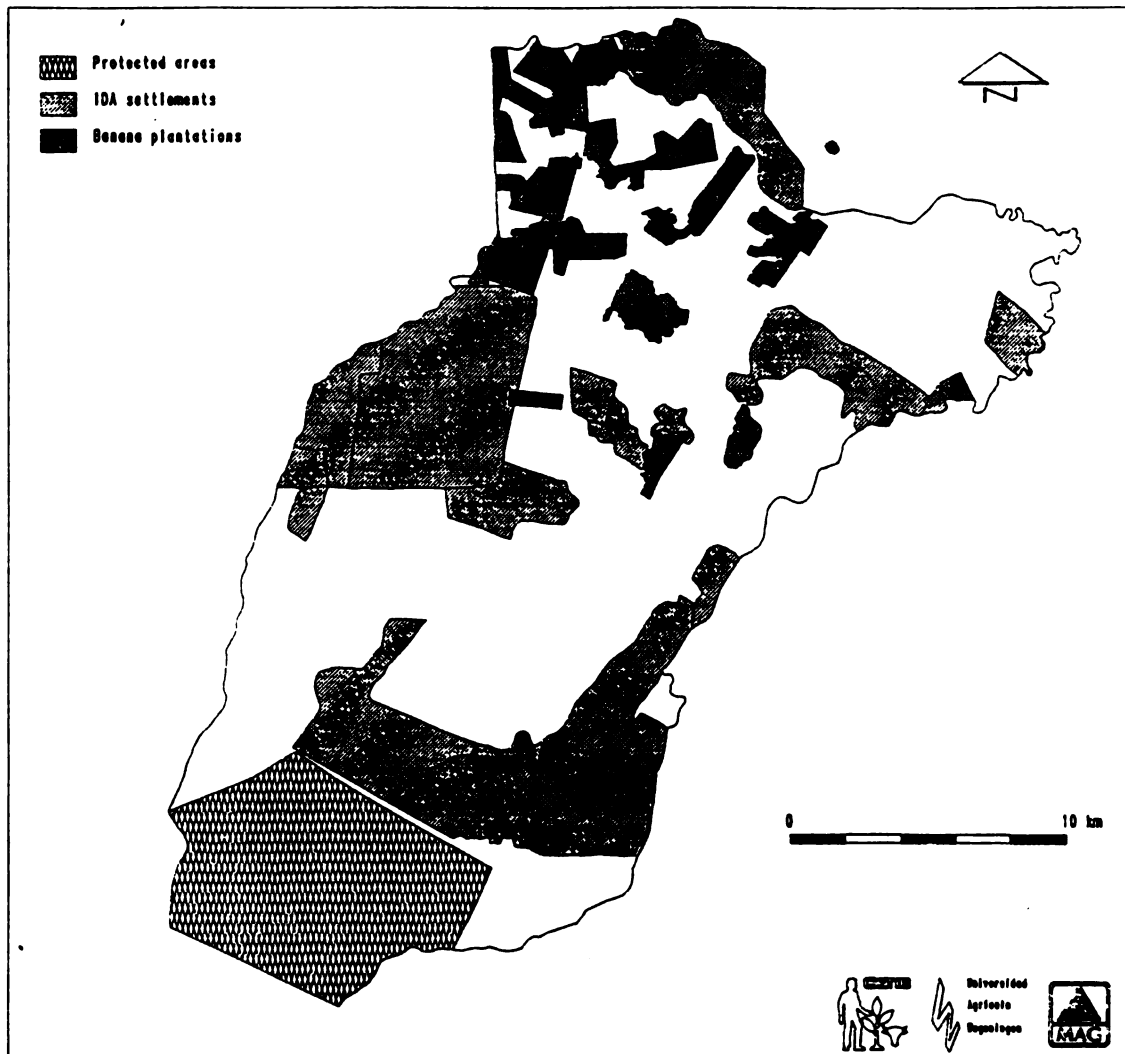
Figure 2.2.1 Guácimo with protected and forest areas, IDA settlements and banana plantations.

Banana plantations with their fixed land use are not of interest for the analysis and planning of land use. Therefor the areas with banana plantations (Figure 2.2.1) are separately indicated in the procedure. Also a large experimental farm (EARTH) is separately indicated, it covers 5 % of the Guácimo canton and is not of interest for the analysis and planning of land use. The total number of farms (X_{tot}) for 1984 is known from census data (DGEC, 1987). The

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1984 census contains data on for instance the number of people living in the districts, the number of people working in agriculture and the number of farms. Every half a year the population data are corrected with birth and death data, without taken into account migration. In other words, births that have taken place between the interval of time under study have been added to the basic population, after which the deaths in the same interval were subtracted, leaving out any consideration of increase or decrease of population due to migration (Lok, 1992).

Assuming that between 1984 and 1992 the relation between farms and population growth is linear, the number of farms for 1992 could estimated. The number of farms for 1992 is established by correcting the 1984 census data on the basis of population growth and banana expansion. The correction for growth of banana plantations can be derived from the GIS data base of the Atlantic Zone Program, by comparing the 1984 and 1992 land use map.

The data about the number of farms for banana plantations and farms of the Institute for Rural Development (IDA) can be more specified. IDA deals with conflicts in land ownerships. It buys land and distributes this under farmers for colonization and occupies about 25 % of the area of the Guácimo canton (Figure 2.2.1). For specific IDA settlements the total area, the number of families and the average farm sizes are presented in Appendix I. To calculate the number of farms in an IDA settlement (X_{IDA}) first the average farm size ($Size_{IDA}$) for this IDA settlement is estimated. The area of the settlement ($Area_{IDA}$) is divided by the number of families. Some of these families are not working in agriculture, but have other employments within the IDA settlement. Using all the families in the calculation causes a decrease in farm size. To adjust the small farm sizes in the calculation of the number of farms, a minimum of 12 Ha is used. The area of the settlement is corrected for ten percent non-agricultural utilization:

$$X_{IDA} = \Sigma((0.9*Area_{IDA})/Size_{IDA}), \text{ for } Size_{IDA} > 12 \text{ Ha,}$$

and

$$X_{IDA} = \Sigma((0.9*Area_{IDA})/12), \text{ for } Size_{IDA} \leq 12 \text{ Ha.}$$

The area and location of banana are known, there are only no borders distinguished between different plantations. Therefore the number of farms has to be estimated. The total number (X_{banana}) can be calculated by dividing the total area of banana plantations ($Area_{banana}$) by the size of an average farm (120 Ha), whereby the average farm size is based on expert knowledge:

$$X_{banana} = Area_{banana}/120.$$

The total number of farms at banana plantations and IDA settlements are indicated as X_{known}:

$$X_{known} = X_{IDA} + X_{banana}.$$

For the area outside settlements and plantations the number of farms will be estimated (X_{est}). The estimated number of farms must be equal to the total number of farms from census data minus the farms at banana plantations and in IDA settlements:

$$X_{est} = X_{tot} - X_{known}.$$

The land use zone map (Huising, 1993; Belder, 1994) indicates areas with similar land use

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patterns, correlating with specific crops, vegetation and parcel sizes. Parcel sizes form the basis to determine farm sizes (Table 2.2.1), whereas it is assumed that a specific parcel size corresponds with the farm size. The relation between farm size and parcel size is based on expert knowledge. The influence of the estimation of the farm size is examined in a sensitively analysis.

Table 2.2.1 Average farm sizes for different land use patterns for the Guácimo canton.

Landuse	Farm size (Ha)
- Extensive agriculture	15
- Pastures, parcels <15 Ha	15
- Pastures, parcels >15 Ha	30
- Pastures, parcels not recognized	60
- 70 % annuals or mixed agriculture, average parcel size 3 Ha	6
- >70 % annuals or mixed agriculture, parcel size 6 - 20 Ha	15
- Plantation, other than banana	65

For each mapping unit, with a similar land use pattern, the number of farms (X_{est}) is calculated by dividing the area of the mapping unit (Area$_i$) with an average farm size (Size$_i$). While the sum of estimated number of farms (ΣX_{est}) must be equal to (X_{tot}-X_{known}), X_{est} is corrected for the ratio of X_{tot}-X_{known} and ΣX_{est}:

$$X_{est} = \sum_{i=1}^{i=n} ((Area_i/Size_i) * ((X_{tot}-X_{known})/\Sigma X_{est})).$$

Knowing the total number of farms in the different districts and additionally in the land use zones, the actual farm sizes (Farm size$_i$) for the different land use zones can be calculated. The land use zone map will be used for the areas of these mapping units. To determine the farm sizes the areas for banana plantations, IDA settlements and various land use types are divided by the number of farms for the diverse components:

$$Farm\ size_i = ((Area_i/X_{est})$$

$$Farm\ size_{banana} = (Area_{banana}/X_{banana})$$

$$Farm\ size_{IDA} = (Area_{IDA}/X_{IDA}).$$

Eventually in association with the soil map for each district the distribution of farms, their sizes and soil types are distinguished. The ultimate farm typology can be determined through combining farm size with soil group. Finally for each mapping unit the farm typology is known.

In the final map with the farm typology banana plantations, protected areas and the experimental farm EARTH are separately indicated. After the determination of the farm typology a field-check has been carried out. For five areas differences in farm typology are study, whereby farm size and soil were examined on basis of information of farmers. It is aimed to cover all the prevailing farm types within these five areas. The soil classification according to farmers' descriptions of Brink & Waaijenberg (1990) is used:
'Tierra Negra', a black fertile soil without problems
'Tierra Colorada', a red soil of low fertility
'Suampo', swamps which can be black soils, located in the lower parts and near the rivers. In general is the 'Tierra Negra' comparable to the fertile, well drained soil group (FWS) (Table 2.1.2). The fertile, poorly drained soils (FPS) are identified by farmers as 'Suampo' and the infertile, well drained soil group (IWS) with 'Tierra Colorada'.

2.4 Results

The total number of farms for 1984 and 1992 from census data are corrected for population growth and changes in area of banana plantations (Table 2.4.1).

Table 2.4.1 Population data (total number of people per district) for Guácimo canton.

District	------------1984-------------			1992	1984-1992
		-------Working-----			
	Farms	Agriculture	Total	Total	Growth
Guácimo	477	1,125	6,158	8,521	1.38
Mercedes	42	182	796	975	1.22
Pocora	134	578	2,717	3,896	1.43
Río Jimenez	368	1,123	4,102	5,884	1.43
Duacari	250	640	2,699	3,517	1.30

The areas of banana plantations for the districts of the canton Guácimo present in 1984 and 1992 are shown in Table 2.4.2. Abandoned plantations indicate the percentage of banana plantations which is deserted between 1984 and 1992. Established plantations are the percentage of banana plantations extended after 1984. In 1992 banana plantations covered about 12 % of the area.

Table 2.4.2 Area (in Ha) of banana plantations for Guácimo canton.

District	1984 (Ha)	1992 (Ha)	Abandoned plantations 1984-1992[1] (%)	Established plantations 1984-1992 (%)
Guácimo	278.0	857.0	0.2	3.3
Mercedes	566.9	242.5	4.1	0.0
Pocora	98.9	97.6	0.0	0.0
Río Jimenez	688.4	797.5	0.0	1.1
Duacari	1224.8	2751.5	0.6	20.2

As can be seen from Table 2.4.2 an expansion of banana plantations took place between 1984 and 1992 for Duacari. It may be likely that the expansion coincided with deforestation. For the Guácimo canton it was verified if deforestation took place by comparing the map of protected and forest areas of 1984 with the 1992 map of banana plantations. Deforestation was not caused by the new established plantations, each banana plantation was started at prior agricultural land.

The number of farms for 1992 is established by correcting the 1984 census data on the basis of population growth and banana expansion (Table 2.4.3).

Table 2.4.3 The number of farms for 1992, corrected for population growth and area of banana plantations for the Guácimo canton.

District	Number of farms (1984)	Correction		
		Population growth	Area of banana	Number of farms (1992)
Guácimo	477	+38%	-3.1%	643
Mercedes	42	+22%	+4.1%	53
Pocora	134	+43%	-	192
Río Jimenez	368	+43%	-1.1%	522
Duacari	250	+38%	-19.6%	296

[1]Abandoned and established plantations are expressed in a percentage of the effective agricultural area; total surface area of district minus surface area of forest and urbanization.

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Small differences in farm sizes do not influence the final result in the calculation of the number of farms. The influence of the estimation of the farm size itself is negligible, Appendix II.

On the basis of three farm sizes and three dominant soil groups nine farm types can be distinguished, of which the total area of a certain soil group is known (Table 2.4.4).

Table 2.4.4 Farm types with absolute distribution to soil groups for the Guácimo canton.

