

**LAND USE CLASSIFICATION THROUGH
OVERLAY PROCEDURES**

**Research investigating the possibilities to classify
land use by combining information from different
thematic maps for the northern part of the
Atlantic Zone of Costa Rica**

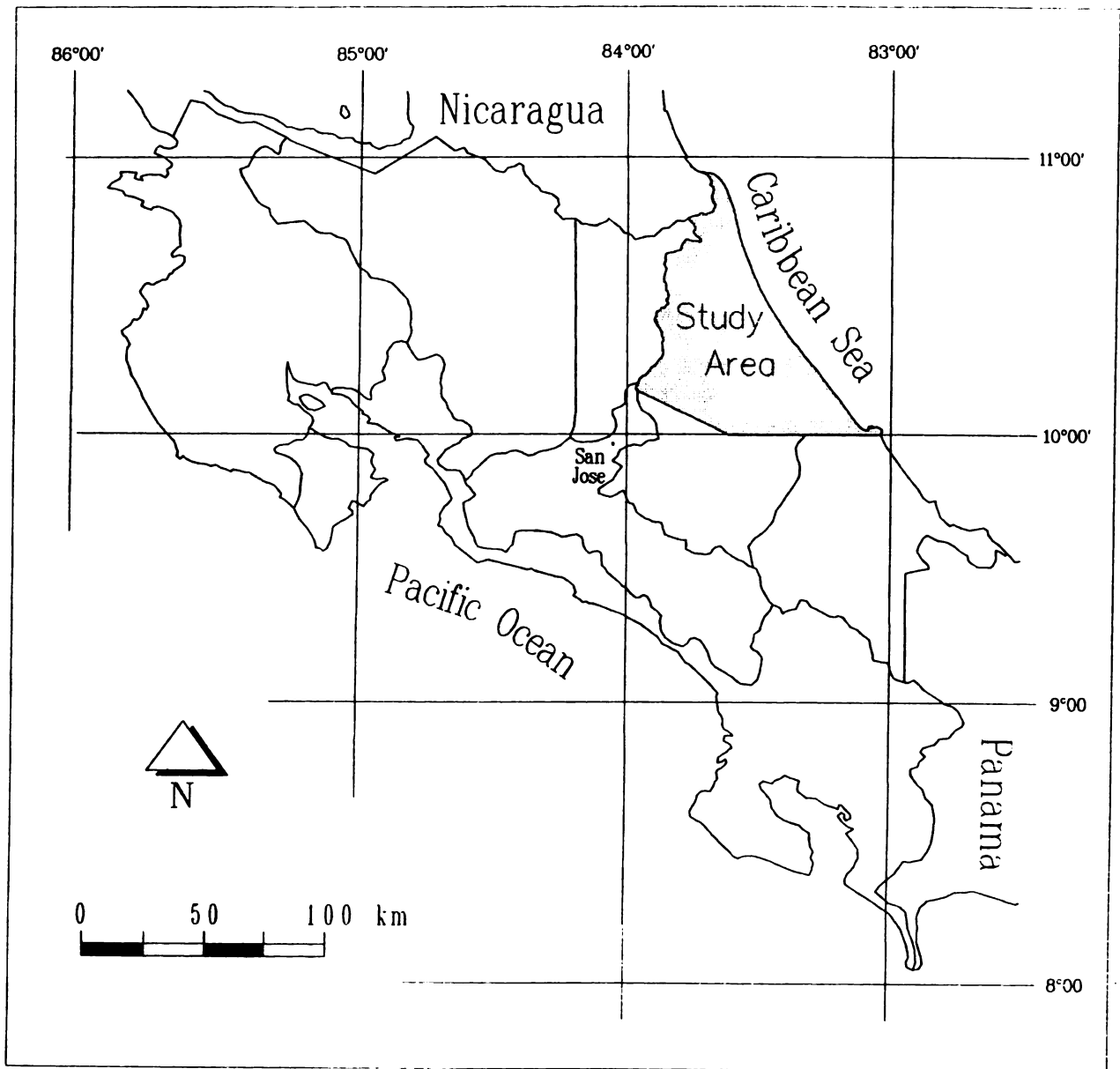
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Framework of the study

In its second phase, the Atlantic Zone Programme focuses on the development of a methodology for land use planning on a sustainable basis. The methodology comprises three successive steps. First relevant combinations of land utilization types and land units are identified, followed by an analysis of these systems and finally the definition of a scenario. On the basis of this scenario the optimal distribution of land use systems over the area is determined.

On a regional level, one can not identify individual farms, although the latter is the level on which decisions on land use are taken. For that reason the concept of land use zones was introduced. Land use zones are areas which are relatively homogeneous. The agriculture in these areas can be described by a relatively small number of farm types. Regional planning models can work on the basis of these land use zones with their farm types.

The present report gives a thorough description of land use zones, their storage in a GIS, and possible ways to link this information with other information present in a GIS. It will form the basis of future work on the land use zone map for 1992.

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Preface

This research investigates the possibility to create a method in which the existing information on land use is combined to create a land use map for the northern part of the Atlantic Zone in Costa Rica.

We stayed in Costa Rica from may until october 1992 to perform this research project. We would like to thank all the people in Costa Rica who assisted us completing our work, especially our companion Jetse Stoorvogel and Willemien Brooijmans. Also we would like to thank prof. M. Molenaar and J. H. Loedeman from the Department of Surveying and GIS of the Agricultural University of Wageningen.

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Summary

Agricultural research programs often require an inventory of land use in the area of research. Land use classification can be performed in several ways, often with the help of expensive remotely sensed data and time consuming ground surveying.

It must be realised that in many cases a lot of land use information is already available in several thematic maps.

This research investigates the possibility to create a method, in which the land use information stored in the thematic maps is combined to produce a 'combined' land use map for the Atlantic Zone of Costa Rica.

The GIS at the Atlantic Zone Program contains thematic maps with the locations of protected areas, banana plantations, forests, IDA-settlements and a soil map. At district level the areas (hectares) covered by different land cover types are documented.

The information on the thematic maps will be combined through overlay procedures in a GIS. All information dates from 1984 and is therefore comparable.

The research objective to produce a land use map for the Atlantic Zone of Costa Rica, by combining land use information stored in several thematic maps, was realised. In the overlay procedure used to combine the land use information, the overlay of the forest-, banana-, demographic- and protected area map proved to be the best possible combination. The areas classified as forest or banana plantation can be interpreted as areas with homogeneous land use. The protected areas are areas with exclusive natural use, no agricultural activity of any substance is present. The remaining areas are classified as associations of land coverage percentages by the demographic map.

Not all the available thematic maps could be used in the overlay procedure.

IDA settlements are a subject of research in the Atlantic Zone program. Therefore specific land use information was assumed to be available for the settlements. Also it was assumed that settlements consist of small farms, with mainly annual crop cultivation. Both assumptions proved to be invalid, the IDA settlement map could therefore not contribute to a further specification of the land use.

The soil map could in theory help to allocate land use types. Certain land use types (e.g. agriculture) have requirements concerning slope gradient, soil fertility etc. The mapping units on the soil map are associations. The overlaying of these associations with other thematic maps proved not to lead to a further specification of land use.

Due to the fact that two maps were unfit for use, the result of the overlay procedure was a less detailed land use description as expected.

The fact however remains that it is advisable to analyze the available land use information (in several thematic maps), before deciding to conduct a new land use inventarisation research.

Huising (Huising, 1993) carried out a land use classification in the Atlantic Zone (scale 1:150.000). Detailed land use maps describe land use with uniform units. With a decrease in the level of detail, associations of land use will occur. Huising dealt with these associations with his concept of land use zones (LUZ). The land use zone map he produced did not cover the entire Atlantic Zone. A photointerpretation was carried out to classify these remaining areas.

For the development of a methodology for analysing and planning sustainable land use (USTED), the land use zone map is very important. The land use zone map describes zones characterised by a unique combination of vegetation types, landscape patterns and other objects with typical forms, sizes and shapes. A distinction between crop types is not made, but would be very useful for the development and evaluation of land use scenarios. With the 'combined' land use map it should be possible to locate different crop types within the land use zones.

With the land use information from the 'combined' land use map, a further specification of the land use zone map created by Huising could not be realised. The problem of associated and/or aggregated objects accounts for this.

Land use zones are aggregated objects, described by a unique combination of land coverage percentages. This makes the land use zones relatively stable objects. Change in the *locations* of land cover types within a land use zone (e.g. annual crop rotation on different parcels), do not affect the land use zone description until the land coverage *percentages* change substantially.

The combination of aggregated objects with other objects in an overlay procedure does not have to lead to more specified (land use) information. Problems arise in the description of the objects in the newly created overlay map. An object originating from overlaying one or more aggregated objects will again be an aggregated object. This aggregation will be more complex and the uncertainty of the information increases significantly. In the case of the land use zones this meant that a more specified localisation of land cover types within the land use zones could not be realised.

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1. Introduction

1.1 The Atlantic Zone Program

Inadequate land use -- causing land degradation and subsequent impoverishment of rural populations -- is becoming a world-wide concern. It stresses the importance and necessity of a land use policy that should lead to viable and *sustainable* land use scenarios.

To improve local land use conditions in the Atlantic Zone of Costa Rica the Atlantic Zone Program was established in 1986 as a joint project between the Costa Rican Ministry of Agriculture (Ministerio de Agricultura y Ganaderia), CATIE ('Centro Agronomico Tropical de Investigacion y Ensenanza') and the Agricultural University of Wageningen (AUW).

The *project research area* is the northern part of the Atlantic Zone (Limon province), in the Eastern part of Costa Rica along the Atlantic Ocean.