Farm type	Farm size	Soil group	Number of farms	Soil1 (Ha)	Soil2 (Ha)	Soil3 (Ha)
F11	1	1	645	6294	1413	139
F12	1	2	153	148	1302	130
F13	1	3	276	9	257	3755
F21	2	1	166	3210	595	114
F22	2	2	250	402	5088	290
F23	2	3	285	25	463	6506
F31	3	1	5	76	52	45
F32	3	2	33	99	816	270
F33	3	3	17	2	36	609
F40	-	-	57	3154	2869	776
F50	-	-	0	1130	495	1483
F60	-	-	0	4099	7011	4227

Figure 2.4.1 shows the map of Guácimo with the farm typology. In this figure banana plantations are separately indicated with F40, EARTH is indicated with F50 and protected areas with F60. IDA settlements are not identified in the results, while the farm typology is independent of the position of a farm is within an IDA settlement or not.During the field work the above map with the farm typology is checked. In Table 2.4.5 to 2.4.9 the farm typology out of the procedure is indicated together with the results of the field description. The five areas for which the field check is carried out, are indicated in Figure 2.4.1.
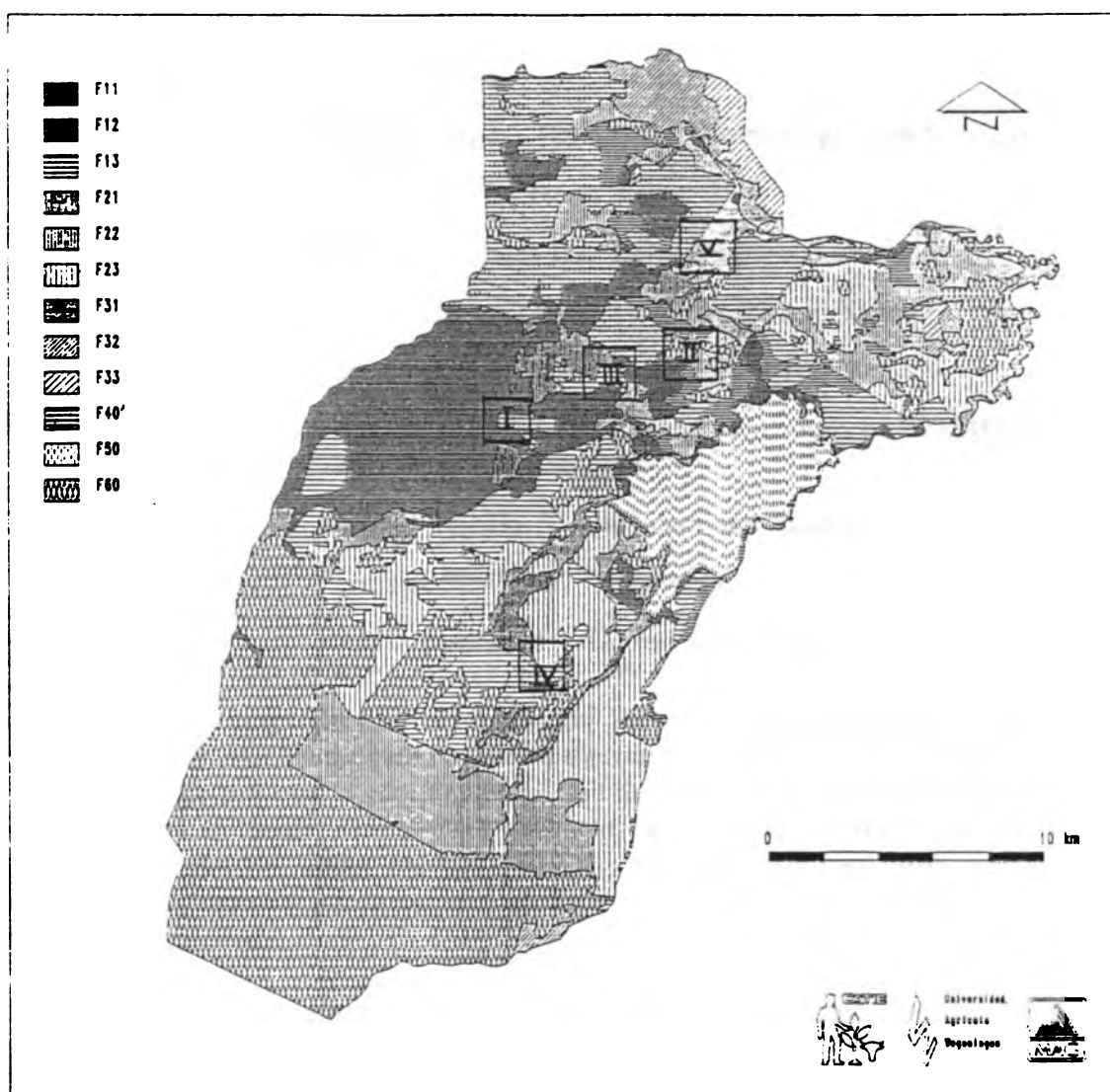
Figure 2.4.1 The farm typology for the Guácimo canton with investigated areas.

Table 2.4.5 The farm typology and field descriptions for investigated area I.

Farm typology	Field description
F11	Parcels smaller than 10 Ha, Tierra Negra
F40	Banana plantation, 120 Ha, Tierra Negra
F11	Parcels smaller than 10 Ha, Tierra Negra
F11	Parcels smaller than 10 Ha, Tierra Negra

The farm typology in Table 2.4.5 correspond with the information of the farmers about soils and farm sizes (Table 2.4.6).

Table 2.4.6 The farm typology and field descriptions for investigated area II.

Farm typology	Field description
F12/F11	All small farms, 18/8/20 Ha, Tierra Negra and Suampo
F22	Farm of 40 Ha, Tierra Negra
F12/F60	All parcels of 1½ Ha, Tierra Negra and Suampo
F12/F11/F13/F11	All parcels are 15 Ha, Tierra Negra and Suampo
F13	Farms of 2½/4/25 Ha, Tierra Negra and Suampo
F13/F60/F60	Farms of 2½/4/25 Ha, Banana plantations of 200/300/300 Ha, Tierra Negra and Suampo
F33/F22	Farm of 180 Ha, Tierra Negra and Suampo
F13	Farms of 30/40 Ha, Tierra Negra
F40	Banana plantations, 400 Ha Tierra Negra

The general field impression of this investigated area and it surroundings corresponds with the farm typology. For investigated area II a discrepancy is found between the information of farmers and the soil map. According to the soil map some soils with reduced fertility must be found; Tierra Colorada. The farmers indicated the soils with Tierra Negra and Suampo, they made no remarks about reduced fertility. The farm typology also indicates some plantations, which are not encountered in the field. The location of the 1½ Ha parcels borders although an plantation.

Table 2.4.7 The farm typology and field descriptions for investigated area III.

Farm typology	Field description
F40/F40	Parcels of 12 to 15 Ha, Tierra Negra and Suampo
F21	Parcels of 10/15/20 Ha, Tierra Negra and Suampo
F11	Parcels of 10/15 Ha, Tierra Negra and Suampo

Similar results are found for area III.

Table 2.4.8 The farm typology and field descriptions for investigated area IV.

Farm typology	Field description
F23	Parcels of 17/30/40 Ha, Tierra Colorada
F60	Macadamia and ornamental plant plantations of 27/30/54/100/200 Ha, Tierra Colorada
F23	Parcels of 20/30 Ha, Tierra Colorada
F40/F40	Macadamia plantations of 1000/3000 Ha, Tierra Colorada
F21	Parcels of 7/8/10½/40 Ha, Tierra Negra
F23	Farm of 400 Ha, Pastures, Tierra Colorada

The soils in this investigated area correspond with the soils indicated in the farm typology. The indicated banana plantations are in reality macadamia plantations.

Table 2.4.9 The farm typology and field descriptions for investigated area V.

Farm typology	Field description
F11	Small parcels, pasture, Tierra Negra
F40	Small parcels, pasture, Tierra Negra
F40	Small parcels, pasture, Tierra Negra
F21/F22	Farm of 100 Ha (more parcels), Tierra Negra
F40/F21	Banana plantation, Tierra Negra
F40	Farm of 600 Ha, pasture, Tierra Negra

The field descriptions for area V are made within or between banana plantations, the farm typology and the field description therefor not always correspond. The land use zone map indicates some areas as 100 percent banana plantations, although between these plantations small pastures occur.

The general impression of the investigated area corresponds with farm typology, there were no large discrepancies found between the actual situation for Guácimo and the results of the procedure.

2.5 Discussion

Small differences in farm sizes do not influence the final result in the calculation of the number of farms (Appendix II). In the determination of the number of farms for each mapping unit, the area of a mapping unit with similar land use is divided by an average farm size. Through this calculation there will be some losses for land which is not assigned to a certain farm, while the area of the mapping unit is too small in relation to the farm size. For each district these losses are less than three percent, also for the different land use patterns the losses will not exceed three percent.

The land use zone map obtains quality data. There are no problems determining the number of farms and corresponding farm sizes for each mapping unit. The soil map instead contains some inaccuracies, probably due to the simplification from 75 different soil series to three soil groups. The farmers' description for the field check gives sometimes insufficient information about soils, although the simple and quick determination in most cases results in the correct soil group.

Both land use zone and soil map contain many mapping units. To enlarge the workability of the farm typology small areas between large mapping units are not utilized. By doing so, for instance, small pastures between banana plantations disappeared, the general field impression of the farm typology is good. During this procedure only a small percentage of the area is neglected or wrong interpreted.

Although the farm typology was carried out using 1992 data, no large discrepancies were seen with 1995 field work. It could be supposed that the low data approach works out rather well and the utilized information was sufficient. Even though there are many assumptions used, like farm and parcel size, it is possible to derive the farm typology for the Guácimo canton. The procedure will therefore be expanded to the Atlantic Zone in Chapter 4.

Finally the calculated farm types with belonging soil groups are used as input for a linear programming model (Stoorvogel et al, 1995). The linear programming model selects and distributes a number of land use systems and technologies for each farm type (Alfaro et al, 1994). The paper of Stoorvogel et al (1995) describes a methodology for land use analysis with an application to the Guácimo canton. Using the farm typology individual farms are included as the ultimate decision makers by grouping the total of farms in Guácimo canton into nine farm types, defined on the basis of three categories each for farm size and dominating soil group. The used model aims to evaluate alternative land use scenarios given land use options and farm level objectives and resources, and in view of different land use determining factors and policies.

3 SOIL VARIATION WITHIN FARMS FOR THE GUÁCIMO CANTON

3.1 Introduction

The original soil map identified 75 different soil series, although part of these soil series are classified on the basis of soil genesis and are similar in their management (Wielemaker & Vogel, 1993). The Atlantic Zone Program is not able to describe the enormous amount of alternative land use systems that result from combinations of soil type, crops and management. The soil map is therefore simplified. This simplified soil map describes mapping units as a soil association, with one to three different soil groups, the division of the different soil groups. The three soil groups are identified on the basis of drainage and soil fertility. For the determination of the farm typology in Chapter 2 the major soil group is utilized, so the final farm typology describes only one soil group.

Within a mapping unit variation in soils occurs, for which an approximate distribution is given by the soil association. The utilized major soil group is not exact for all prevailing farms within a mapping unit. The following chapter aims to indicate the effect of soil variation on farm typology. It is assumed the 1:150,000 soil map is inaccurate for studying soil variation at farm level. The variation is therefore studied in the field at farm scale, to exclude inaccuracies due to generalization by the soil map.

3.2 Methods

Five transects are studied for the Guácimo canton and pass several mapping units of the soil map. It is aimed to cover the different farm types all over Guácimo, whereby the transects variate from 1300 to 3700 meter. In a transect, for every twenty meter the soil group is determined. After the determination of the soil groups along the transect, the division of farms is estimated. In Chapter 2.3 the prevailing farm sizes are approached with the land use zone map, so for each transect the occurring farm sizes are known. Along the transect the distribution of farms is determined with a simple calculation program. This calculation program places at ad random positions farms with a certain size. To simplify the procedure every farm size encloses a rectangle farm with a fixed width and length. A sensitively analysis is carried out to study the influence of the chosen width and length.

Running the calculation program results in a distribution of farms along the transect for which the soil variation is known. The output of the calculation program consists of a set of randomly chosen farms with their respective soil variation.

3.3 Results

The first transect is situated north of the village Guácimo (Figure 3.3.1) and is almost three kilometer long. The transect is carried out in an area of small farms (≤15 ha) on dominantly fertile well drained soils. Besides the well drained fertile soils, poorly drained swamps are found. The combination of soil groups along the transect as indicated by the soil map is presented in Table 3.3.1.
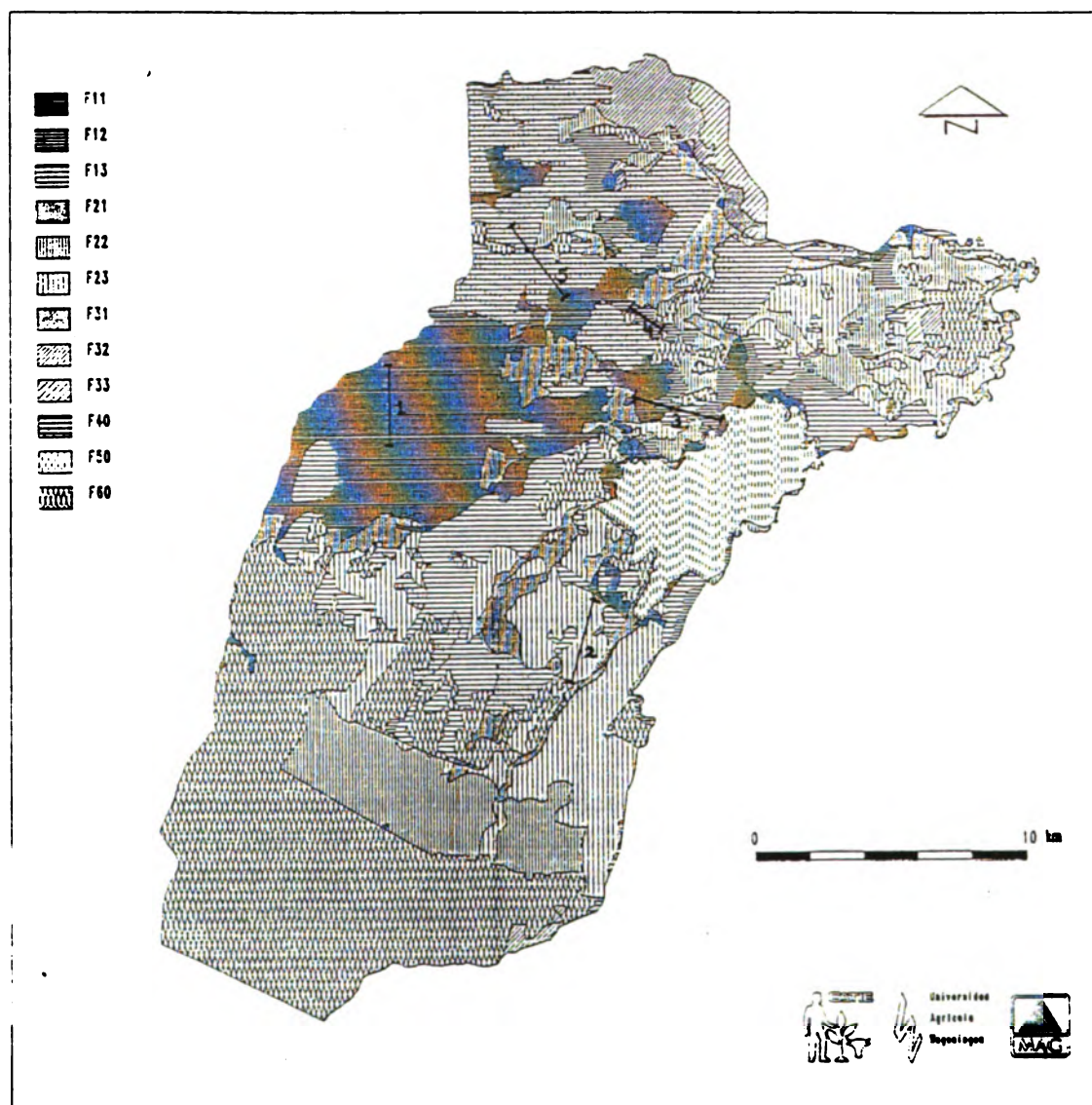
Figure 3.2.1 The location of the transects in the Guácimo canton.

Table 3.3.1 Association of soil groups corresponding the soil map for transect 1.

Farm type	SFW	SFP	SIW
F11	70	30	0
F11	70	30	0
F11	100	0	0

The prevailing farm size for each transect is known. But for a certain farm size it is possible to modify length and width in several options. For several combinations of farm width and size the average division of soil groups are given in Table 3.3.2. The given distributions are averages with standard deviations.

Table 3.3.2 The average division of soil groups for combinations of farm width and size.

Width	Length	SFW (%)	SFP (%)	SIW (%)
200	750	86 ±9.2	12 ±8.4	0
150	1000	87 ±7.8	13 ±7.6	0
250	600	84 ±8.4	15 ±8.1	0
50	3000	85 ±7.0	14 ±7.0	0
300	500	85 ±7.7	13 ±7.3	0

It is difficult to estimate farm widths and lengths, due to the possibility a farm is subdivided in parcels. The chosen farm widths correspond more or less with the observed field widths. As can been seen from Table 3.3.2 the influence of the combination farm width and length is negligible.

Some remarks can be made about the distribution of soils within farms (Figure 3.3.2). It is possible a parcel contain for 100 percent a fertile well drained soil, but there will be also parcels which contain almost 30 percent swamps. As can been seen from the figure most farms contain only a small percentage of swamps, the average soil distribution is separately indicated.

The average soil distribution within the farms for the remaining transects are given in Table 3.3.3. The third transect is divided into two parts, while it is carried out in two mapping units with different prevailing soil groups.

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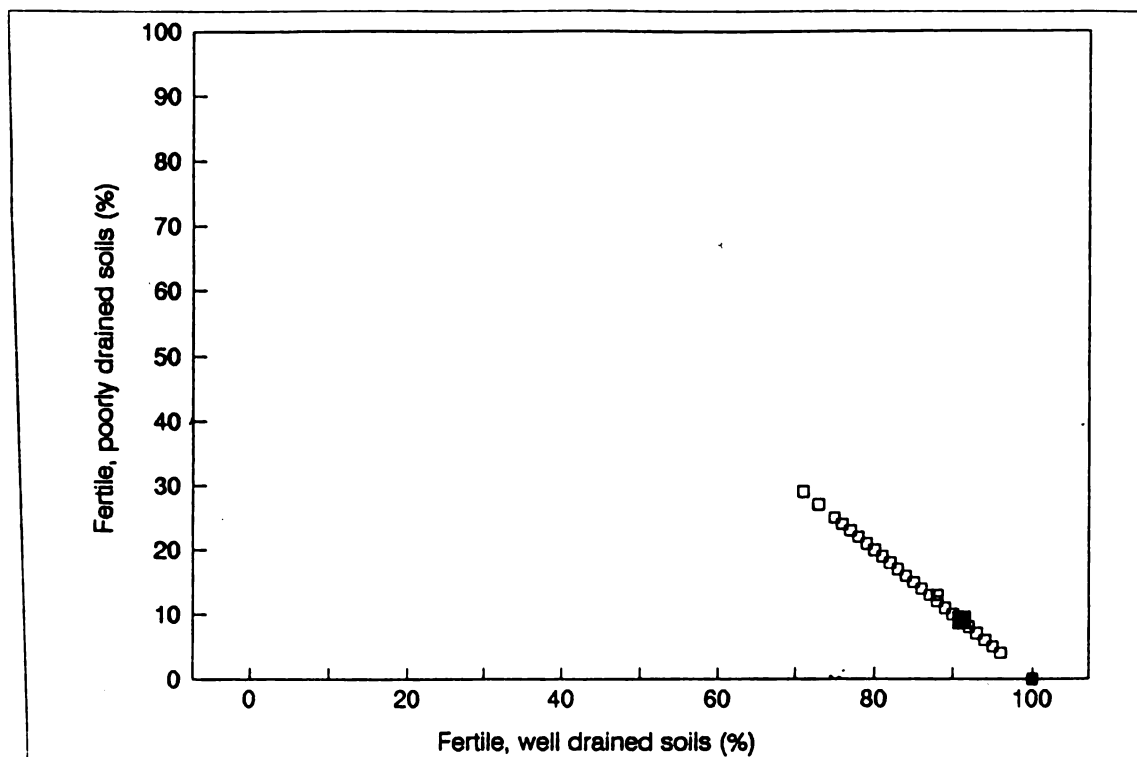
Figure 3.3.2 Distribution of soil groups within farms for the first transect.

Table 3.3.3 The average division of soil groups within the farms for the different transects.

Transect	SFW (%)	SFP (%)	SIW (%)
2	0	2.9 ±5.0	97.2 ±5.0
3 - 1	89.5 ±10.1	10.5 ±10.1	0
3 - 2	0	4.9 ±5.4	95.1 ±5.4
4	0	10.8 ±19.8	89.3 ±19.8
5	85.6 ±22.1	14.4 ±22.2	0

Transect 2 is located near Pocora (Figure 3.3.1) and comprises a length of 3380 m. According the soil map this area contains only infertile well drained soils (Table 3.3.4).

Table 3.3.4 Association of soil groups corresponding the soil map for transect 2.

Farm type	SFW	SFP	SIW
F23	0	0	100
F23	0	0	· 100

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Figure 3.3.3 Distribution of soil groups within farms for the second transect.

During the execution of transect 2 small swamps were found in the lower situated parts near the river. The average distribution within farms is indicated in Table 3.3.3 and Figure 3.3.3. As can been seen almost every farm contains a small amount of swamps, which is not identified on the soil map.

The third transect is situated near Río Jimenez (Figure 3.3.1) and has a length of 3460 m. This area is divided in two parts while the prevailing soil group changes within the transect. In the first part (800 m) of the transect the prevailing soil group is the fertile, well drained soil. The second part (2660 m) contains mainly infertile, well drained soils. The data from the soil map are indicated in Table 3.3.5.

Table 3.3.5 Associations of soil groups corresponding the soil map for the third transect.

Farm type	SF W	SFP	SIW
F11	70	30	0
F11	70	30	0
F11	70	30	0
F12	0	100	0
F12	0	100	0
F13	0	30	70

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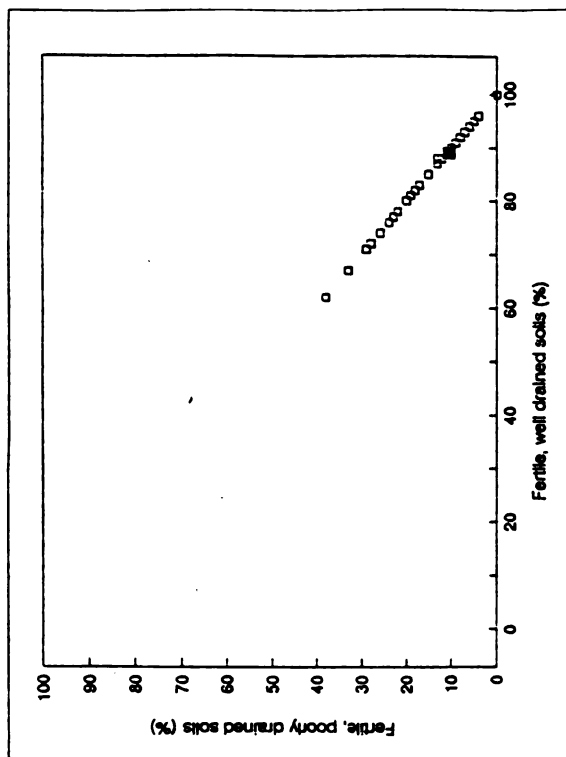
Figure 3.3.4 Soil distribution within farms for first part of transect 3.
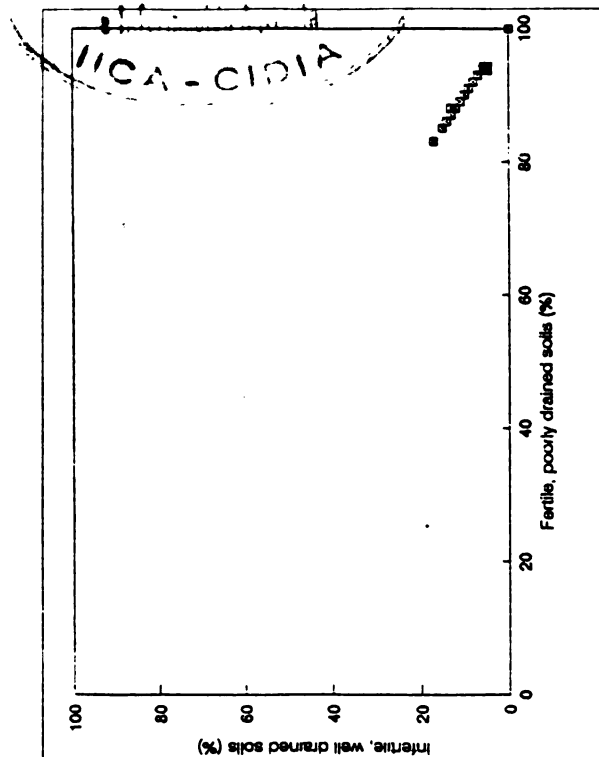
Figure 3.3.5. Soil distribution within farms for second part of transect 3.

From Figure 3.3.4 and 3.3.5 and from Table 3.3.3 can be derived that most farms contain a small percentage of poorly drained soils. The field observations disagree with the information of the soil map (Table 3.3.5), the observed amount poorly drained soils are considerably lower.

The fourth transect (Figure 3.3.1), with a length of 1360 m, contains prevailing an infertile, well drained soil. In Table 3.3.3 is indicated also swamps occur. The soil map indicates this region only with poorly drained soils. As can be seen in Figure 3.3.6 some farms contain indeed a rather large percentage of swamps, although most farms only include a small percentage poorly drained soils.

Transect five covers a length of 3760 m (Figure 3.3.1). According to the soil map this transect contains primary fertile well drained soils (Table 3.3.6).

Table 3.3.6 Association of soil groups corresponding the soil map for transect 5.

Farm type	SFW	SFP	SIW
F40	70	30	0
F11	70	30	0
F40	0	100	0

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The area of swamps within a farm is larger (Figure 3.3.7) compared to transect four. But relatively more farms contain only small amount of these poorly drained soils.
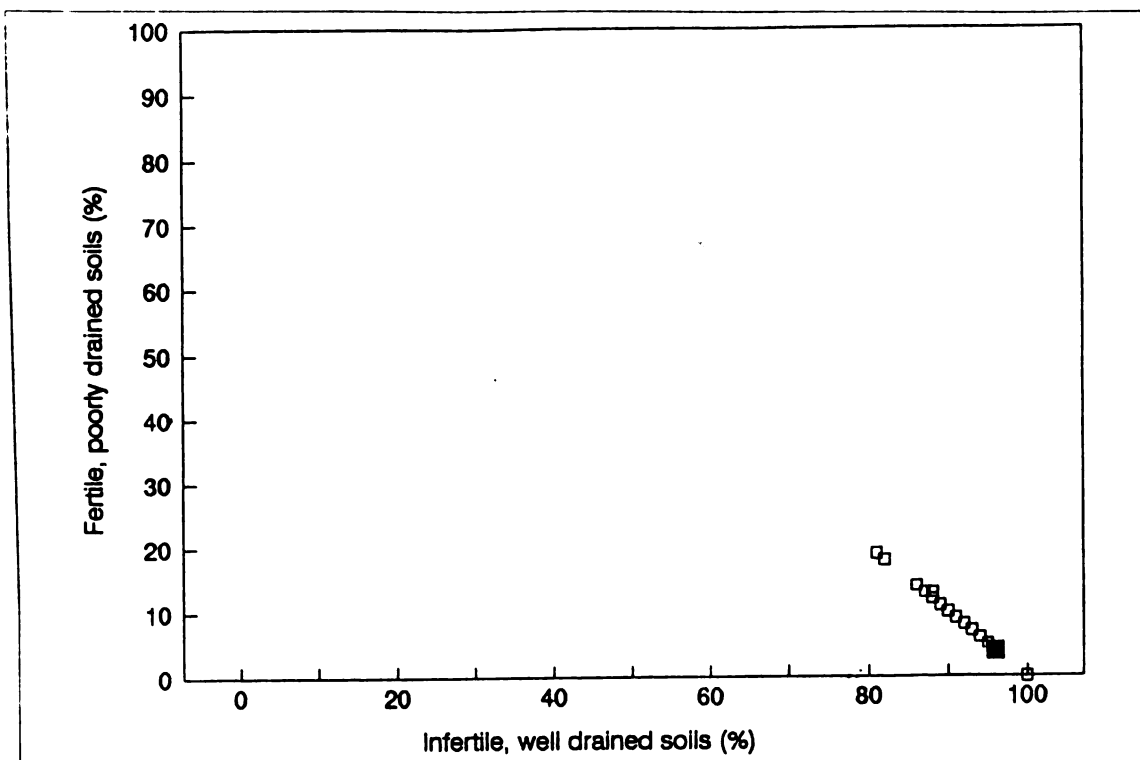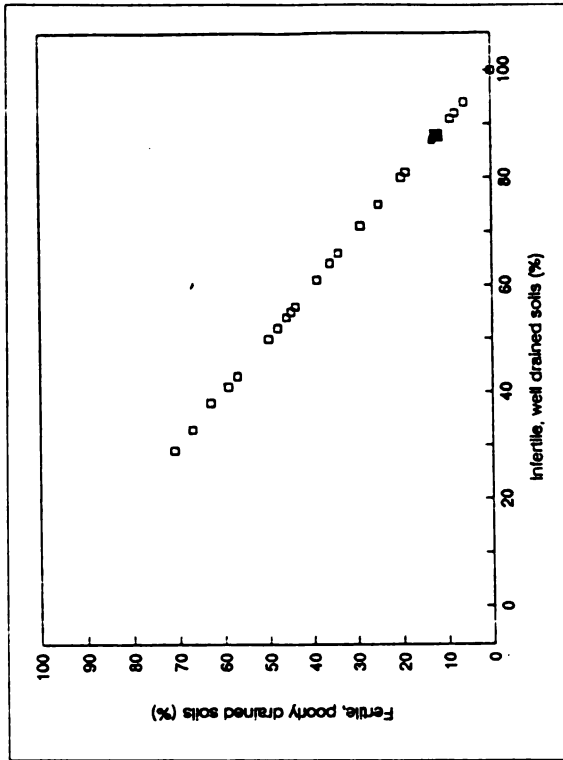

Figure 3.3.6 Distribution of soil groups within farms for transect 4.
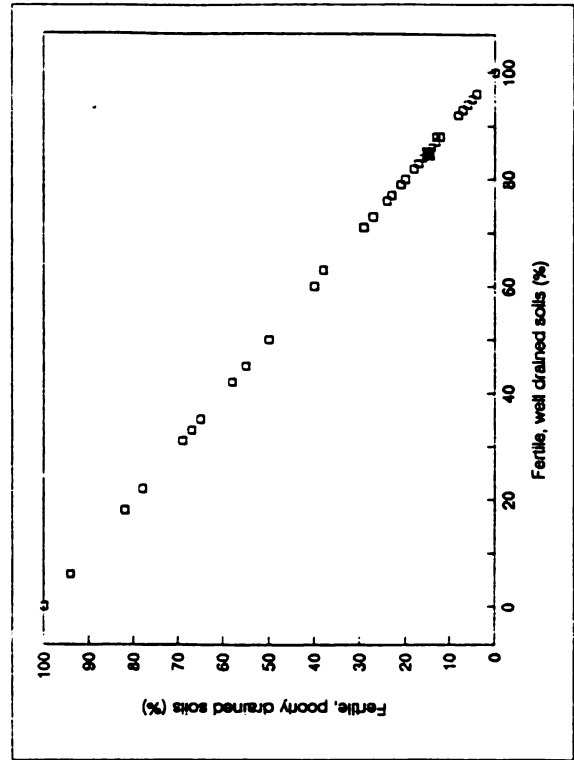
Figure 3.3.7 Distribution of soil groups within farms for transect 5.