Of the cultivated area about 70% consists of pasture land with some trees, 20% of plantations (mainly banana) and 10% of arable land cultivated by farmers. The area is subdivided in cantons, i. e. Poccoci, Guacimo, Siquirres, Cocori, Rio Jimenez and Neguev (Appendix 1).

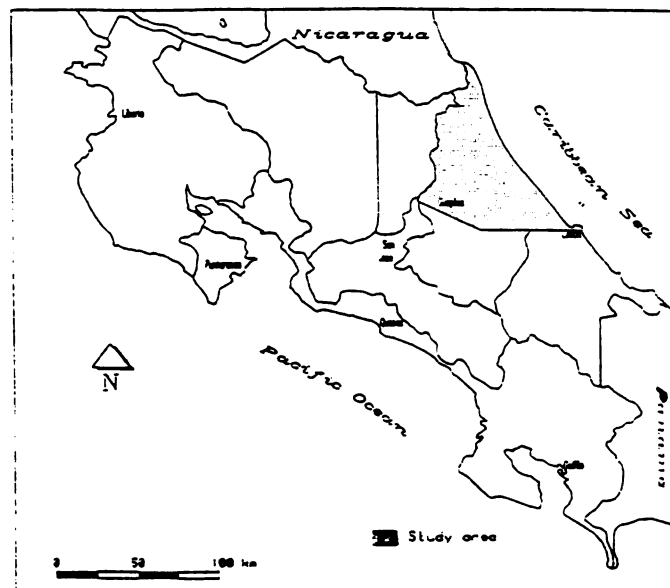


Figure 1.1: The location of the Atlantic Zone in Costa Rica

Since the start of the project the numbers of the banana plantations as well as the area covered by them is rapidly increasing from about 21.258 ha. ($\pm 5\%$ of total area) in 1984 to 44.188 ha. ($\pm 10\%$ of total area) at the end of 1992.

The main, long-term objective of the project is to analyze and improve the land use in the Atlantic Zone of Costa Rica by contributing to ecologically sound, socially acceptable and economically viable land use. A methodology for analysing and planning sustainable land use is being developed (USTED; Uso Sostenible de Tierras En Desarrollo; Sustainable Use of Land under Development).

The methodology integrates the ecological and economic dimensions of sustainability in a three level approach:

- *the plant-soil level*, in which the demands of the main crops of the area are analyzed in relation to the soil resources in terms of actual, limited and potential production.
- *the farm system level*, in which the economic and agronomic decisions of the farm management are evaluated.
- *the regional level*, analysing boundary conditions beyond the farm level, like employment and the marketing system of products, but also ecological events like flooding (Alfaro, R. et al, 1993).

The techniques that support this methodology include the development of crop growth simulation models, an interactive multiple goal linear programming model, remote sensing and a Geographical Information System (GIS). The latter comprises the central database of the program and functions as a tool for analysis and display of geographical data.

Policy makers are equipped with a large number of measures like incentives and regulations to influence land use. In many cases the effect of these measures and other major land use determinants (e.g. population growth, demand prices and sustainability issues) are unknown. Scenarios, indicating possible trends with regard to major land use determinants and/or policy measures, may be evaluated through USTED with regard to the use of land (Alfaro, R. et al, 1993).

In its present state, USTED may serve as an aid in land use planning at sub-regional level. At this moment (august, 1993) the Neguev settlement of 4675 ha in the southern part of the Atlantic Zone has been studied. Two scenarios for this settlement are available. Both land use and other results can be displayed in the GIS. This eases the interpretation of the outcome of the scenarios, which may include comparisons with other scenarios and or the actual land use.

The *climate* in the Atlantic Zone is very humid and warm throughout the year. The mean annual temperature is 26^o C. Daily temperatures vary little, and differences in day and night temperature are small (a maximum of about 12 degrees).

The mean yearly precipitation varies between 3000 and 6000 mm/yr with mean monthly precipitation between 300 and 700 mm. The months of february, march and april represent a relatively dry period, with mean monthly precipitation values between 100 and 300 mm.

The *soils* in the area belong predominantly to the Andosols and Inceptosols. Their fertility status depends largely on the age of the deposits. The younger deposits are covered with nutrient rich and non-acid soils, whereas the older are covered with nutrient poor and acid soils. The younger lava and lahar deposits on and near the volcanoes can be extremely

stony. The soils of the coastal plain are fertile but often suffer from impeded drainage. Very recent fluvial deposits are shallow and sandy, limiting agricultural use (Huisling, 1993). This study has been completed within the framework of 'La Programma Zona Atlantica' in the town Guapiles, Costa Rica.

1.2 Research Objectives

Research programs often require an inventory of land use in the research area. Land use classification can be performed in several ways, often based on remotely sensed data (expensive but covering large areas) which are calibrated by time consuming ground survey.

In many cases a vast amount of land use information is already available in all kinds of thematic maps. This research investigates the possibility to create a method, in which the land use information stored in several thematic maps is combined to produce a 'combined' land use map for the Atlantic Zone of Costa Rica.

The GIS at the Atlantic Zone Program contains thematic maps with the locations of protected areas, banana plantations, forests, IDA-settlements and a soil map. At district level the areas (hectares) covered by different land cover types are documented.

The information on the thematic maps will be combined through overlay procedures in a GIS (Arc-Info, ESRI, 1990). All information dates from 1984 and is therefore comparable.

Huisling (Huisling, 1993) carried out a land use classification in the Atlantic Zone (scale 1:150.000). Detailed land use maps describe land use with uniform units. With a decrease in the level of detail, associations of land use will occur. Huisling dealt with these associations with his concept of land use zones (LUZ). The land use zone map he produced did not cover the entire Atlantic Zone. A photointerpretation was carried out to classify these remaining areas.

For the development of a methodology for analysing and planning sustainable land use (USTED), the land use zone map is very important. The land use zone map describes zones characterised by a unique combination of vegetation types, landscape patterns and other objects with typical forms, sizes and shapes. A distinction between crop types is not made, but would be very usefull for the development and evaluation of land use scenarios. With the 'combined' land use map it should be possible to locate different crop types within the land use zones.

2 Remote Sensing and Photointerpretation

2.1 Remote Sensing

Remote sensing may be defined as the acquisition of information with a detection device that is not in physical contact with the object of study (US Geological Survey Bulletin, 1983).

Remote sensing can be *photographic* and *non photographic*. Photographic sensors reproduce an image directly on a film emulsion from reflected electromagnetic radiation of wavelengths in the visible to near-infrared spectrum. Non photographic sensor images are captured by a suitable detector and stored as electronic impulses by a recording device. Non photographic sensors may operate in the visible, infrared and microwave ranges of the electromagnetic spectrum. Remotely sensed data are used for land use interpretation and classification.

Aerial photographs with a relatively large scale and high resolution (minimum separation between two objects at which the objects still appear as separate objects on the image) and are generally used to acquire detailed land use information. Information for more generalized land use mapping may be extracted from *multispectral scanning satellite images* as produced by Landsat.

2.2 Aerial Photointerpretation for Land Use Planning

Aerial photointerpretation may be defined as: the detection, identification, description and assessment of the significance of objects and patterns on a photograph.

With respect to land use mapping, photointerpretation requires that land areas are identified and assigned (classified) to a class in accordance with a land use classification scheme (US Geological Survey Bulletin, 1983).

The characteristics of importance for the recognition of objects and patterns on aerial photographs are:

- pattern
- size, shape, colour
- site association

Pattern: describes the way different objects are related to each other. Common terms in describing patterns are irregular, regular, linear, random or congested.

Size: a known scale factor is required for size comparison.

Shape: describes the form of an object as being round, square, irregular or parallel shaped.

Colour may be characteristic for an object. An interpreter by experience learns to recognize different colour characteristics and uses them to identify different objects. An example is that cultivated fields tend to show darker than fallow fields.

Site association: implies that certain features always or often occur in the presence of other objects. For example, industries are normally located near railways, water or roads.

To be able to interpret aerial photographs with confidence it is most important that the interpreter acquires detailed information by visiting the area he has to interpret. This allows him to calibrate the dataset. A visit may involve talking to various persons and institutes.

Interpretation may also be improved by use of *comparative coverages*. The comparative coverages may include photographs of the study area made in different seasons or at a different scale.

Magnification and stereoscopic viewing will also improve the interpretation results.

2.3 Photointerpreting the Atlantic Zone for Land Use Zone Identification

For the Atlantic Zone in Costa Rica Huising (Huising, 1993) has carried out a photointerpretation with the aim to create a land use map. The land use map identifies different areas, characterised by different land coverages and utilisation. The interpretation was performed on colour infrared aerial photographs, dating from 1984 with a scale of 1 : 80.000.

Land use mapping can be defined as the systematic delineation of man's activities in relation to the surface cover of the land (US Geological Survey Bulletin, 1983).

From the aerial photographs the Atlantic Zone was divided into different land use zones (LUZ).

A land use zone can be defined as a bordered area characterised by a unique combination of vegetation types, landscape patterns and other objects with typical forms, sizes and shapes.

Huising defines a land use zone as a geographic area which exhibits a characteristic landcoverage pattern. With landcoverage patterns the division of locations of all vegetation and/or crops is understood. A land use zone can be seen as an aggregation, i.e. it can consist of smaller homogeneous areas of different land coverage and land use. A land use zone is described after the percentages covered by these smaller areas it is built from.

2.3.1 Changes made to the Delineation of the Land Use Zones

Huising describes directives he followed for his photointerpretation of the Atlantic Zone. However there are some indistinctnesses between the directives and the results of the interpretation.