3.4 Discussion

Field observations at farm level indicate a variation of the soil, which is not always indicated at the soil map. The mapping units of the soil map are a generalization of the actual situation. In general can be said for the soil map that the association of the mapping units gives an indication of the variation in soils. Data from the soil map can not be related to the variation within a farm, or merely should be said the farms contain an average division of soil groups based on the association of the soil map. The variation within a farm corresponds indeed with this average division. Just a small percentage of the farms contain primary out of a minor soil group. For the determination of the farm types the usage of the prevailing soil group is therefore a rather good assumption. It is not necessary to adapt the procedure utilized in Chapter 2 regarding to the soil groups. Although it is advisable to give an indication of the likelihood a farm contains the major soil group.

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4 A FARM TYPOLOGY FOR THE ATLANTIC ZONE

4.1 Introduction

In the following chapter the procedure to determine farm types will be applied for the cantons of the northern Atlantic Zone. The northern Atlantic Zone is divided into five cantons (Figure 4.1.1). For a general description of the Atlantic Zone is referred to Chapter 1.2.
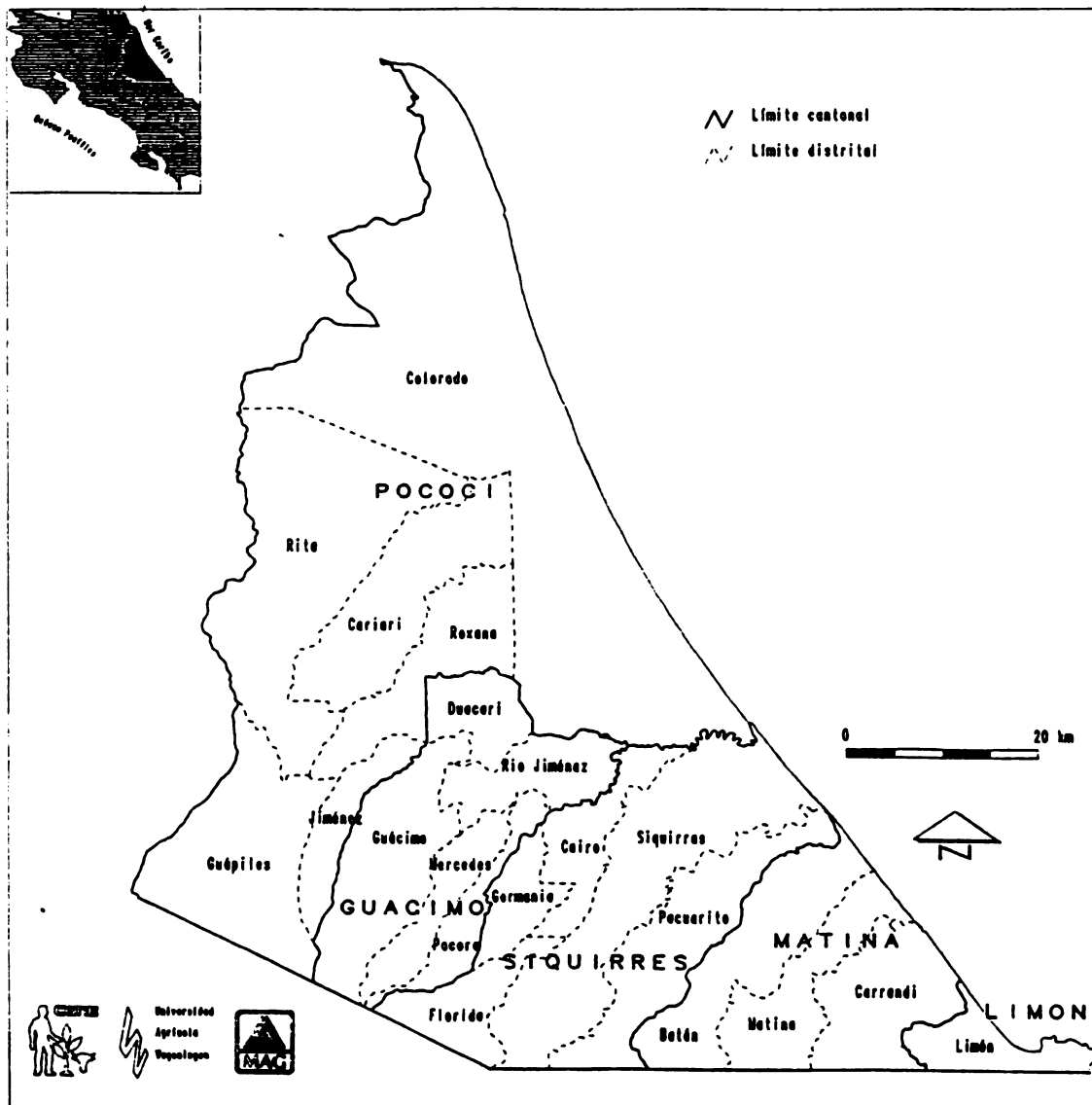
Figure 4.1.1 The cantons of the Atlantic Zone.

The followed procedure is identical as utilized in Chapter 2, therefore the explanation will be restrict. This chapter will not repeat the calculation procedure which is explained in Chapter 2.2, only some adaptions will be clarified.

4.2 Methods

The total area of the cantons of the Atlantic Zone minus the area with protected and forest areas is the area for which the actual farm typology will be carried out, while it is assumed there are no farms in the protected areas. The protected and forest areas (Figure 4.2.1) covers an area of 15,000 Ha, about 30 % of the Atlantic Zone.
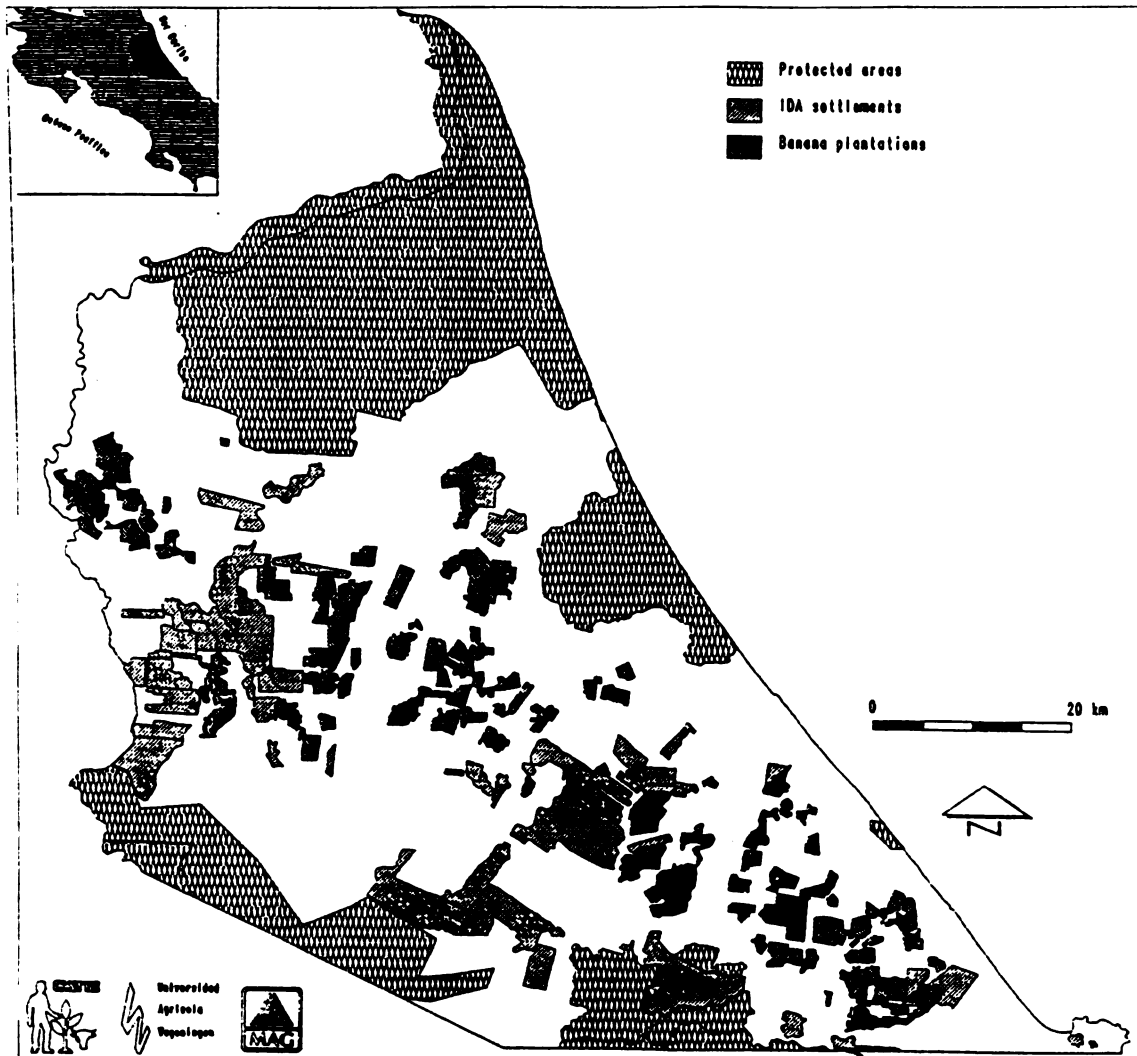
Figure 4.2.1 The Atlantic Zone with protected and forest areas, IDA settlements and banana plantations.

Banana plantations with their fixed land use are not of interest for the analysis and planning of land use. The area of 37,000 Ha with banana plantations are, like in the procedure for Guácimo, separately indicated (Figure 4.2.1).

The total number of farms (X_{tot}) for 1984 is known from the census (DGEC, 1987). It is supposed that between 1984 and 1992 the relation between farms and population growth is linear. Dislike for Guácimo, there is no information available of population growth. An average population growth of 38 % is presumed. It is also assumed that the reduction of farms is linear with the growth of banana plantations. The information about changes in banana plantations between 1984 and 1992 will be used to correct the total number of farms.

For the entire Atlantic Zone the number of farms in IDA settlements is unknown. Consequently it is impossible to calculate the average farm sizes for the distinct IDA settlements. Only for about 60 IDA settlements the surface area and the amount of families is known. Correcting this surface area with ten percent losses by infra-structure and dividing this by the number of families, an average farm size of 15 ha appears to be a good approximation. For all IDA settlements the area and location is known and an average farm size of 15 ha is used.

The division of land use zones is adapted compared to Guácimo. In the Atlantic Zone more land use zones are discerned. The land use patterns with their representative parcel sizes are indicated in Table 4.2.1.

Table 4.2.1 Average farm sizes for different land use patterns for the Atlantic Zone.

Land use pattern	Ha
Parcels, >50% covered with trees	15
Small farms, parcels for 25 - 50% covered with trees	15
Medium farms, parcels for 25 - 50% covered with trees	30
Large farms, parcels for 25 - 50% covered with trees	60
Small farms, intensive agriculture	15
Medium farms, intensive agriculture	30
Large farms, intensive agriculture	60
Banana plantation	120
Plantation, other than banana	60

A division of three soil groups, like for Guácimo, is not sufficient for the Atlantic Zone. The soil map utilized in this chapter is based on the classification of Nieuwenhuyse (1995), Table 4.2.2 and Figure 4.2.2.
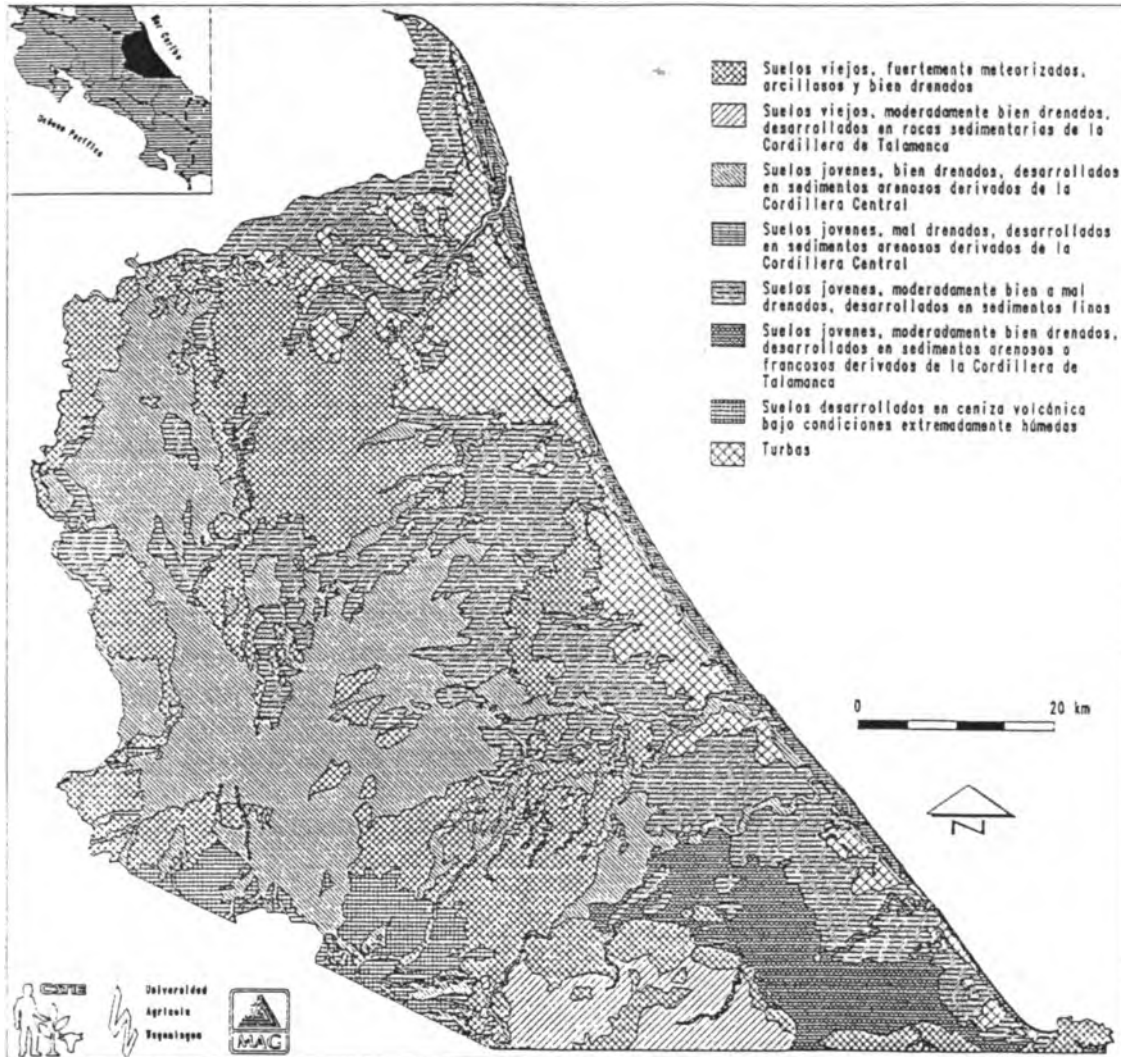
Figure 4.2.2 The soil groups of the Atlantic Zone.