An important aspect in the delineation of the land use zones is the way in which the land use zone borders are drawn. Huising recommends to take rivers or other physical barriers as a border. These borders are relatively stable compared to for instance borders between forested and adjacent deforested areas, not caused by any natural barrier. Another statement is that clearly visible boundaries that extend over hundreds of meters or more are to become land use zone boundaries. The two statements above raise a problem when it comes to the boundaries of (banana) plantations.

Plantations are well visible on the photographs, showing straight boundaries that can extend up to several kilometres. Huising sometimes let a land use zone boundary coincide with these plantation boundaries, but often chose to let the land use zone boundary correspond with nearby river courses. The reason for this, as stated above, is that natural barriers are stable borders. Also the land, separating a plantation from a nearby river course, is often owned by the plantation. However the land use within the plantation boundaries is clearly very different from the land use outside the plantation boundaries. Therefore, from a land use point of view, it is not just to incorporate these areas within the land use zone 'plantation'.

Another reason to choose for the plantation boundaries as land use zone boundaries is related to the use of context information in performing the photointerpretation. Context information must therefore be further specified.

Context information can be subdivided into different contextual levels, which can be applied at different stages in a photointerpretation. Here three contextual levels will be distinguished; basic-, photo(image) related- and specific context information.

Basic context information is absolutely indispensable for an interpretation. It concerns the basic understanding of what one observes, acquired by teaching and experience. This includes the recognition of an object as a tree, house, person etc.

Photo- or image related context information is in fact an extension of the basic context information, acquired by an interpreter through his experience in imageinterpretation. It concerns the recognition of objects on an image as represented in pattern, size/shape/colour and site association (section 2.2).

Specific context information is acquired by visiting the study area to be interpreted. It concerns different types of information that can not be acquired from a (photographic) image. Specific context information may include the history of, government policy for or peoples preferences in a study area.

Huising (Huising, 1993) describes that the use of specific context information, obtained through field visits, is often informally incorporated in a photointerpretation. This means that the interpretation may not be clear to future users or interpreters with less knowledge on the study area. The application of specific context information in a photointerpretation must therefore be carefully documented. This documentation was not available for the photointerpretation of the Atlantic Zone. To avoid indistinctnesses, specific context information was not used in this research.

This choice gives us another reason to choose the plantation boundaries as boundaries for a land use zone. It was stated before that a river course provides a more stable boundary and that the land separating a plantation from a river is often owned by the plantation. Information on land ownership can however not be extracted from the aerial photos and is therefore specific context information that will not be used in this research.

On basis of the arguments mentioned, the plantation boundaries on the LUZ map created by Huising were changed. The clearly visible plantation boundaries replaced the boundaries drawn by Huising in all cases where the two did not correspond with eachother.

2.3.2 Photointerpretation of Limon and Surroundings

The photointerpretation as carried out by Huising did not cover the entire research area of the Atlantic Zone program. To complete the land use zone map, two additional areas were interpreted from the aerial photographs and added to the existing map. The land use zones identified in these areas were classified according to the same classification structure as used for the rest of the Atlantic Zone (figure 3.2).

The first area was a homogeneous natural forest area in the north-east corner of the Atlantic Zone, bounded in the north by the boarder of Nicaragua.

The second area covered the surroundings of the city of Limon. This area is heterogeneous in land cover and consists of different land use zones.

3 Land use Classification

3.1 Introduction

Land use classification as used in this research can be defined as the identification of land use zones with characteristic land cover patterns. The land cover patterns are interpreted in terms of land use characteristics, which are classified as land use classes. Class relations are described in a land use classification structure.

Depending on the measure of detail to be represented in a land use classification, different ways to acquire information are available. Two important tools for information acquisition are remote sensing and field surveying. Remotely sensed data are extracted from aerial photographs and/or satellite images and are especially suitable for land cover inventories at a sub regional or smaller scale. When non land cover information (e.g. soil characteristics as drainage class and fertility) is desired, data will have to be acquired in the field. Field surveying is also inevitable when very detailed land use information is required.

3.2 Object Definition and Description

Before a land use classification can be performed it is necessary to define the objects that will be identified and the way in which they will be described. Objects are conceptual entities that have been defined within the context of some mapping disciplines. This implies that the semantic aspects of object description are context related (Molenaar, Janssen, 1991). Each context such as cadastral mapping or land use planning has its own object definitions.

The land use information for the Atlantic Zone in Costa Rica is stored in an information system for geographical data (GIS). A GIS offers two methods for terrain description. The first method directly links thematic attribute values to a position. The positions may be random points or points in a regular grid. The second method identifies terrain objects with thematic and geometric characteristics. An object will be represented in a GIS by an object identifier (name or number) which is linked to a set of thematic and geometric data. The thematic aspects in most cases play a dominant role in the object definition. The second *object oriented* method was used for land use data storage in the Atlantic Zone.

The land use zones (LUZ) were introduced as objects. A land use zone is defined in chapter one as a bordered area characterised by a unique combination of vegetation types, landscape patterns and other entities with typical forms, sizes and shapes. A LUZ is a composition and therefore not a homogeneous, but an aggregated object. Exceptions are the plantations, mostly with the homogeneous land use type 'banana cultivation'. The land use zones are identified by an identification number (LUZ ID) to which the thematic and geometric descriptions are linked.

The land use classification was performed at a regional scale. Classification at parcel level would require larger scaled aerial photographs, which were not available.

The introduction of land use zones as the objects of classification in the Atlantic Zone had several advantages. A land use classification identifying land use zones means a stable classification. Land use within a zone will not be outdated when the land coverage of some parcels changes due to for instance crop rotation. A land use zone is a composition of different land coverages with different land use. This implies that the land use within a zone will only change when the share of different land cover types in the total land coverage clearly changes.

An example will explain this; the land use in a land use zone will not change when one or two pasture parcels are changed into parcels for the tillage of annual crops. The land use will only change when pasture parcels are structurally converted into parcels for cultivation of annuals. The share of pasture in the total land coverage of the zone then clearly diminishes in favour of the share of annual crops. A structural change of land cover composition within a land use zone is far less frequent than coverage changes at parcel level. Concluding it can be stated that land use zones are relatively stable objects, which make them suitable objects for land use classification.

3.3 Land use Classification Structure

A classification structure stepwise divides a research area into smaller areas, which at each lower level in the classification structure are described in greater detail. The lowest level in a classification hierarchy is the object level. The object level determines the greatest level of detail in land use description.

Different types of classification structures are available to group objects, in our case the land use zones. Terrain objects are grouped in different classes. According to their thematic aspects a list of attributes is connected to each class. Objects belonging to a class inherit the attribute structure from that class. Each object belonging to a class has a list containing a value for each attribute of the class attribute list (Molenaar, 1992).

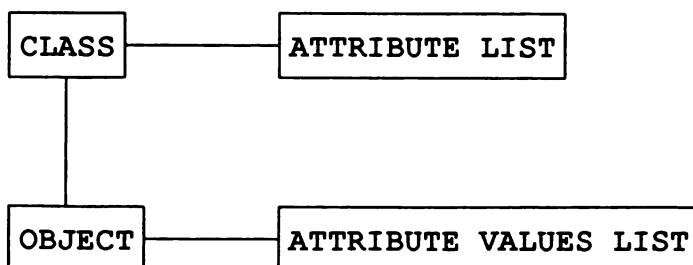


Figure 3.1: Object-Class relationship

Classification structures can be distinguished after the way the classes inherit their attribute structure.

Class relations may be described as 'top-down', i.e. each class level inherits the attribute structure from the next higher class level in the classification structure and with the possibility of extending the attribute structure propagates it to the next lower level. At the lowest level in the hierarchy are the terrain objects; at this level the attribute structure is extended no more and the inherited class attributes are evaluated. This structure can also be characterised as an 'is-a' structure, each class level has an 'is-a' relation to the next higher level. An example for this relation structure: a house is a building, is a man made object.

Other classification structures show 'bottom-up' class relations, such as the aggregation structure. It describes how composite objects are built from elementary objects and how these composite objects can build more complex objects and so on (Molenaar, Janssen, 1991). Composite objects belonging to one class inherit their attribute values from their constituent parts. The relation of a class to a class at a next higher level in an aggregation hierarchy can be described as a 'part-of' link. An example of this structure: a house is part of a residential district, is part of a city, is part of a state.

A non hierarchical grouping of objects can be realised through object associations. Associations are simply a group of objects that have something in common. Examples are all houses built before 1980 or all houses along a route from A to B.

The classification structure used for the land use classification in the Atlantic Zone is an aggregation structure. The bottom level in the hierarchy constitutes of land use classes that describe a group of land use zones. This differs from the standard definition of the aggregation structure in which the bottom level classes describe groups of elementary objects.

Several land use zones with similar characteristics belong to a land use class. If or not a land use zone belongs to a land use class is determined by decision rules. After Molenaar, 1992 these rules can be described as a decision function:

$$D(x,C) = \begin{cases} \text{true; } x \text{ element of } C \\ \\ \text{false; } x \text{ not element of } C \end{cases}$$

If a land use zone has certain characteristics that are typical for a land use class the decision function will be true. The land use zone will be classified as belonging to class C.

The decision rules used for the Atlantic Zone have the following structure (Huising, 1993):

IF {condition} **THEN** {conclusion}

If a land use zone meets the conditions of a land use class it will be classified as belonging to this class. The conditions concern land coverage percentages, land coverage dispersion and parcel size.

An example of the 'part-of' relation between classes in the Atlantic Zone-land use classification structure will illustrate the class relations. At the bottom level we for instance see land use zones belonging to the land use class 'dominant pasture on medium parcels'. This land use class together with other classes builds the class 'dominant pasture' which itself partly builds the class 'agricultural use' and so on (figure 3.2). For a detailed description of the different classes (Appendix 2).