Table 4.2.2 Description of the soil groups for the Atlantic Zone.

Group	Description
1	Old, strongly weathered, well drained clayey soils (oxic Humitropept and Haploperox) on mudflows both on the foodslopes and as remnants in the alluvial plains
2	Old, moderately weathered, sandy and moderately well drained soils (aeric Tropaquept and aquic Humitropept) developed in sedimentary rock in the Talamanca mountain range
3	Young, well drained soils (andic Tropopsamment and andic Dystropept) developed in young alluvial deposited sediments of volcanic origin
4	Young, slightly weathered poorly drained soils (Tropaquept) developed on sandy volcanic sediments from the Central mountain range
5	Young, slightly weathered poorly drained soils (Eutropept) developed in fine textured sediments
6	Young, slightly weathered moderately well to well drained soils (Dystropept and Tropaquept) developed in sandy to loamy sediments from the Talamanca mountain range
	Soil (Hydrudand) developed in volcanic ashes under extremely humid conditions
8	Peat soils (Histosols) developed in the coastal backswamps

4.3 Results

The GIS data base of the Atlantic Zone Program contains data about banana plantations for 1984 and 1992. The areas of banana plantations for the Atlantic Zone present in 1984 and 1992 are shown in Table 4.3.1. As can be seen from Table 4.3.1 a large expansion of banana plantations took place between 1984 and 1992 for Roxana, Cariari, Matina, Batán, Carrandi and Duacari. The expansion of banana is used to correct the number of farms. Effects of deforestation are not included in the procedure.

The total number of farms from the 1984 census data are corrected by population growth and changes in area of banana plantations (Table 4.3.2).

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Table 4.3.1 Area (in Ha) of banana plantations for the Atlantic Zone.

District	1984 (Ha)	1992 (Ha)	Abandoned[2] (%)	Established (%)
Limón	0.0	0.0	0.00	0.00
Guápiles	469.4	469.4	0.00	0.00
Jiménez	464.5	488.9	0.05	0.38
Rita	3573.7	4003.7	0.00	1.29
Roxana	834.2	3837.2	2.42	21.82
Cariari	3255.5	5465.0	0.00	10.29
Colorado	0.0	869.2	0.00	3.31
Siquirres	2827.6	4009.9	1.15	5.06
Pacuarito	1583.3	2766.6	1.74	9.90
Florida	0.0	0.0	0.00	0.00
Germania	306.6	0.0	4.89	0.00
Cairo	0.0	226.1	0.00	2.37
Matina	452.8	1700.4	1.43	11.66
Batán	1059.7	3759.8	0.18	19.07
Carrandi	559.4	4744.6	0.18	27.24
Guácimo	277.9	857.2	0.22	3.84
Mercedes	566.9	242.5	5.53	0.00
Pocora	98.9	97.6	0.02	0.00
Río Jimenez	688.4	797.5	0.00	1.08
Duacari	1224.8	2751.5	0.69	21.44

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[2]Abandoned and established banana plantations are expressed in a percentage of the effective agricultural area; total surface area of district minus surface area of forest and urbanization.

Table 4.3.2 The number of farms for 1992, corrected for population growth and area of banana plantations for the Atlantic Zone.

District	Number of farms, 1984	Correction		
		Population growth	Area banana	Number of farms, 1992
Limón	985	38%	-	1359
Guápiles	328	38%	-	453
Jiménez	229	38%	-0.33%	315
Rita	838	38%	-1.29%	1146
Roxana	298	38%	-19.40%	353
Cariari	605	38%	-10.29%	773
Colorado	85	38%	-3.31%	114
Siquires	931	38%	-3.91%	1248
Pacuarito	431	38%	-8.16%	560
Florida	244	38%	-	337
Germania	294	38%	4.89%	420
Cairo	273	38%	-2.37%	370
Matina	379	38%	-10.23%	484
Batán	496	38%	-18.89%	591
Carrande	451	38%	-27.06%	500
Guácimo	477	38%	-3.62%	641
Mercedus	42	38%	5.53%	60
Pocora	134	38%	0.02%	185
Río Jimenez	368	38%	-1.08%	504
Duacari	250	38%	-20.75%	293

The correction for changes in area of banana plantations for the districts of the Guácimo canton is different as utilized in Chapter 2, because in this case no correction is made for the experimental farm EARTH. Especially the results for Pocora and Mercedus of the Guácimo canton differentiate from Chapter 2, but can be neglected in consideration to the total number of farms of the Atlantic Zone.

A map of the farm typology of the Atlantic Zone is not presented. The large number of combinations makes a clear representation of the farm typology almost impossible.
A map with the farm sizes is although available (Figure 4.3.1). Plantations correspond with banana plantations and additional ones like ornamental and palm heart plantations. Figure 4.3.1 together with the soil map (Figure 4.2.2) represent the map of the farm typology of the Atlantic Zone. The soil map covers an area which is larger than the area of the cantons of the Atlantic Zone. This additional area, in the western part of the map, is not utilized for the farm typology.
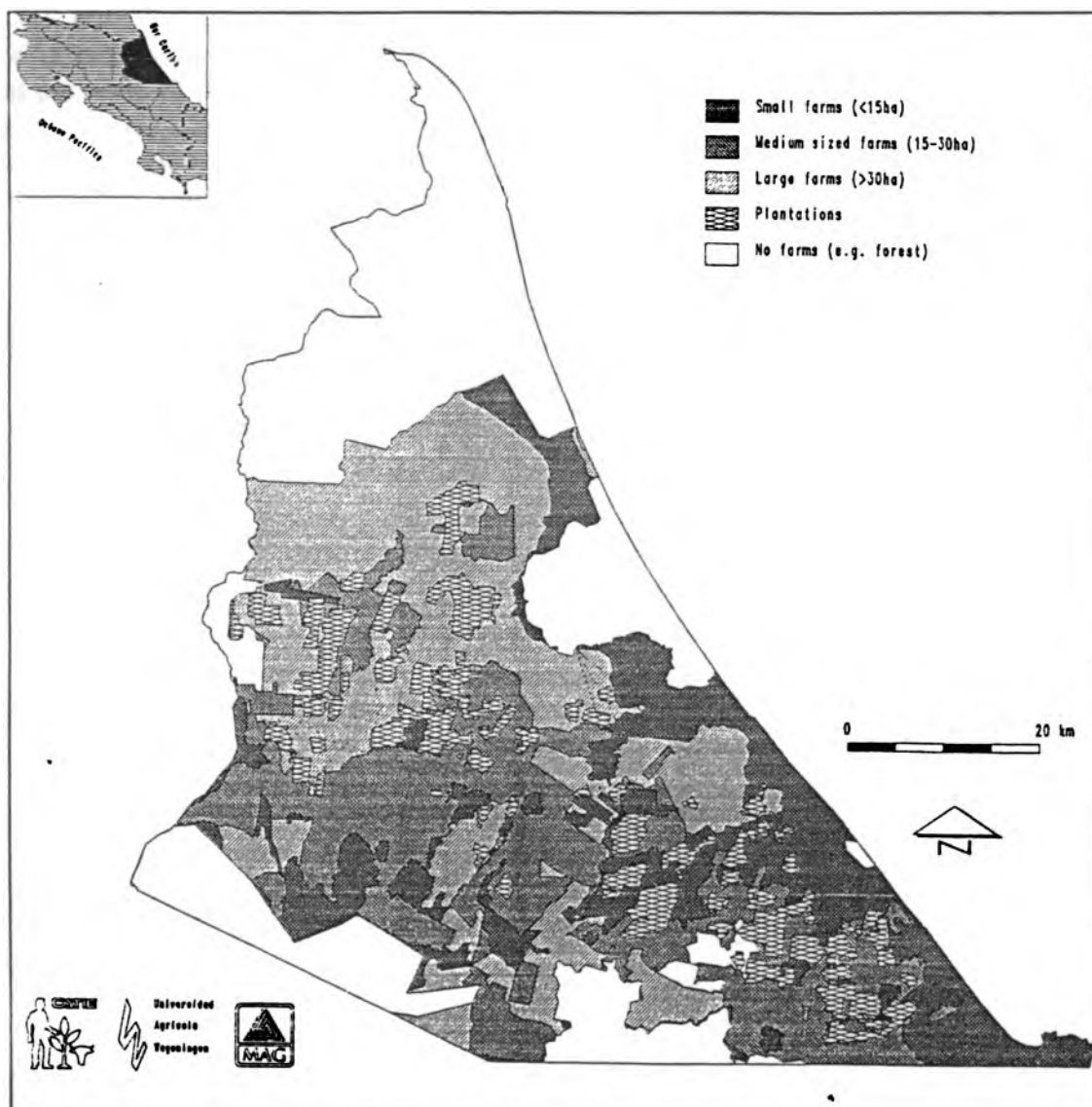
Figure 4.3.1 Distribution of farm sizes for the Atlantic Zone.

Both the map of the farm sizes and the soil map are checked in the field by comparing the map with the actual situation at ad random locations. No large discrepancies are found, although in some areas banana plantations are expanded. Also new small fields with palm heart are established, new palm heart plantations are not found.

4.4 Discussion

In the determination of the number of farms, the area of a mapping unit with similar land use is divided by an average farm size. There will be some losses for land which is not assigned to a' certain farm, while the area of the mapping unit is too small in relation to the farm size. Like for the Guácimo canton, for each district of the Atlantic Zone these losses are less than three percent. Also for the different land use patterns the losses will not exceed three percent.

The procedure is a simple and quick way to determine the farm typology, on condition that the scale of the soil map gives sufficient information about soils at farm level and that the land use zone map is reliable. The land use zone map is a very important and determining factor in the succeeding of the procedure. In this case the land use zone map is up to date and very secure. Therefore no large discrepancies are seen between the 1995 field work and the farm typology, carried out using 1992 data.

A restriction in the soil map is necessary, but a too aggregated scale will loose information which is required at farm level. In Chapter 3 is concluded that the used soil grouping for the Guácimo canton gives sufficient information at farm level. For the Atlantic Zone is also found that the extended soil grouping gives satisfactory information for the farm typology. It could be supposed that the low data approach works out rather well.

5 A FUNCTIONAL SOIL GROUPING FOR THE ATLANTIC ZONE

5.1 Introduction

The Atlantic Zone Program gives special attention to sustainability in their analysis of alternative land use scenarios. The concept of sustainability is complex (Fresco & Kroonenberg, 1992), but it is possible to indicate in what situations a system will no longer meet criteria for sustainability, once these have been defined and quantified (Janssen et al, 1990). The Atlantic Zone Program operationalizes sustainability in terms of biocide use and soil nutrient balance.

For this study it is far too comprehensive to specify biocide use and the soil nutrient balances for the different soil groups of the Atlantic Zone. While obtaining and interpreting soil physical characteristics is rather laborious and time consuming, it is difficult to expand measurements to larger areas or more different soil groups. Therefore effort is put in relating soil physical characteristics with easily measured basic characteristics, creating so-called pedotransfer functions (Bouma & van Lanen, 1987). The analysis of biocide use and the nutrient balance is rather comprehensive, so pedotransfer functions are utilized. In stead of the soil nutrient balance only an indication is given for soil fertility. For biocide use an estimation is given for the potential risk for contamination of ground- and surface water after a biocide application.

The land classification in this chapter utilizes relevant soil criteria for sustainability instead of the traditional classification based on pedogenesis. The outcome of the pedotransfer functions are added to the costa rican land evaluation system (SEPSA, 1992). The costa rican land evaluation system is used to determine the suitability of soils for a certain land use with low erosion risks and sustained productivity. Additionally taken into account soil fertility and biocide leaching makes it possible to study environmental aspects. The results are used to classify soils to a functional soil grouping. In the previous chapter a more or less arbitrary classification is utilized, in this chapter the possibilities for a more functional soil grouping is studied.

5.1.1 Pesticide leaching

Stoorvogel (1994b) developed a procedure for a relatively easy and fast appraisal of groundwater contamination with a biocide, based on soil survey data and one additional soil property, the biocide fixation to the soil. It indicates the potential risk for ground- and surface water contamination after a biocide application. Different biocides have a distinctive behavior in the soil, but as example Ethoprop is used. One of the most commonly used nematicide in the Atlantic Zone.

Ethoprop is used in banana, palm heart and ornamental plantations which together occupied in 1984 approximately 5% of the total surface of the area increasing to almost 10% in 1992. On the basis of the soil information system and a few additional measurements the risk of contamination of ground- and surface water with Ethoprop was determined for the Atlantic Zone of Costa Rica.