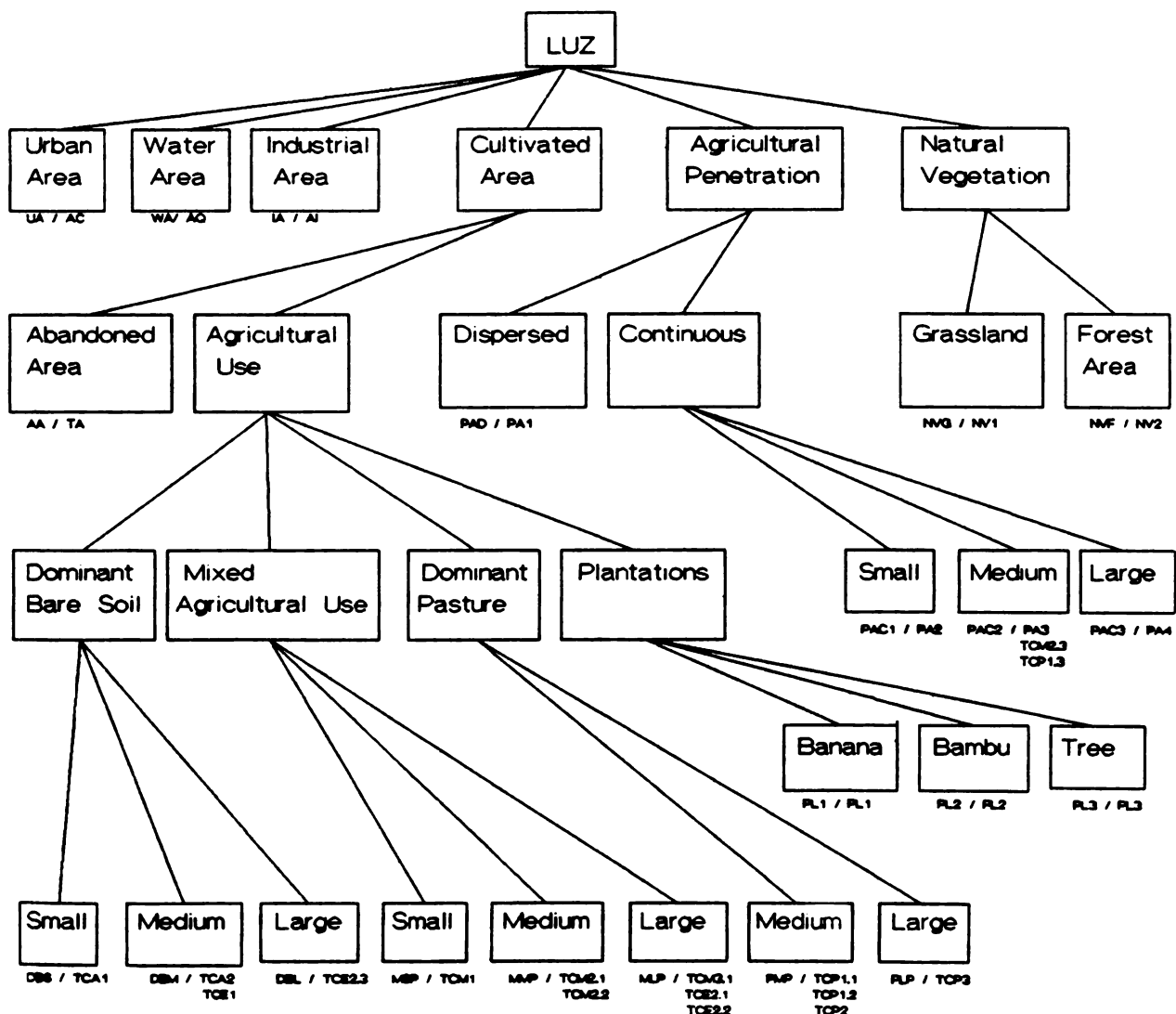


Figure 3.2: Land use classification structure

3.4 Effect of Changes In the Classification Structure on the Land Use Map

The classification structure as shown in figure 3.2 is a modified version of the original one designed by Huising for his classification (appendix 3). When the original and the modified structure are compared it becomes clear that some classes in the original structure have ceased to exist as separate classes in the modified structure. In figure 3.2 each class appears as a box in the tree structure. Under each box the abbreviation of the corresponding classname is noted, followed by the abbreviation(s) of the 'old' classes which have been combined in the newly defined class.

It may be clear that the description of the newly defined classes is very similar to the description of the 'old' classes as defined by Huising. The land use zones belonging to the classes that have ceased to exist have been added to their new classes. As a result of the altered classification structure, some borders dividing land use zones with formerly differing land use classes became unnecessary and have been removed from the land use map. How can the changes made in Huisings' classification structure be justified? Before performing the land use classification Huising had acquired a substantial amount of specific context information. In his attempt to include as much information as possible in the land use classification he distinguishes between different land use classes that in fact can not be distinguished on the aerial photographs. An example may be the classes abandoned area and penetration area. The land use zones belonging to these classes are characterised by a landcoverage pattern composed of a mixture of forest, wooded area, deforested areas, pasture and bare soil. On the photographs the images of both classes may be identical. This means that Huising distinguishes them on the basis of specific context information.

As stated before in section 2.3.1 the choice was made to avoid the use of specific context information in this research. No documentation was available on the use of specific context information in the definition of the land use classes. Therefore the classification may not be clear to future users. Reduction in the differentiation of land use classes, by merging classes when land use zones belonging to these classes could not be distinguished on the aerial photographs, avoids indistinctnesses in the future.

The effect on the land use map of the dissolving of borders, separating land use zones belonging to merged classes, was minimal. This is confirmation for the justness of the changes made to the original classification. It must be noted that this justification is related to the context of this research. The use of specific context information for land use classifications may well be useful within another research project.

A second reason for changing the original classification structure is it's indistinctness. In pursuit of trying to include all known information into the distinguishing of land use classes, the clarity of the classification as a whole decreased. The merging of some classes as described above, combined with slight changes in the definition (name and description) of the classes, led to a more clear and better understandable classification structure (compare appendices 2 and 3). The land use map and its land use classes can be used by many

different users for different applications, e.g. research and presentations. Therefore a classification structure that is more clear to all users is an improvement.

4 Thematic Maps and Overlay Procedures

4.1 General Introduction

As stated in the research objectives, this study investigates the possibility to produce a land use map for the Atlantic Zone of Costa Rica by combining land use information stored in different thematic maps. This 'combined' land use map can possibly be used to further specify the description of the land use zones in the land use zone map.

For the main, long term objective of the Atlantic Zone Program (chapter 1.1) the land use zone map is very important. The land use zone map describes zones characterised by a unique combination of vegetation types, landscape patterns and other objects with typical forms, sizes and shapes. A distinction between crop types is not made, but would be very useful for the development and ex-post evaluation of the land use scenarios. With the 'combined' land use map it should be possible to locate different crop types within the land use zones.

Thematic maps link thematic information to geometrical locations. The maps may describe a single theme, e.g. forest areas, or multiple themes. The Atlantic Zone program has several thematic maps at its disposal, namely:

- IDA settlements
- protected areas
- forest areas
- banana plantations
- demographic units
- land use zones
- soils

Most of the thematic maps were initially available as 'naked' maps, containing only geometrical information. The thematic information belonging to the geometrical areas was either available on paper, or was thought to be easy to acquire elsewhere. In order to be able to analyze the land use information contained by the maps in a GIS, the available thematic information was entered into a database and linked to geometrical units on the maps.

To support its land use planning research, the Atlantic Zone program is interested in the former and present land use in the Atlantic Zone. The thematic maps contain a considerable amount of land use information. The value of this information should be analyzed for the two objectives described above; production of a land use map and localisation of crop types on the land use zone map.

The method used to systematically combine the land use information from the different thematic maps was an overlay procedure. This chapter first describes the basic concept of

overlay procedures. This is followed by an individual description of the various thematic maps, the assumptions made about the information and the role a map played in the overlay procedure. The results achieved with the overlay procedure in this research conclude the chapter.

4.2 Overlay Procedures

The overlay procedure is a powerful tool for combining information stored in different maps. Arc-Info supports three variations, namely:

- union
- intersect
- identity

The basic concept of overlaying corresponds with the *union* procedure (Fig. 4.1). An overlay map is 'laid over' another map. Where the areas covered by both maps coincide, new polygons are built with the polygonborders of the originating maps. The identifying values (ID values) belonging to the original polygons are saved as attributes for the newly created overlay polygons. Thematic information linked to the ID-values in the originating maps can therefore be applied to the overlay polygons. This is in fact what makes the overlay procedure so useful. Not only geometrical, but also the thematic information of various maps can be combined.

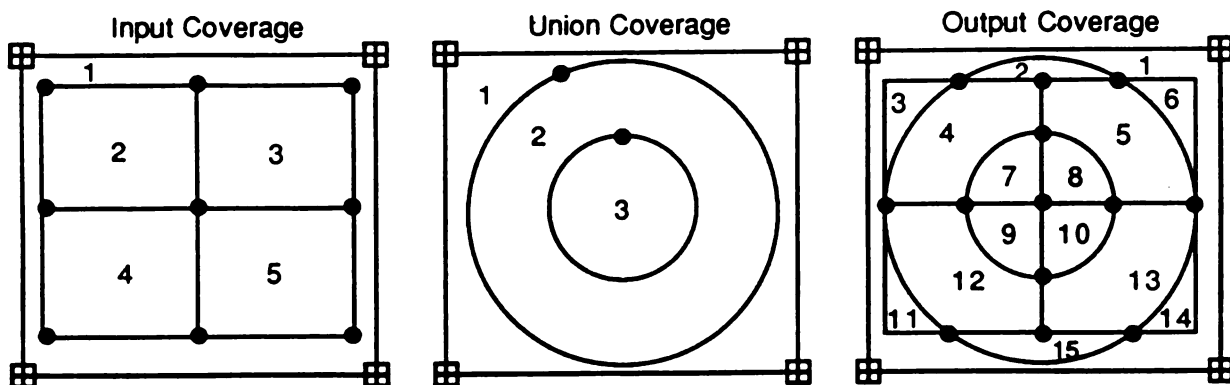


Figure 4.1: Union overlay procedure

The *identity* procedure differs from the union procedure in that the overlay map is cut off for as far as it does not coincide with the area covered by the input map (Fig. 4.2). The result

of an identity overlay procedure is a map with the same area as the input map. New polygons are defined for the area covered by the both the input and the overlay map, the remaining area is not changed.

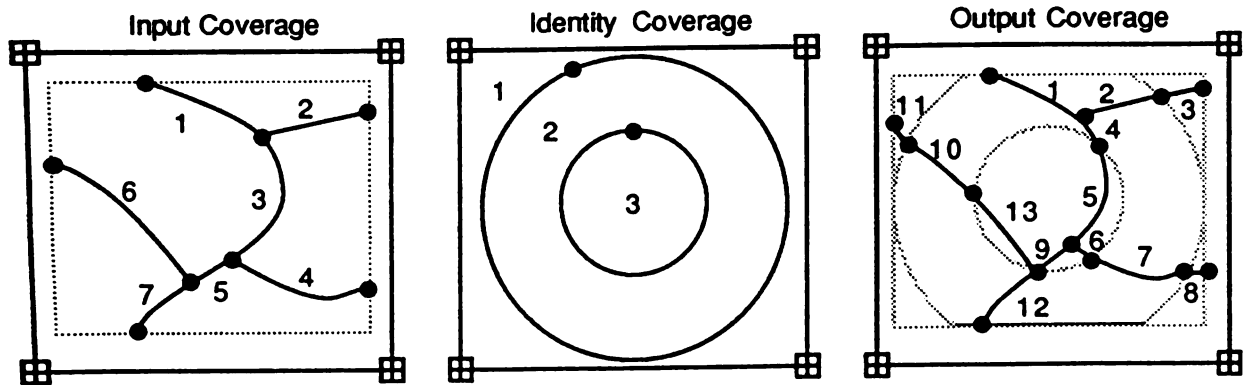


Figure 4.2: Identity overlay procedure

The *intersect* procedure intersects two coverages (Fig. 4.3). The result is a coverage built from the arcs of the input and overlay coverage for as far as the area covered by these two coverages coincides.

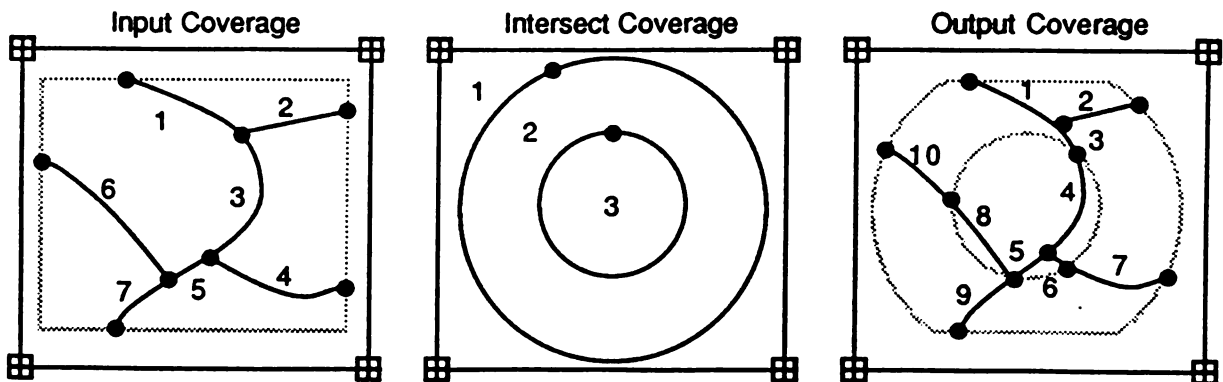


Figure 4.3: Intersect overlay procedure

4.3 The IDA Settlement Map

4.3.1 Introduction

IDA stands for Instituto de Desarrollo Agraria, translated as institute for rural development. The IDA was founded in 1962 and aims to help solve the problem of land allocation in Costa Rica. Departing from the end of the last century, colonisation has become a common fact in Costa Rica. Unemployment and concentration of landownership to a relatively small group of landowners, led to stimulation by the government for the colonisation of unused areas. These unused areas are mainly located in the lower parts of the country such as the Atlantic Zone. The colonisation would release the pressure on land elsewhere and could help in bringing down unemployment. IDA receives government funds and uses these funds to buy and distribute land, hereby creating a more justified allocation and use of the land. Since the foundation in 1962 IDA has acquired a total of 650.000 ha in different parts of the country. Large parts of this land are destined as national parks or forest reserves. The remaining land is divided under farmers for colonisation and now gives housing to about 35.000 families. Up to this moment, partly by economic limitations such as decreasing funding by the government, IDA has not been able to solve the problems of land allocation.

4.3.2 The IDA Settlement Map

The map present in the GIS of the Program contained only the borders of the different IDA settlements in the Atlantic Zone (Appendix 11). Some assumptions were made about the settlements, namely:

- Settlements consist of small farms, with mainly annual crop cultivation.
- IDA settlements are a subject of research in the Program. For that reason specific land use information per settlement is easy to gather.

An interview with W. Brooijmans, who works on a PhD. research for the department of Agricultural Law at the Agricultural University Wageningen, made clear that both assumptions were not justified. There are great differences in land use between IDA settlements. Farms varying in size from small to medium are located within every settlement. The farms do not concentrate only on the cultivation of annual crops. Large areas covered with pasture, wooded area or forest areas are also found (Appendix 13). The IDA organization has the exact land use information (1984) for the different settlements. This information is however not orderly stored but spread out over different departments. Accessing it would be a time consuming project. This time was not available within this research.

4.3.3 Role In Overlay Procedure

Unfortunately the IDA settlement map was of no use for this research. The large diversity between the settlements does not allow general assumptions to be made about land use types within the settlements. The assumption that the cultivation of annual crops could to a large extent be localised within the IDA settlements, proved to be unrealistic.

The land use within IDA settlements is very useful information for the Program. The difficult accessibility is however a problem.

Together with the protected areas and the banana plantations, the IDA settlements cover a major part of the Atlantic Zone. If exact land use information were available for all settlements, it would help much to further localize land use types in the Atlantic Zone.

4.4 The Protected Areas

4.4.1 Introduction

Three kinds of protected areas can be distinguished, namely:

- the zones proposed by the IUCN
- the indian reservations
- a political buffer zone along the border with Nicaragua

The International Union for the Conservation of Nature (IUCN) is an organization funded in major part by the European Community. In collaboration with other organizations and the Costa Rican ministry of natural resources, mines and energy, it has drawn a proposal for conservation areas that house an extensive biological diversity (R. Lok, 1992). They proposed a zone which is totally protected and an adjacent zone with a semi protected character, the buffer zone. These zones should provide for an improvement of the quality of life and guarantee the sustainability of production for the people in the area. The indian reserves are small areas containing small settlements of native inhabitants. These areas are protected against big landowners who seek extension of their property. The political buffer zone was established by the Costa Rican government in the time a civil war ravaged Nicaragua. Sandinists and Nicaraguan farmers fled, rested and settled themselves in Costa Rica. This zone was, and still is, a place where settlement and farming are forbidden. The civil war is over and control in the zone is not as strict as it was. Probably agricultural activity is reentering the zone¹.

¹Note: (august, 1993) With current development in Nicaragua between the Contra's and the Sandinists control in the buffer zone could become more strict again.

4.4.2 The Protected Area Map

The protected area map contains the geometrical delineation of the protected areas, indian reserves and the political buffer zone. Only small scale agricultural activity is present in the indian reserves. The majority of the protected areas is covered by natural forest or natural grass land (Appendix 4).

4.4.3 Role In Overlay Procedure

The areas in the map were checked with the aerial photographs. This showed that the assumed natural land use was present. Small scale farming was not recognisable at the scale of 1:80.000. In the overlay procedure the protected area map indicates the areas with exclusively natural use.

4.5 The Forest Map

4.5.1 Introduction

Natural forest areas cover a large part of the Atlantic Zone. The last decade an explosive expansion of the banana plantations has reduced the forest areas. To prevent excessive penetration of the forest by agriculture, the major part of the forests have become protected areas (section 4.3, protected areas).

4.5.2 The Forest Map

The forest map was extracted from the land use map made by Huising. The areas classified as natural forest were first checked for misclassifications on the aerial photographs. In Arc-Info the natural forest areas were selected from the land use map, and put into a new coverage (Appendix 5).

4.5.3 Role In Overlay Procedure

In the overlay procedures the forest map indicates the areas covered with natural forest. Areas classified as natural forest are homogeneous, no other land use types are present (compare to aggregated land use classes).

4.6 The Banana Plantations

4.6.1 Introduction

As every crop, bananas have certain demands for optimal growth and commercial production. The Atlantic Zone fulfils most of these demands. This has led to an explosive growth of banana plantations in area and numbers. In the last decade Costa Rica became the biggest banana producing country.