5.1.2 Soil fertility

To determine the nutrient supply by the soil the QUEFTS model (Calibration of the Quantitative Evaluation of the Fertility of Tropic Soils) can be used (Janssen et al, 1990). The model is calibrated for the Neguev and Río Jimenez, two areas in the Atlantic Zone. The method appears to be an appropriate approach for defining the limits to sustainable agricultural production in cases where the calculation of more detailed and accurate nutrient balances are not possible, due to lack of adequate field measurements (Guiking et al, 1994).

5.1.3 Land evaluation

Land evaluation is the process of estimating the potential of land for alternative kinds of use (Dent & Young, 1981; Landon, 1984). A number of efforts have been made in recent years to classify land according to its biophysical use capacity. Different classifications can be made according to how much weight is given to individual land qualities. Appropriate or optimal land use will be according to type of land classified by capacity, but at an intensity usually less than maximum biological capacity, for the given type of use (Lutz & Daly, 1991). The costa rican government developed a classification for soils focused on conservation, determining the maximum intensity of land use consistent with low erosion risks and sustained productivity (SEPSA, 1992).

5.2 Methods

To come to a functional soil grouping sixty profile descriptions are carried out, whereby it is aimed to cover the large differences in major soils of the northern Atlantic Zone. Within soils of the same geological origin (based on the soil grouping of Nieuwenhuyse, Table 4.2.4) more descriptions are made to comprise variation within these units. For these profiles the potential fixation of a pesticide, soil fertility and the outcome of the costa rican land evaluation system are determined.

First the pedotransfer functions for the potential fixation of a pesticide and soil fertility are defined. Followed by an explanation about the costa rican land evaluation system.

5.2.1 Pesticide leaching

The Atlantic Zone program sampled and determined the Ethoprop fixation for the functional horizons of the Atlantic Zone, whereby soil horizons below the groundwater table and C-horizons that do not allow water transport are excluded. On the basis of these fixation figures the total amount of Ethoprop which can be fixed in the soil above the groundwater table (E_{fix}, in mg/kg) is calculated by Stoorvogel, 1994b:

$$E_{fix} = 1.2*OM + 0.21*Clay \qquad r^2=0.86 \text{ and } n=19$$

whereby
OM   =   organic matter content (%)
Clay   =   clay content (%).

The organic matter content is determined by the following formula, based on a regression of 30 soil horizons sampled by Stoorvogel, 1990:

$$OM = -1*Value + 0.11*Clay + 3 \qquad r^2=0.7 \text{ and } n=30$$

whereby

Value   =   value of the soil color charts of Munsell
Clay   =   clay content (%).

If E_{fix} exceeds twenty times a normal Ethoprop application of 10 kg Ethoprop per ha, the soil is not considered prone to Ethoprop leaching. For soils where the application is equal or higher than the fixation of Ethoprop leaching is almost certain to occur and the soils are classified to be extremely susceptible. The remaining soils are considered to have an intermediate risk of Ethoprop leaching.

A simple system in the form of a decision tree is given by Stoorvogel, 1995 (Table 5.2.1).

Table 5.2.1 Decision tree for the estimation of pesticide leaching.

Ground water	Organic matter	Clay content	Risk leaching
> 120 cm			low
80 - 120 cm	< 4%		low
	> 4%	> 30%	low
	> 4%	< 30%	moderate
40 - 80 cm	< 8%		moderate
	> 8%	> 30%	moderate
	> 8%	< 30%	high
< 40 cm			high

5.2.2 Soil fertility

Calibrations of the QUEFTS model, using field experiments, resulted in the following equation for the potential supply of soil nitrogen (SN), on a hectare basis:

$$SN = 0.25 * (pH - 3) * 2.9 * \text{organic C.}$$

While the profile description are rather limited and no additional measurements are taken, some estimations have to be made. In this procedure estimations of the pH and organic C are utilized. For soils with a hue of 10YR, an average pH of 6 is used. From survey data is known the pH varies more or less from 5.5 to 6.5. For soils with a hue of 5YR or 7.5YR an average pH of 4.8 is used, while it ranges from about 4 to 5.5. Organic C is derived from the percentage organic matter multiplied by factor 0.58. The organic matter content for each soil group is estimated for pesticide leaching in the preceding paragraph. The potential supply of soil nitrogen is divided in three classes to indicate the relative fertility of the soil groups.

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A simple system in the form of a decision tree is given in Table 5.2.2.

Table 5.2.2 Decision tree for the estimation of soil fertility.

Organic matter	Clay content	Colour / pH	Fertility
< 2%			low
2 - 5%	< 5%		low
	> 5%	5 YR / 7.5 YR	moderate
	> 5%	10 YR	high
> 5%			high

5.2.3 Soil evaluation

The soil is evaluated by the methodology used in Costa Rica, developed by the 'Ministerio of Agricultura y Ganaderia' and 'Ministerio de Recursos Naturales Energia y Minas'. The capacity of the soils is concluded by the effective depth, texture, fertility, stoniness and drainage, whereby the most limiting factor is taken into consideration. The evaluation itself is not explained here, for that is referred to SEPSA, 1992. Only the resulting eight capacity classes are illustrated:

I   Soils with none to almost none limitations for agricultural use
II   Soils with almost none limitations, but which have restrictions with regard to the activities or need higher costs for management and conservation
III   Soils with moderate limitations, having restrictions with regard to the selection of crops or needing higher production costs
IV   Soils with severe limitations, restricted to the use of semi-permanent and permanent vegetation
V   Soils with severe limitations for the cultivation of annual crops, semi-permanent and permanent or forest. Restricted to pastures or management of the natural vegetation
VI   The soils within this class are used for the production forest, or permanent trees . like fruit trees or coffee, whereby the last ones an intensive management and conservation of soils and water need
VII·   Soils with strict limitations and is only used for forest
VIII   Soils which not comprise the minimal requirements for agricultural production or forest, these soils should be used solely preservation of flora and fauna.

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5.3 Results

The profile descriptions are explained in Appendix III and indicated in Figure 5.3.1.
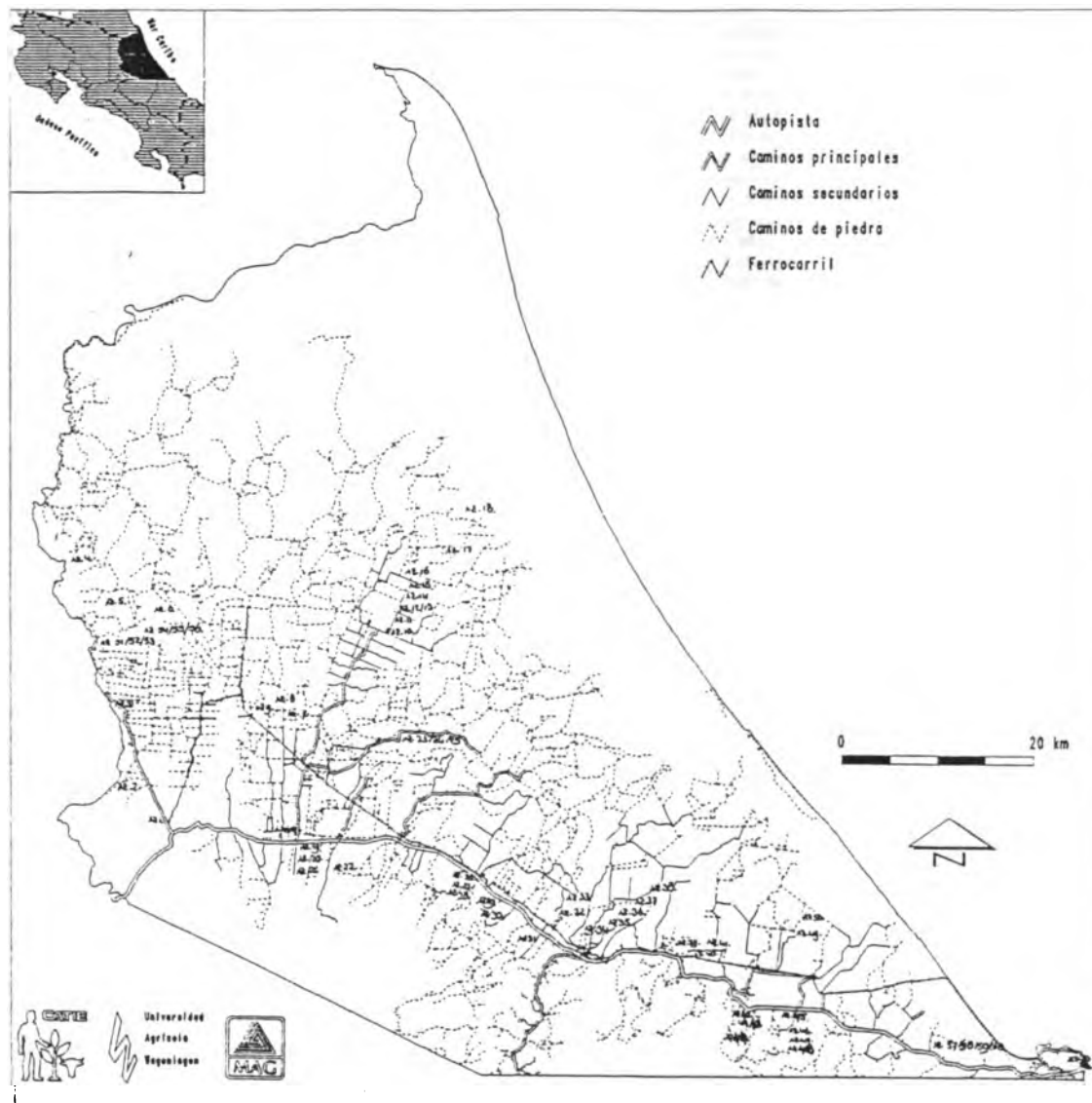
Figure 5.3.1 The location of the profile descriptions in the Atlantic Zone.

For each profile the outcome of the pedotransfer functions and of the land evaluation are given in Table 5.3.1.

Table 5.3.1 The profile descriptions with biocide fixation, soil fertility and capacity.

Profile	Soil group	Capacity	Risk biocide leaching	Fertility
AZ15	5	III	low	high
AZ37	6	III	low	moderate
AZ48	6	III	low	moderate
AZ59	5	III	low	moderate
AZ8	5	III	low	moderate
AZ58	5	III	low	moderate
AZ9	5	III	low	moderate
AZ12	3	III	low	moderate
AZ10	3	III	low	moderate
AZ20	3	III	low	moderate
AZ26	1	III	low	moderate
AZ52	1	III	low	moderate
AZ51	1	III	low	moderate
AZ16	5	III	moderate	moderate
AZ34	6	IV	low	high
AZ57	5	IV	low	high
AZ5	3	IV	low	high
AZ2	3	IV	low	high
AZ11	3	IV	low	high
AZ1	3	IV	low	high
AZ4	3	IV	low	high
AZ14	3	IV	low	high
AZ25	3	IV	low	high
AZ23	3	IV	low	high
AZ42	2	IV	low	high
AZ44	2	IV	low	high
AZ17	1	IV	low	high
AZ55	1	IV	low	high
AZ3	1	IV	low	high
AZ18	1	IV	low	high
AZ56	1	IV	low	high
AZ54	1	IV	low	high
AZ27	1	IV	low	high
AZ13	3	IV	low	moderate
AZ45	6	IV	moderate	high
AZ24	5	IV	moderate	high
AZ60	8	V	high	high
AZ40	6	V	high	moderate
AZ19	3	V	low	high
AZ22	3	V	low	high
AZ21	3	V	low	high
AZ46	6	V	low	low
AZ47	6	V	low	low
AZ35	6	V	low	moderate
AZ38	6	V	low	moderate
AZ36	6	V	low	moderate
AZ32	5	V	low	moderate
AZ33	5	V	low	moderate
AZ31	1	V	low	moderate
AZ30	1	V	low	moderate
AZ53	1	V	low	moderate
AZ28	1	V	low	moderate
AZ29	1	V	low	moderate
AZ41	6	V	moderate	high
AZ50	5	V	moderate	high
AZ6	3	V	moderate	high
AZ7	5	V	moderate	low
AZ43	2	V	moderate	low
AZ39	6	V	moderate	moderate
AZ49	5	V	moderate	moderate

The most prevailing soil groups are 1, 3, 5 and 6. There are also some profile description of soil group 2 and 8, but none of 4 and 7. These latest soil groups are inferior and borders the soil map. All the soil groups are, according to SEPSA, classified as III, IV and V. Soil group 5 and 6 are in some cases prone to biocide leaching, soil group 8 is risky for leaching due to the high ground water level of this peat soil. The remaining soil groups are not determined as sensitive of biocide leaching. Soil group 1 and 3 are fertile soils, soil group 5 and 6 are comparatively less, but fertile soils.

Soil group 1, 5 and 6 are, according to SEPSA, for most profile descriptions classified as V, although 1 also is classified as IV by a considerable number of profiles. The limitations of the soils are the result of a fine texture and/or bad drainage and/or the abundance of stones. Soil group 3 is mostly classified as IV, although also as III and as V. The sandy texture makes the soil less sensitive to erosion and more suitable for sustained productivity.

Soils with a higher risk of biocide leaching are prevailing classified as V in the land evaluation and have a more reduced fertility, caused by the fine texture and bad drainage conditions. Capacity III and IV have a low risk of biocide leaching. Soils classified as capacity III have a moderate fertility, due to the relative low clay content. Although the soils are less fertile, the better drainage conditions, caused by the coarser texture, makes the soil more suitable. No relation is found between biocide leaching and fertility, probably caused by the fact that most soils are classified as moderate to high fertile.

With the aid of the pedotransfer functions and determination of the capacity of the soils, it is possible to come to a functional soil grouping. As can be seen from Table 5.3.1, it is possible to make a soil grouping for land evaluation in relation to risk of leaching and fertility. First for each capacity class a subdivision has to be made to risk of biocide leaching. For example capacity class III is subdivided in soils with a low to moderate risk of biocide leaching. Next the risk of biocide leaching is subdivided in fertility classes. So soils with a low risk of biocide leaching, for capacity class III, are subdivided in high to moderate fertile. Using this type of soil grouping a subdivision in 14 classes is made.

5.4 Discussion

The profile descriptions are very limited and no additional measurements are taken. The texture of the soil is a deficiency in the descriptions, while the texture class is mentioned without comments on percentages of clay, silt and sand (Appendix III). Following by a rough estimation of the organic matter content and influencing the outcome of the fixation with Ethoprop and supply of soil nitrogen. The organic matter content is however a good indicator and therefore can be used determining the fixation with Ethoprop and the supply of soil nitrogen. The result of calculation is a measure for soil fertility and for the potential risk for contamination of ground- and surface water after a biocide application.