4.6.2 The Banana Plantation Map

A banana/forest map produced by IUCN was present at the Program. This map was checked with aerial photographs and turned out to be inaccurate. A photointerpretation was carried out to produce an accurate map of the locations of banana plantations (Appendix 6). This map was later inserted into the LUZ map of Huising (Chapter 2).

4.6.3 Role In Overlay Procedure

The geometrical accuracy of the banana map was checked with different maps present in the GIS of the Program, including a Landsat thematic mapper image. In the overlay procedures the banana map indicates the areas applied for banana cultivation. 'Banana plantation' is a homogeneous land use type, no other land use types are present (compare to aggregated land use classes).

4.7 The Demographic Areas

4.7.1 Introduction

For administration purposes Costa Rica is divided into provinces, cantons and districts. The Atlantic Zone is part of two provinces, Limon and Heredia. The provinces are further divided into districts. The districts are the geometrical units to which the demographic information is linked. This information includes data on the population, land use and agricultural production. The official population census was held in 1984 and described in the 'Censo Agropecuario, 1984'.

4.7.2 The Demographic Map

Lok (Lok, 1992) carried out a demographic study for the Atlantic Zone. She decided that the districts were not adequate geometrical units for a detailed illustration of the distribution of frequencies of the demographic indices. For this reason she introduced a

further division of the Atlantic Zone by four belts of land. These areas are confined by the following boundaries:

- the administrative boundaries of the cantons
- the highway between San Jose and Limon
- the hypothetical buffer zone discriminated by the IUCN
- the official limits of coastal nature reserves

Lok used information of the 1984 Census combined with more recent information. The goal of this research is to make a land use map of 1984, more recent information can not be used.

The land use information is described at district level. The subdivisions within the districts added by Lok are therefore of no use within this research context. These boundaries were removed from the map. The land use information in the 1984 Census contains the total area per district and the percentages of this area covered by different crops. Brooijmans gathered and ordered these figures into more clear and comprehensible tables (Appendix 12). The area, followed by percentages of colonization, forest, pasture, annuals and perennials, are given for each district.

4.7.3 Role In Overlay Procedure

The 1984 Census gives hard figures, but after examination some questions arose:

- In two districts the sum of the percentages for landcoverage exceeded 100%.
- The area figures in the census differed from the area figures in the demographic map. These differences were in some cases too large to be explained as slight miscalculations.

The origin of these inaccuracies is not clear. Hopefully Brooijmans can find answers to the questions in her PhD research. The assumption was made that the area figures in the map are accurate and that the percentages for land coverage can be applied to these areas. In the overlay procedure the demographic map supplies land coverage percentages per district. They can be applied to the areas not yet classified by the other thematic maps.

4.8 The Soil and Terrain Properties

4.8.1 Introduction

In the inventory phase of the Atlantic Zone project the geology, geomorphology and pedology of the Atlantic Zone were mapped. This information was later entered into a GIS. The information system was called SIESTA (Systema de Informacion y Evaluacion de Suelos y Tierras del Atlantico, Information System for the Evaluation of the Soils and Land in the Atlantic Zone) (Wielemaker, W.G. and A.P. Oosterom, 1992). Two types of information are distinguished:

- terrain information
- soil information

Terrain information among others includes geography, stoniness and slope gradient. Soil information includes texture, acidity, soil ripening etc.

4.8.2 The Soil Map

The soil and terrain information is related to different mapping units. Mapping units are here defined as bordered areas which are characterised by a unique combination of soil and terrain properties. The soil map consists of 171 mapping units. These mapping units can each be further divided into a maximum of five areas. The mapping units are therefore associations of areas with different values for a soil or terrain property. Areas are not visible on the soil map, they are merely percentages of a mapping unit. For different properties a mapping unit can consist of a different number of areas. To explain the map structure two examples of mapping unit description will be given. The stoniness may be described as: 20% no stones, 40% medium stoniness, 40% very stony. The drainage class for the same mapping unit may be: 40% well drained and 60% moderately drained.

4.8.3 Role In Overlay Procedure

In theory soil and terrain information can be used to help allocate land use types on a land use map. Certain land use types (e.g. agriculture) have requirements concerning slope gradient, soil fertility etc. By overlaying soil and terrain information with the land use information of the land use map a further specification of land use can be realised.

In practice this theory proved not valid. The soil map was not used in the overlay procedures. The map consists of mapping units. These mapping units are associated objects, composed of areas. The areas are given as percentages, their exact location within a mapping unit is not known. In an overlay procedure this causes problems in the description of the polygons in the newly created overlay map. A polygon originating from

overlaying one or more associated polygons will again be an association. This association will be more complex and the uncertainty of the information increases significantly. The overlaying of associations therefore in practice does not lead to a further specification of land use information.

4.9 The Land Use Zones

4.9.1 Introduction

Huising (Huising, 1993) created a land use map for the Atlantic Zone. For the procedures he followed and his objectives reference is made to chapter two.

4.9.2 The Land Use Zone Map

The land use zone map as created by Huising has been changed into an adjusted land use zone map with an altered classification structure and land use zone delineation. The original map, the adjustments made to the map and the classification structure are described in chapters two and three. Appendix 7 contains the adjusted land use zone map.

4.9.3 Role In Overlay Procedure

The objective to further specify the land use zone map with information gathered from the thematic maps could only be partially realised. The reason for the limited results correspond very much with the reason not to use the soil map in the overlay procedures (chapter 4.7.3). The land use map consists of land use zones. Where the mapping units of the soil map are associated objects, the land use zones are aggregated objects. The land use information extracted from the thematic maps is for a large part grouped in aggregated units. When an aggregated object is overlaid with another (aggregated) object, problems arise in the description of the newly created objects. A polygon originating from overlaying one or more aggregated objects, will again be an aggregated object. This aggregation will be more complex and the uncertainty of the information increases significantly. Combining aggregated objects does therefore not lead to a further specification of land use information.

4.10 Checking the Reliability of the Different Thematic Maps

The reliability of the thematic maps can be tested by overlaying maps that in theory may not show overlap between their geometrical units. An example of an overlay that may never show overlap is the overlay of the banana map with the protected area map. An area labelled as 'banana plantation' on the banana map may in theory never show overlap with

an area labelled as 'protected area' on the protected area map. If an overlap occurs it is clear there is something wrong.

Errors indicating inaccuracies in the maps can have different causes, namely:

- inaccurate digitizing of one or both maps
- illegal agricultural activity
- an unidentified cause which may require specific research

Before the overlay procedure was carried out, the maps with theoretically exclusive polygons were overlaid with each other. An overlap that required further research was the overlap between some banana plantations and IDA settlements. No exact information was available on the land use within the different IDA settlements, but it had been assumed that banana was not cultivated in IDA settlements. This assumption turned out to be unreliable (section 4.2.2) so no adjustments were made to the maps. More inaccuracies did not occur.

4.11 Overlay Procedure

The overlay procedure used in this research project was the union procedure. All thematic maps used in the overlay procedure cover the same area: the Atlantic Zone of Costa Rica. Therefore, in this case the different procedures should give the same result. The union procedure is the 'safest' overlay procedure as no information is lost, with both other procedures this could still be the case. The union procedure was also a check for little inaccuracies in the delimitation of the border of the Atlantic Zone in the different maps. Little differences appeared as very small polygons after overlaying.

In the foregoing sections the role of each thematic map in the overlay procedure is described. Only the results will be stated here.

After analysing the thematic maps, four maps proved to be useful in the overlay procedure (see 'role in overlay procedure' sections). These maps were:

- forest area map
- banana plantation map
- protected area map
- demographic map

Three of these maps can be interpreted as maps indicating areas with homogeneous land use. In the case of forest areas and banana plantations this is clear. Forest and banana plantation are exclusive land use types, no other land use is present within areas classified as such. Protected areas however, consist of different types of natural vegetation, e.g. natural forest and natural pasture. This natural character implies that no agricultural activity of any substance is present in the protected areas. The protected areas may therefore be

interpreted as areas with an exclusive natural land use.

An overlay of the forest, banana and protected area maps, classifies the land use in the Atlantic Zone to a large extent. The areas remaining unclassified can be classified by overlaying this map with the demographic map (Appendices 8,9 and 10). The demographic map supplies land coverage percentages per district. Large areas of these districts have already been classified as forest, banana plantation or protected area. The area to which the land coverage percentages apply, is therefore narrowed down to the areas not yet classified. These areas are then classified as associations of different land coverages (compare to the homogeneous land use areas).

The large overlap between the protected area map and the forest map must be noted. The Cost Rican government has been one of the first in central and south america to declare large forest areas as protected natural reserves.

5. Conclusion

The research objective to produce a land use map for the Atlantic Zone of Costa Rica, by combining land use information stored in several thematic maps, was realised. In the overlay procedure used to combine the land use information, the overlay of the forest-, banana-, demographic- and protected area map proved to be the best possible combination. The areas classified as forest or banana plantation can be interpreted as areas with homogeneous land use. The protected areas are areas with exclusive natural use, no agricultural activity of any substance is present. The remaining areas are classified as associations of land coverage percentages by the demographic map.

Not all the available thematic maps could be used in the overlay procedure.

IDA settlements are a subject of research in the Atlantic Zone program. Therefore specific land use information was assumed to be available for the settlements. Also it was assumed that settlements consist of small farms, with mainly annual crop cultivation. Both assumptions proved to be invalid, the IDA settlement map could therefore not contribute to a further specification of the land use.

The soil map could in theory help to allocate land use types. Certain land use types (e.g. agriculture) have requirements concerning slope gradient, soil fertility etc. The mapping units on the soil map are associations. The overlaying of these associations with other thematic maps proved not to lead to a further specification of land use.

Due to the fact that two maps were unfit for use, the result of the overlay procedure was a less detailed land use description as expected.

The fact however remains that it is advisable to analyze the available land use information (in several thematic maps), before deciding to conduct a new land use inventarisation research.

For the development of a methodology for analysing and planning sustainable land use (USTED), the land use zone map is very important. With the land use information from the 'combined' land use map, a further specification of the land use zone map created by Huising could not be realised. The problem of associated and/or aggregated objects accounts for this.

Land use zones are aggregated objects, described by a unique combination of land coverage percentages. This makes the land use zones relatively stable objects. Change in the *locations* of land cover types within a land use zone (e.g. annual crop rotation on different parcels), do not affect the land use zone description until the land coverage *percentages* change substantially.

The combination of aggregated objects with other objects in an overlay procedure does not have to lead to more specified (land use) information. Problems arise in the description of the objects in the newly created overlay map. An object originating from overlaying one or

more aggregated objects will again be an aggregated object. This aggregation will be more complex and the uncertainty of the information increases significantly. In the case of the land use zones this meant that a more specified localisation of land cover types within the land use zones could not be realised.

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Appendices



Description of the land use zone classesLevel 1: The main classes

1. Natural Vegetation, area of natural or semi natural vegetation.
2. Agricultural Penetration, area where the natural or semi natural vegetation has partly been removed to apply the soil for agricultural use.
3. Cultivated Area, area where the land use is or was dominated by various types of agricultural use.
4. Urban Area (UA), area covered by a town or village.
5. Water area (WA), areas consisting of canals or rivers with adjacent area.
6. Industrial Area (IA), area characterised by the presence of an industrial enterprise.

Level 2: Subdividing the main classes

1. Natural Vegetation:

- Natural Vegetation Grassland (NVG), the dominant vegetation type is grass.
- Natural Vegetation Forest (NVF), area dominantly covered by forest.

2. Agricultural Penetration:

- Penetration Area Dispersed (PAD), deforested areas are located dispersed over the zone with a size varying from small to medium. Forest is still the dominant vegetation type (covers at least 25 - 50 % of the zone), other types of vegetation are wooded area, secondary vegetation and secondary pasture.
- Penetration Area Continuous, the deforested areas form continuous areas. Within these areas parcels of various sizes can be distinguished.

3. Cultivated Area:

- Abandoned Area (AA), area without agricultural use or partial agricultural use. These areas differ from penetration and mixed agricultural use areas in that an important part of the cultivated area is no longer in use. Dominant vegetation types are forest and wooded area, secondary vegetation and (secondary) pasture are found in limited percentages.
- Agricultural Use, area where various forms of agriculture dominate the land use.

Level 3: subdividing level 2**1. Penetration Arae Continuous:**

- Small Parcels (PAC1), deforested areas form continuous areas in the zone. Within these areas small to medium parcels can be destinguished. Forest covers from 25 to 50 % of the zone, the rest is covered in varying percentages by wooded area, (secondary) pasture and bare soil.
- Medium Parcels (PAC2), deforested areas form continuous areas in the zone. Within these areas the generally medium sized, irregularly shaped parcels can be hard to destinguish. Forest covers from 35 to more than 50 % of the zone, the rest is covered by wooded area and (secondary) pasture.
- Large Parcels (PAC3), deforested areas form continuous areas in the zone. Within these areas large parcels with a regular, rectangular form can be destinguished. Forest covers from 25 to more than 50 % of the zone, the rest is covered by wooded area and secondary pasture.

2. Agricultural Use:

- Dominant Bare Soil, these zones are characterised by a percentage of bare soil generally higher than 40 %. This presence of bare soil indicates that the soil is used up to a high percentage for the cultivation of annual crops.
- Dominant Pasture, these zones are characterised by pasture as the or one of the dominant vegetation types. These zones are mostly used for cattle-breeding.
- Mixed Agricultural Use, this zone lies in between the classes of dominant bare soil and dominant pasture. Bare soil and pasture are both found without one beeing dominant over the other. Wooded area also covers a considerable area.
- Plantations, areas with well marked borders which can be clearly destinguished. Plantations are homogeneous cocerning crop cultivation.

Level 4: subdividing level 3**1. Dominant Bare Soil:**

- Small Parcels (DBS), bare soil covers up to 45 % of the zone. The rest is covered by wooded area and (secondary) pasture. Within the zone small parcels can be destinguished.
- Medium Parcels (DBM), bare soil covers up to 50 % of the zone, the rest is covered by (secondary) pasture and wooded area. Within the zone medium parcels can be destinguished.
- Large Parcels (DBL), bare soil covers the mayor part of the soil, secondary pasture and wooded area are found in minor percentages. Within the zone large, square or rectangular formed parcels can be destinguished.

2. Dominant Pasture:

- **Medium Parcels (PMP)**, pasture is the dominant vegetation type, also wooded area and secondary pasture can be found as considerable percentage of the cover, sometimes bare soil is encountered in very small percentages. Within the zone parcels are hard to distinguish. Their form is generally irregular and they are medium sized.
- **Large Parcels (PLP)**, Pasture and secondary pasture cover from 35 to 50 % of the zone, wooded area, bare soil and some secondary vegetation cover the remaining part of the zone. Within the zone parcels can be clearly distinguished. Their size is large and they seem to be oriented.

3. Mixed Agricultural Use:

- **Small Parcels (MSP)**, (secondary) pasture and bare soil are both present. Mostly pasture is found in higher percentages than bare soil and may even be the dominant vegetation type in the zone, however bare soil in all cases covers a considerable part of the zone. Wooded area is also covers 25 to 35 % of the zone. The parcels that can be distinguished in the zone are small sized.
- **Medium Parcels (MMP)**, pasture covers from 20 to 35 % of the zone, bare soil covers between 20 and 25 %. Wooded area may cover a considerable part of the zone in which small to medium parcels can be distinguished.
- **Large Parcels (MLP)**, pasture and bare soil are both present in more or less equal percentages. Wooded area and secondary pasture also cover considerable parts of the zone. The parcels that can be distinguished are generally large and square or rectangular in shape.

4. Plantations:

- **Plantation Banana (PL1).**
- **Plantation Bambu (PL2).**
- **Plantation Tree (PL3).**

Note: Classcodes in brackets are given for classes which are not further subdivided.

THE CLASSES OF THE LAND USE ZONE CLASSIFICATION FOR THE NORTHERN REGION OF THE ATLANTIC ZONE OF COSTA RICA BY E.J. HUISING (Mücher, 1992)

NV. NATURAL VEGETATION

- NV1. Natural wet grassland vegetation, partly inundated.**
- NV2. Area with forest as dominant land cover.**
- NV2.1 Lowland and premountainous humid tropical forest.**
- NV2.2.1 Lowland forest with peat and swamp areas.**
- NV2.2.2 Forest with some secondary vegetation.**
- NV2.2.3 Forested area, partly classified as wooded area.**

PA. AREA OF AGRICULTURAL PENETRATION

- PA1 Small scattered deforested areas.**
- PA1.1 Forest covers more than 75% of the area. Wooded area and secondary vegetation cover the remaining parts.**
- PA1.2 Forest covers between 50% and 75% of the area. The deforested parts consist of wooded area, secondary pasture and secondary vegetation.**
- PA1.3 Forest covers between 25% and 50% of the area. The subdominant cover types are: wooded area, secondary pasture and secondary vegetation.**
- PA2. Area with large continuous deforested parts, with recent deforestation. In the deforested parts small "faces" are located. More than 10% of the area consists of bare soil.**
- PA2.1 Forest covers the area for more than 25%, but less than 50%.**
- PA2.2 Forest covers the area for less than 25%.**
- PA3. Area with large continuous deforested parts; small to medium sized, and irregular shaped "faces", difficult to distinguish. No more than 10% of the area consists of bare soil. Dominant use: livestock breeding.**
- PA3.1 Forest covers between 35% and 50% of the area.**
- PA3.2 Forest covers the area for less than 25%.**
- PA4. Area with large continuous deforested parts; small to medium sized, and irregular shaped "faces". Use; Large cattle farms with parts of degraded pastures.**
- PA4.1 Forest covers the area for more than 50%. The subdominant cover consists of wooded and secondary vegetation.**
- PA4.2 Forest covers between 25% and 50% of the area. Secondary pasture covers more than 25% the area.**

TC. AGRICULTURAL LAND

- TCP. Livestock production**
- TCP1. Small, irregular "faces", little pronounced; small to medium sized cattle farms.**
- TCP1.1 The dominant cover is pasture. Bare soil covers the area for more than 9%; some annual and perennial cropping occurs.**
- TCP1.2.1 The dominant cover is pasture. Forest covers the area for more than 15%.**
- TCP1.2.2 The dominant cover is pasture. Forest covers the area for less than 15%. Wooded areas and secondary vegetation are present in small quantities.**
- TCP3. Medium sized to large "faces", very pronounced and with similar orientation; large cattle farms.**
- TCP3.1 Pasture covers the area for more than 50%. Subdominant cover types are secondary pasture or wooded area; large commercially managed cattle farm.**
- TCP3.2 Pasture and wooded areas cover each between 20% and 35% of the area.**
- TCP3.3 Secondary pasture covers for more than 35% of the area. Secondary vegetation and pasture are subdominant covers; large cattle farms, with parts neglected or not used.**
- TCA. Arable cropping areas. Areas with part classified as bare soil; land is used for arable cropping or is recently cleared. The farm land is dedicated to high percentages of grains and root crops.**
- TCA1.1 Bare soil covers for more than 45% of the area. Pasture is the subdominant cover type.**
- TCA1.2 Bare soil covers between 25% and 45% of the area. Wooded area, pasture and secondary pasture are the subdominant cover types.**
- TCM. Arable farming and livestock breeding.**
- TCM1 Small "faces"; small to medium sized farms.**
- TCM1.1 Bare soil covers for more than 25% of the area. Pasture, secondary pasture and wooded area each cover the area for 15% or more. Important part of the area is dedicated to arable farming (maize).**
- TCM1.2 Livestock breeding is the most important activity. Bare soil covers between 15% and 25% of the area. The wooded area is less than 35%.**
- TCM1.3.1 The dominant activity is livestock production. Minor part is dedicated to arable farming. Wooded area covers less than 35% of the whole area.**
- TCM1.3.2 The wooded area (tree crops, mostly cacao) covers more than 35% of the area. Pasture, secondary pasture and bare soil are found in limited quantities.**
- TCM3.1 Medium to large "faces". Large farms.**
- TCM3.2 Bare soil and pasture are the dominant covers. Secondary pasture and wooded are subdominant covers.**
- TCE. Commercial enterprises; production for export. Pasture and secondary pasture cover less than 35% of the area.**
- TCE1 Small "faces".**

TCE2 Medium to large "faces".