The costa rican land evaluation system is used to determine the suitability of soils for a certain land use. Almost every investigated soil is classified to the category with moderate to severe limitations. Many high fertile soils are restrained by ground water level or stoniness and the land use is restricted to permanent crops and pastures. Banana plantations and pastures are indeed the prevailing crops of the region.

The soil grouping in this chapter is based on a limited amount of profile descriptions. At this moment it is hardly possible to study the environmental aspects of biocide use and soil nutrient balances. The results however, give sufficient reasons for further research.
The linkage to environmental aspects will be very interesting, while plantations use the costa rican land evaluation to determine the suitability of their soils. These plantations use large amounts of fertilizers and biocides.

It is possible to determine a soil map based on soil grouping. This map indicates, for example, areas which have a reduced fertility and which are prone to contamination of surface and ground water after a biocide application. The map can be used in the procedure to determine a farm typology. This farm typology can be used as input for the linear programming model in the analysis of alternative land use scenarios (Stoorvogel et al, 1995). The used model aims to evaluate alternative land use scenarios given land use options and farm level objectives and resources, and in view of different land use determining factors and policies. The linkage to environmental aspects will addition valuable information. It will be interesting to give an indication for the potential risk for contamination of ground- and surface water after a biocide application.

When is decided to utilize a soil grouping, it is possible to describe the horizons of the soil profiles to functional soil classes. The original description on pedogenesis can be replaced by functional horizons. The soil layers can be determined by organic matter content, colour and clay content. The layer will be classified according the conditions for capacity, risk of leaching and fertility. A new layer is distinguished when the condition for fertility, for example, is exceeded.

6 DISCUSSION

This research presents a procedure to perform a farm typology for the northern Atlantic Zone. The procedure is a simple and quick way to determine the farm typology based on farm size and soil group. Additional is concluded that the variation of soils within a farm correspond with the soil association of the soil map. Also is found that a soil grouping for the Atlantic Zone can be based on the costa rican land evaluation, combined with soil fertility and risk for biocide leaching.

The methodology of the Atlantic Zone Program, developed in the humid part of Costa Rica, must be useful under varying circumstances with limited time and data available. To test its practical use, the method will be applied in the province of Guanacaste in the north-west of Costa Rica. The climate of Guanacaste is characterized by a dry season and has less rainfall than other parts of Costa Rica. The procedure to perform a farm typology can be adapted for Guanacaste. The low input approach can be an useful input for the lineair programming model in the analysis of alternative land use scenarios.

To perform a farm typoloy in a simple and quick way, a land use zone and a soil map are necessary. At this moment the Atlantic Zone Program works on a soil map based on the main geological units. This soil map has to be simplified. Other criteria have to be utilized as for the Atlantic Zone. In this mountainous region for example the angle of the slope must be taken in consideration. Possibilities for land use are highly correlated with slope and restricted by erosion.

The land use zone map of Guanacaste is prepared by Van Vulpen, 1995. The land use types as utilized in this report have to be adapted. Guanacaste is mainly dominated by pastures, sugar cane and rice. Almost half of the area is under intensive pasture and an additional area is used as extensive grazing land, so called charrales and tacotales. Other important crops are melon and mango. When the land use zone map is related to specific farm information, the location and farm sizes can be determined. Farm sizes can not be compared with the Atlantic Zone. A large farm in Guanacaste contains 1000 to 3000 Ha, while a small farm consists of only 5 Ha.

SUMMARY

In land use analysis it is often necessary to generalize individual farms into a number of farm types. In this research the farm typology is based on the physical production possibilities presented by farm size and soil group. For the Atlantic zone of Costa Rica the location of farms at regional level is unknown and additionally the small scale soil map contains many soil associations. This report deals with these problems and presents a procedure to perform a farm typology. Special attention is given to soil variation within farms and to functional soil grouping.

To perform a farm typology, first of all the farm sizes have to be known. Farm sizes are based on the land use zone map. For each land use pattern the distribution of farms is calculated, so the number of farms for specific mapping units are known. The farm sizes are calculated by dividing the area of a mapping unit by the number of farms.
Next the belonging soil groups have to be determined. The original soil map identified 75 different soil series. To deal with the enormous amount of alternative land use systems that result from combinations of soil type, crops and management, the soil map is simplified. The simplified soil map describes different soil groups of a mapping unit as a soil association. The farm typology is based on the prevailing soil of this association.
When the farm typology is performed, the variation of soils within farms is examined. An approximate distribution of the variation in a farm is given by the soil association. The utilzed soil for the farm typology is therefore a good indicator.
At last specific attention is given to functional soil grouping. With the aid of simple transfer functions, biocide leaching and soil fertility are studied for the soils of the Atlantic Zone. The results of these transfer functions are added to the outcome of the costa rican land evaluation system and are used to determine a functional soil grouping. The costa rican land evaluation system is used to determine the suitability of soils for a certain land use with low erosion risks and sustained productivity. Additionally taken into account, soil fertility and biocide leaching make it possible to study environmental aspects.

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APPENDICES

APPENDIX I   The total area, the number of farms and the average farm size of IDA settlements for Guácimo canton.

Name	Total area	Families	Farm size[1]
Astua Pirie	19900.50	520	34.4
Seis Amigos	1059.17	-	-
Neguev	5340.05	319	15.1
El Socorro	200.35	20	9.0
Ana y Castilla	870.00	58	13.5
Adrimaga S.A.	345.00	-	-
Adrimaga S.A.	345.00	-	-
El Bosque	1551.69	364	3.8
Anita Grande	1231.71	146	7.6
Eden	242.60	24	9.1
El Socorro	200.35	20	9.0
Angelina	242.60	24	9.1
Precipicio Sur	736.61	225	2.9
Fox Hall	152.30	26	5.3
Tierra Grande	3267.26	132	22.3
Neguev	5340.05	319	15.1
Tierra Grande	3267.26	132	22.3
Adrimaga S.A.	345.00	-	-
Tierra Grande	3267.26	132	22.3

[1]The farm size is an average of the total surface area divided by the number of families, whereby the total surface area is corrected for ten percent loses by infra-structure.

APPENDIX II

Influence of farm sizes at calculation of the number of farms for the Guácimo canton.

The average farm size for a banana plantation is set at 120 Ha, in the following example the number of farms are also calculated with farm sizes of 100 and 140 Ha:

District	--------Farms---------		
	120	100	140
Duacari	68	73	64
Río Jimenez	108	109	106
Guácimo	507	508	506
Pocora	143	143	143
Mercedes	51	51	51

The average farm size for plantations, other than banana, is set at 65 Ha, in the following example the number of farms are also calculated with farm sizes of 60 and 70 Ha:

District	------Xestimated-------		
	----------Ha----------		
	65	60	70
Duacari	129	129	129
Río Jimenez	279	279	278
Guácimo	210	210	209
Pocora	14	14	14
Mercedes	104	104	103

As can be seen from the tables the influence of the farm size is rather small at the number of farms. Only in Duacari the number of farms will change with five to seven percent, when the farm size for banana plantations changes. This is caused by the fact that Duacari contains the largest area of banana. But in comparison to the total number of all farms in a district this change is still negligible.

APPENDIX II   Influence of farm sizes at calculation of the number of farms for the Guácimo canton.

The average farm size for extensive agriculture is set at 15 Ha, in the following example the number of farms are also calculated with farm sizes of 10 and 20 Ha:

| District | --------Farms-------- | | |
| | ----------Ha---------- | | |
	15	10	20
Duacari	129	129	129
Río Jimenez	279	279	279
Guácimo	210	212	208
Pocora	14	14	14
Merdeces	104	104	104

The average farm size for pastures is set at 15 Ha, in the following example the number of farms are also calculated with farm sizes of 10 and 20 Ha:

| District | --------Farms-------- | | |
| | ----------Ha---------- | | |
	15	10	20
Duacari	129	151	118
Río Jimenez	279	296	270
Guácimo	210	240	194
Pocora	14	16	13
Mercedes	104	104	103

As can be seen from the tables for extensive agriculture the influence of the farm size is rather small at the number of farms. The influence of a change in farm size for pasture is significant larger, while the area of pasture in this canton is abundant. Still seems 15 Ha a rather good estimation for the average farm size.

2

AZ1   Pasture with about 5 % trees, many large boulders and small swamps, near Santa
         Clara (Guápiles). Small parcels.
I   0 - 50 cm   Dark yellowish brown (10 YR 3/4); clay; no mottles; no
                                stones.
II   50 - 60 cm   Yellowish brown (10 YR 5/8); clay; slightly sticky; no
                                stones; no mottles.
At 60 cm large stones, not possible to auger. Reduction mottles visible.

AZ2   Palmito plantation, near Finca Zaragoza (Guápiles).
I   0 - 50 cm   Dark yellowish brown (10 YR 3/4); clay; no mottles; gravel,
                                very few.
II   50 - 70 cm   Dark yellowish brown (10 YR 4/4); clay; frequent gravel; no
                                mottles.
After 70 cm it is not possible to auger any further: stones.

AZ3   Intensive pasture near Finca Indaco (Río Sucio), surrounded by large palmito
         plantations and reforestation project of MAG.
I   0 - 50 cm   Dark yellowish brown (10 YR 4/4); clay; no mottles; no
                                stones.
II   50 - 120 cm   Dark yellowish brown (10 YR 4/6); clay; no stones; no
                                mottles.

AZ4   Pasture with about 5 % trees, near Chilimate (Río Cuatro). Area contains about 60
         % pastures and 40 % small plots (0.5 - 1 Ha) of plantain, cassava or pine apple.
I   0 - 10 cm   Dark yellowish brown (10 YR 3/4); clay; no mottles; no
                                stones.
II   10 - 120 cm   Dark yellowish brown (10 YR 4/4); clay; no stones; no
                                mottles.

AZ5   Pasture with about 30 % dead tree trunks, near Finca Flaminea (Río Sucio).
I   0 - 10 cm   Dark yellowish brown (10 YR 3/4); clay; no mottles; no
                                stones.
II   10 - 120 cm   Dark yellowish brown (10 YR 4/4); clay; no stones; no
                                mottles.

AZ6   Area with large variation of crops: parcels of 1 to almost 10 ha of banana, sugar
         cane and ornamentals near Quebrada Ceiba (Río Sucio).
I   0 - 30 cm   Dark brown (10 YR 3/3); clay; no mottles; no stones.
II   30 - 50 cm   Dark yellowish brown (10 YR 4/4); clay; no stones; no
                                mottles.
III   50 - 120 cm   Dark yellowish brown (10 YR 4/4); sandy clay; no stones;
                                reduction mottles.
At 50 cm groundwater!

AZ7	Intensive pasture at the crossing of Calle el Gobierno and Río Tortuguero (Guápiles).	
I	0 - 30 cm	Dark yellowish brown (10 YR 3/4); loamy sand; no mottles.
II	30 - 90 cm	Dark yellowish brown (10 YR 4/4); sand; no stones; no mottles.
III	90 - 120 cm	Dark gray (2.5 Y 4/0); sandy clay; no stones; reduction mottles.

At 90 cm groundwater!

AZ8	Intensive pasture near Tarire (Guiles).	
I	0 - 10 cm	Very dark grayish brown (10 YR 3/2); clay loam; no mottles; no stones.
II	10 - 30 cm	Dark yellowish brown (10 YR 3/4); clay loam; no stones; no mottles.
III	30 - 60 cm	Dark yellowish brown (10 YR 3/4); clay; no stones; no mottles.
IV	60 - 110 cm	Dark yellowish brown (10 YR 4/4); clay; no stones; no mottles.
V	110 - 120 cm	Dark yellowish brown (10 YR 4/4); sandy loam; no stones; no mottles.

AZ9	Intensive pasture next to palmito plantation of 40 ha, near Balastre (Guápiles).	
I	0 - 15 cm	Brown (10 YR 4/3); clay loam; no mottles; no stones.
II	15 - 30 cm	Dark yellowish brown (10 YR 4/4); clay loam; no stones; no mottles.
III	30 - 120 cm	Dark yellowish brown (10 YR 4/6); clay; no stones; no mottles.

AZ10	Intensive pasture, very large farms, near Campo Dos (Agua Fria).	
I	0 - 50 cm	Dark yellowish brown (10 YR 3/4); clay loam; no mottles; no stones.
II	50 - 90 cm	Dark brown (10 YR 3/3); clay; no stones; no mottles.
III	90 - 120 cm	Dark yellowish brown (10 YR 3/6); sandy clay; no stones; no mottles.

AZ11	Intensive pasture south of Canta Rana (Agua Fria).	
I	0 - 90 cm	Brown (10 YR 4/3); clay; no mottles; no stones.
II	90 - 120 cm	Dark yellowish brown (10 YR 4/4); clay; no stones; no mottles.

AZ12   Pasture with about 3 % trees, north of Canta Rana (Agua Fria).
I   0 - 10 cm   Dark brown (10 YR 3/3); clay loam; no mottles; no stones.
II   10 - 50 cm   Dark grayish brown (10 YR 4/2); sandy clay; no stones; no mottles.
III   50 - 90 cm   Dark grayish brown (10 YR 4/2); clay sand; no stones; no mottles.
IV   90 - 120 cm   Grayish brown (2.5 Y 5/2); sandy clay; no stones; no mottles.

AZ13   Pasture with about 3 % trees, two hundred meters north of point AZ12.
I   0 - 20 cm   Dark yellowish brown (10 YR 3/6); clay; no mottles; no stones.
II   20 - 120 cm   Dark yellowish brown (10 YR 4/4); clay; no stones; no mottles.

AZ14   Pasture, south of Cuatro Esquinas (Agua Fria).
I   0 - 120 cm   Dark yellowish brown (10 YR 4/4); clay; no mottles; no stones.

AZ15   Swamp, hundred meter of point AZ14, 8 meter lower.
I   0 - 5 cm   Brown (10 YR 5/3); clay; no mottles; no stones.
II   5 - 100 cm   Dark gray (10 YR 4/1); sandy clay; no stones; no mottles.
III   100 - 120 cm   Pale brown (10 YR 6/3); silt; no stones; no mottles.

AZ16   Intensive pasture north of Cuatro Esuinas (Agua Fria), bordered by production wood.
I   0 - 20 cm   Dark yellowish brown (10 YR 3/4); sandy clay; no mottles; no stones.
II   20 - 40 cm   Dark yellowish brown (10 YR 3/6); clay sand; no stones; no mottles.
III   40 - 60 cm   Dark yellowish brown (10 YR 4/6); sand; no mottles; no stones.
IV ·   60 - 90 cm   Dark yellowish brown (10 YR 4/4); loam; no stones; mottles.
V   90 - 120 cm   Gray (10 YR 5/1); silt; mottles; no stones.
At 60 cm ground water.

AZ17   Pasture with about 3 % trees, few hundred meters north of point AZ16.
I   0 - 120 cm   Dark yellowish brown (10 YR 4/4); clay; no mottles; no stones.

AZ18   Banana plantation of 3000 ha in valley, Finca Frutera (Agua Fria).
I   0 - 120 cm   Dark yellowish brown (10 YR 4/4); clay; no mottles; no stones.

AZ19	Pasture with about 5 % trees and a lot of dead trunks, crossed by many small steams. Situated near Molino (Guápiles).	
I	0 - 20 cm	Very dark brown (10 YR 2/2); clay loam; no mottles; no stones.
II	20 - 40 cm	Black (10 YR 2/1); sandy clay; no stones; no mottles.
III	40 - 50 cm	Brown (10 YR 4/3); sandy clay loam; no stones; no mottles.

AZ20	Intensive pasture surrounded by citrus plantation and sugar cane, near Calle Seis crossing Río Cristina (Guápiles).	
I	0 - 20 cm	Very dark grayish brown (10 YR 3/2); silt clay; no mottles; no stones.
II	20 - 60 cm	Dark brown (10 YR 3/3); clay; no stones; no mottles.
III	60 - 80 cm	Dark yellowish brown (10 YR 3/4); loamy sandy; no stones; no mottles.
IV	80 - 100 cm	Dark yellowish brown (10 YR 3/4); sandy clay; no stones; no mottles.

AZ21	Pasture with about 3 % trees and few large boulders, few hundred meters south of AZ20.	
I	0 - 15 cm	Very dark grayish brown (10 YR 3/2); clay; no mottles; no stones.

Not possible to auger any further because of stones.

AZ22	Pasture with about 5 % trees, near Suerre (Guápiles). All parcels are very small with a lot of trees and sometimes stones.	
I	0 - 10 cm	Very dark grayish brown (10 YR 3/2); clay; no mottles; no stones.
II	10 - 45 cm	Dark brown (10 YR 3/3); clay; no stones; no mottles.

AZ23	Pasture with about 5 % trees, south of Fox Hall (Guácimo).	
I	0 - 20 cm	Dark yellowish brown (10 YR 3/4); clay; no mottles; no stones.
II	20 - 100 cm	Dark yellowish brown (10 YR 3/4); clay; no stones; no mottles.
III	100 - 120 cm	Dark yellowish brown (10 YR 4/4); clay loam; no stones; no mottles.

AZ24	Pasture with about 3 % scrubs and very swampy, few hundred meters south of AZ23.	
I	0 - 30 cm	Dark yellowish brown (10 YR 3/4); clay; no mottles; no stones.
II	30 - 90 cm	Brown (10 YR 4/3); sandy clay; no stones; no mottles.
III	90 - 110 cm	Dark brown (10 YR 3/3); sandy clay; no stones; no mottles.

At 90 cm groundwater!

AZ25   Intensive pasture, few hundred meters south of AZ24.
I   0 - 10 cm   Dark yellowish brown (10 YR 3/4); clay; no mottles; no stones.
II   10 - 120 cm   Dark yellowish brown (10 YR 4/4); clay; no stones; no mottles.

AZ26   Citrus plantation of 200 ha, on the road Alin Aprox Tranvia (Bonilla).
I   0 - 10 cm   Dark yellowish brown (10 YR 3/4); loam; no mottles; no stones.
II   10 - 120 cm   Dark yellowish brown (10 YR 4/4); clay loam; no stones; no mottles.

AZ27   Same citrus plantation as AZ26. Trees are smaller through drainage problems.
I   0 - 120 cm   Brown (10 YR 4/3); clay; no mottles; no stones.

AZ28   Sugar cane borders citrus plantation on the road Alin Aprox Tranvia (Bonilla).
I   0 - 30 cm   Dark yellowish brown (10 YR 3/4); loam; no mottles; no stones.
After 30 cm large stones, not possible to auger further.

AZ29   Macadamia plantation of 50 ha, on the road Tranvia Desmantelado (Bonilla). Bordered by cacao plantation and ornamental plantation OSV.
I   0 - 30 cm   Dark yellowish brown (10 YR 3/4); clay loam; no mottles; no stones.
After 30 cm large stones, not possible to auger further.

AZ30   Same macadamia plantation on the road Tranvia Desmantelado (Bonilla), 500 meters south of AZ29.
I   0 - 45 cm   Dark yellowish brown (10 YR 3/4); clay loam; no mottles; no stones.
After 45 cm large stones, not possible to auger further.

AZ31   Macadamia plantation, near Finca Francia (Bonilla).
I   0 - 40 cm   Dark yellowish brown (10 YR 4/4); clay loam; no mottles; no stones.
After 40 cm large stones, not possible to auger further.

AZ32   Pasture of IDA settlement with parcels of 6.3 ha, near Louisiana (Bonilla).
I   0 - 30 cm   Dark yellowish brown (10 YR 4/4); clay loam; no mottles; no stones.
After 30 cm large stones, not possible to auger further.

AZ33   Pasture of IDA settlement with parcels of 6.3 ha, near Louisiana (Bonilla).
I   0 - 30 cm   Dark yellowish brown (10 YR 4/4); clay loam; no mottles; no stones.
After 30 cm large stones, not possible to auger further.

AZ34   Pasture with about 5% trees and frequent large boulders, north of Siquirres (Matina).
I   0 - 120 cm   Dark yellowish brown (10 YR 4/4); clay; no mottles; no stones.

AZ35   Plot of 3 ha with cocos palms, near Indiana Dos (Matina).
I   0 - 35 cm   Dark brown (10 YR 3/3); sandy clay; no mottles; no stones.
After 35 cm large stones, not possible to auger further.

AZ36   Plot of 3 ha with cocos palms, near Indiana Dos (Matina).
I   0 - 20 cm   Dark brown (10 YR 3/3); sandy clay; no mottles; no stones.
II   20 - 40 cm   Dark yellowish brown (10 YR 3/4); sand; no stones; no mottles.
III   40 - 50 cm   Brown (10 YR 4/3); loamy sandy; no stones; no mottles.
IV   50 - 60 cm   Brown (10 YR 4/3); sandy clay; no stones; no mottles.

AZ37   Home garden with mainly plantain, on the road among Brazo el Río Reventazón (Matina).
I   0 - 40 cm   Very dark brown (10 YR 2/2); sand; no mottles; no stones.
II   40 - 50 cm   Brown (10 YR 4/3); clay; no stones; no mottles.
III   50 - 70 cm   Brown (10 YR 4/3); sandy clay; no stones; no mottles.
IV   70 - 90 cm   Dark grayish brown (10 YR 4/2); sandy clay; no stones; no mottles.
V   90 - 120 cm   Very dark grayish brown (10 YR 3/2); sand; no stones; no mottles.

AZ38   Home garden, on the road among Brazo del Río Reventazón (Matina).
I   0 - 10 cm   Dark brown (10 YR 3/3); sandy clay; no mottles; no stones.
II   10 - 40 cm   Dark yellowish brown (10 YR 3/4); sand; no stones; no mottles.
III   40 - 70 cm   Dark yellowish brown (10 YR 4/4); sandy clay; no stones; no mottles.
IV   70 - 110 cm   Dark yellowish brown (10 YR 3/4); sand; no stones; no mottles.
V   110 - 120 cm   Brown (10 YR 4/3); loamy sand; no stones; no mottles.

AZ39   Swampy pasture with many dead tree trunks, west of Santa Rosa (Matina).
I   0 - 10 cm   Dark brown (10 YR 3/3); sandy clay; no mottles; no stones.
II   10 - 40 cm   Dark brown (10 YR 3/3); sand; no stones; no mottles.

AZ40   Swampy pasture with many trees, west of Santa Rosa (Matina). Few hundred
        meters of AZ39
I   0 - 30 cm   Dark brown (10 YR 3/3); clay loam; no mottles; no stones.
II   60 - 70 cm   Dark grayish brown (10 YR 4/2); sandy clay; no stones.
After 30 cm ground water, at 60 cm it possible to auger further.

AZ41   Swampy pasture with many trees, west of Santa Rosa (Matina). Few hundred
        meters of AZ40.
I   0 - 10 cm   Dark grayish brown (10 YR 4/2); clay; no mottles; no stones.
II   10 - 30 cm   Dark yellowish brown (10 YR 4/4); clay; no stones; no
                           mottles.
Stones after 30 cm.

AZ42   Homegarden of 1.5 ha surrounded by swamps, north of San Miguel (Matina).
I   0 - 120 cm   Brown (10 YR 4/3); clay; no mottles; no stones.

AZ43   Intensive pasture, large parcels north of San Miguel (Matina).
I   0 - 60 cm   Brown (10 YR 5/3); loam; no mottles; no stones.
II   60 - 110 cm   Gray (2.5 Y 5/0); clay loam; no stones.
After 60 cm ground water.

AZ44   Intensive pasture, south of San Miguel.
I   0 - 70 cm   Dark yellowish brown (10 YR 4/4); clay; no mottles; no
                           stones.
After 70 cm stones.

AZ45   Homegarden with a large variation of crops, near Línea B (Matina).
I   0 - 40 cm   Brown (10 YR 4/3); clay; no mottles; no stones.
II   40 - 120 cm   Brown (10 YR 4/3); sandy clay; no stones.
At 100 cm ground water.

AZ46   Homegarden surrounded by banana plantations, Plaza Baltimore (Matina).
I   0 - 30 cm   Dark grayish brown (10 YR 4/2); sand; no mottles; no
                           stones.
II   30 - 120 cm   Very dark grayish brown (10 YR 3/2); sand; no stones; no
                           mottles.

AZ47   Homegarden bordered by an ornamentals, Plaza Baltimore (Matina).
I   0 - 50 cm   Brown (10 YR 4/3); sand; no mottles; no stones.
After 50 cm large stones.

AZ48	Pasture with about 5% large trees, Plaza Baltimore (Matina).	
I	0 - 15 cm	Very dark grayish brown (10 YR 3/2); loam; no mottles; no stones.
II	15 - 120 cm	Brown (10 YR 4/3); sand; no stones; no mottles.
AZ49	Pasture with about 30% large trees, surrounded by banana plantations. Near Santa Marta (Matina).	
I	0 - 30 cm	Brown (10 YR 4/3); sandy clay; no mottles; no stones.
II	30 - 120 cm	Brown (10 YR 5/3); loamy sand; no stones.

At 80 cm ground water.

AZ50	Pasture with about 30% trees, surrounded by banana plantations. Near Santa Marta (Matina).	
I	0 - 40 cm	Dark brown (10 YR 3/3); clay; no mottles; no stones.
II	40 - 50 cm	Dark yellowish brown (10 YR 4/4); sandy clay; no stones; no mottles.
III	50 - 120 cm	Dark grayish brown (10 YR 4/2); sand; no stones.

At 50 cm ground water.

AZ51	Homegarden surrounded by palmito plantations, near Finca Malatoba (Río Cuatro).	
I	0 - 10 cm	Dark yellowish brown (10 YR 3/4); loam; no mottles; no stones.
II	10 - 60 cm	Dark grayish brown (10 YR 4/2); clay loam; no stones; no mottles.
III	60 - 120 cm	Brown (10 YR 4/3); clay loam; no stones; no mottles.

AZ52	Homegarden surrounded by palmito plantations, near Finca Malatoba (Río Cuatro). Few hundred meter of point AZ51.	
I	0 - 10 cm	Dark brown (10 YR 3/3); loam; no mottles; no stones.
II	10 - 80 cm	Dark yellowish brown (10 YR 3/4); clay loam; no stones; no mottles.
III	80 - 120 cm	Brown (10 YR 4/3); clay loam; no stones; no mottles.

AZ53	Pasture with about 3% trees and small swamps, surrounded by palmito plantations, near Finca Malatoba (Río Cuatro). Few hundred meter of point AZ52.	
I	0 - 20 cm	Dark yellowish brown (10 YR 3/6); clay loam; no mottles; no stones.
II	20 - 50 cm	Dark yellowish brown (10 YR 4/4); clay loam; no stones; no mottles.
III	50 - 60 cm	Dark yellowish brown (10 YR 3/4); sandy clay; no stones; no mottles.

AZ54   Homegarden surrounded by palmito plantations, near Finca Malatoba (Río Cuatro).
        Few hundred meter of point AZ53.
I   0 - 120 cm   Dark yellowish brown (10 YR 4/4); clay; no mottles; no
                                stones.

AZ55   Pasture with about 30% trees, near Finca Agua (Río Cuatro).
I   0 - 20 cm   Brown (10 YR 4/3); clay; no mottles; no stones.
II   20 - 120 cm   Dark yellowish brown (10 YR 4/4); sandy clay; no stones; no
                               mottles.

AZ56   Homegarden surrounded by palmito and pineapple, near Finca Agua (Río Cuatro).
I   0 - 120 cm   Dark yellowish brown (10 YR 3/6); clay; no mottles; no
                                stones.

AZ57   Homegarden, near Río Madre (Moin).
I   0 - 40 cm   Dark yellowish brown (10 YR 4/4); clay; no mottles; no
                               stones.
II   40 - 100 cm   Dark yellowish brown (10 YR 4/4); loam; frequent gravel; no
                               mottles.
At 100 cm to many stones to auger.

AZ58   Homegarden, near Río Madre (Moin). Few hundred meters from AZ57.
I   0 - 30 cm   Dark yellowish brown (10 YR 4/4); clay loam; no mottles;
                               no stones.
II   30 - 120 cm   Yellowish brown (10 YR 5/6); loam; no stones; no mottles.

AZ59   Pasture with about 5% trees, near Búfalo (Moin).
I   0 - 10 cm   Brown (10 YR 4/3); sandy loam; no mottles; no stones.
II   10 - 40 cm   Brown (10 YR 4/3); loam; no stones; no mottles.
III   40 - 120 cm   Dark yellowish brown (10 YR 4/4); loam; no stones; no
                               mottles.

AZ60   Swampy pasture, near Búfalo (Moin). Few hundred meters of point AZ59.
I   0 - 5 cm   Dark grayish brown (10 YR 4/2); clay; no mottles; no stones.
II   5 - 60 cm   Yellowish brown (10 YR 5/8); clay; no stones; mottles,
                               frequent (2.5 Y 5/0).
III   60 - 120 cm   Very dark gray (5 Y 3/1); clay.
Ground water at 60 cm.