PL. PLANTATIONS

- PL1.1** Banana covers for more than 55% the area.
- PL1.2** Banana covers between 35% and 55% of the area.
- PL2** Bamboo plantations.
- PL3** Production forest.

TA. WASTELAND

- TA1** Forest and wooded area cover 50% or more of the area. Secondary vegetation covers the area for less than 15%.
- TA2** Wooded area and forest are the dominant land covers. Secondary vegetation covers more than 15% of the area.
- TA4** Pasture and secondary pasture are the dominant cover types, secondary vegetation is also important.

AC. TOWNS, VILLAGES AND BUILDING AREA

- AC1** Towns

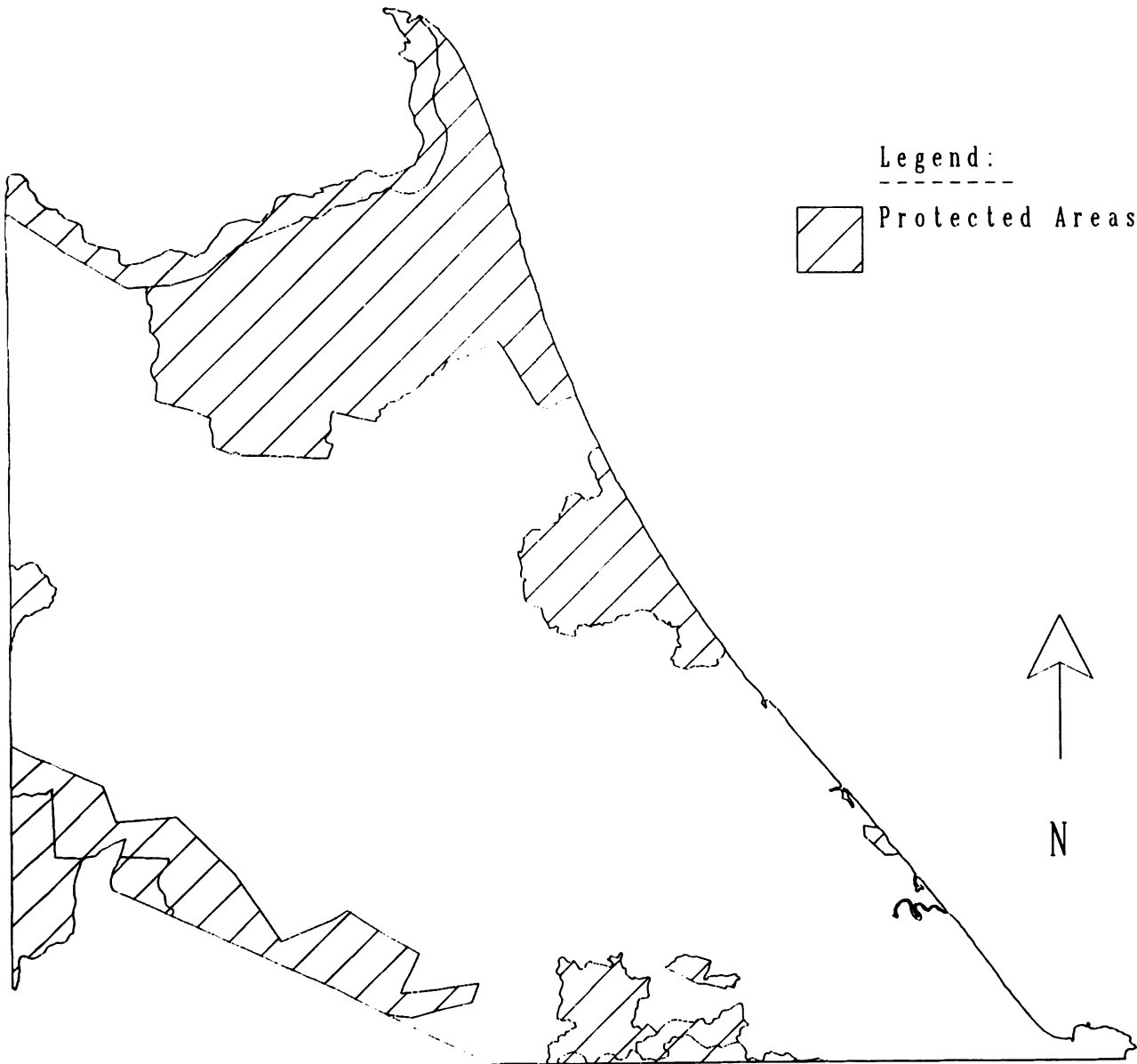
AQ. WATERBODIES

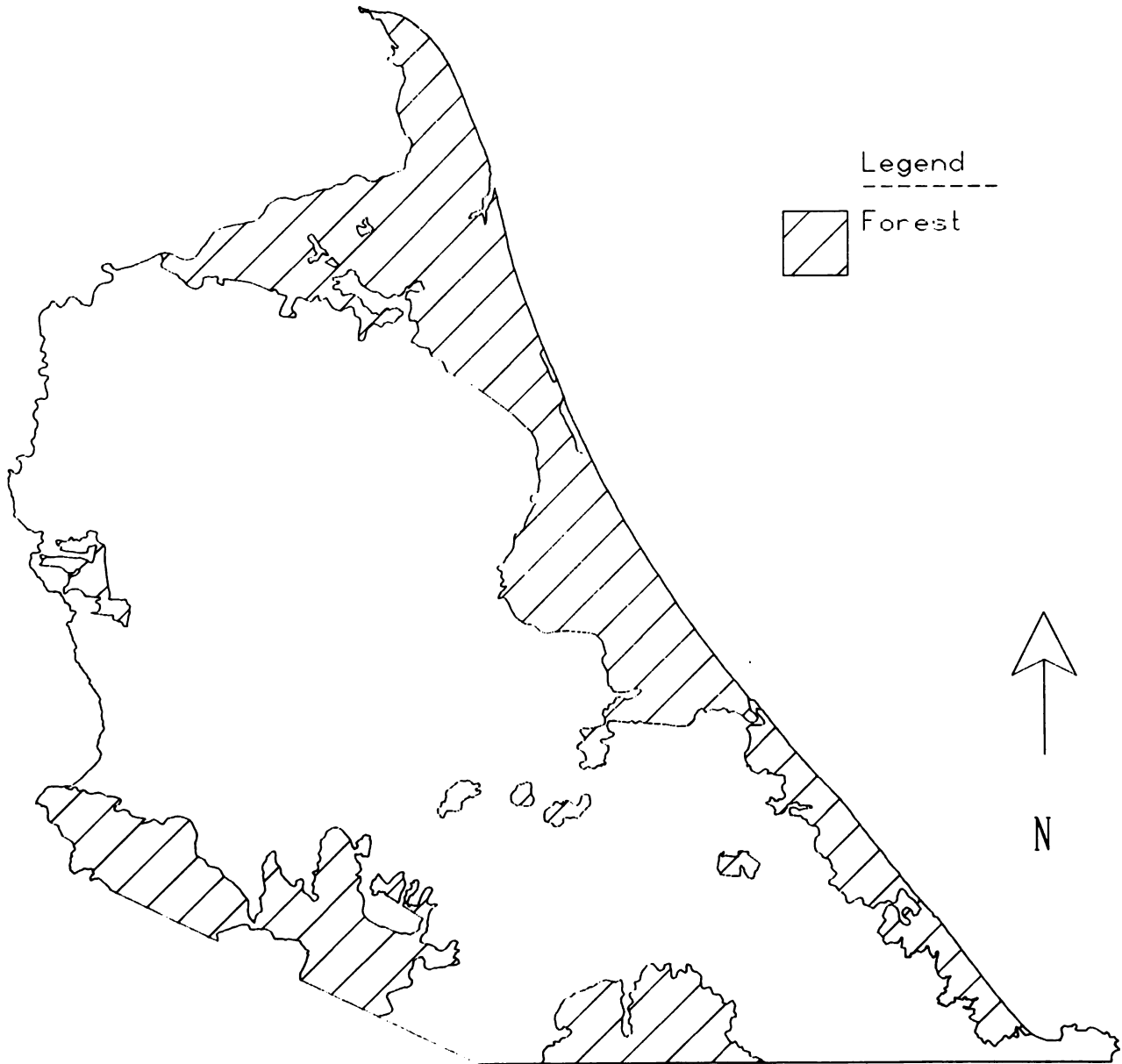
- AQ1** Rivers and canals.
- AQ2** River beds and river banks.

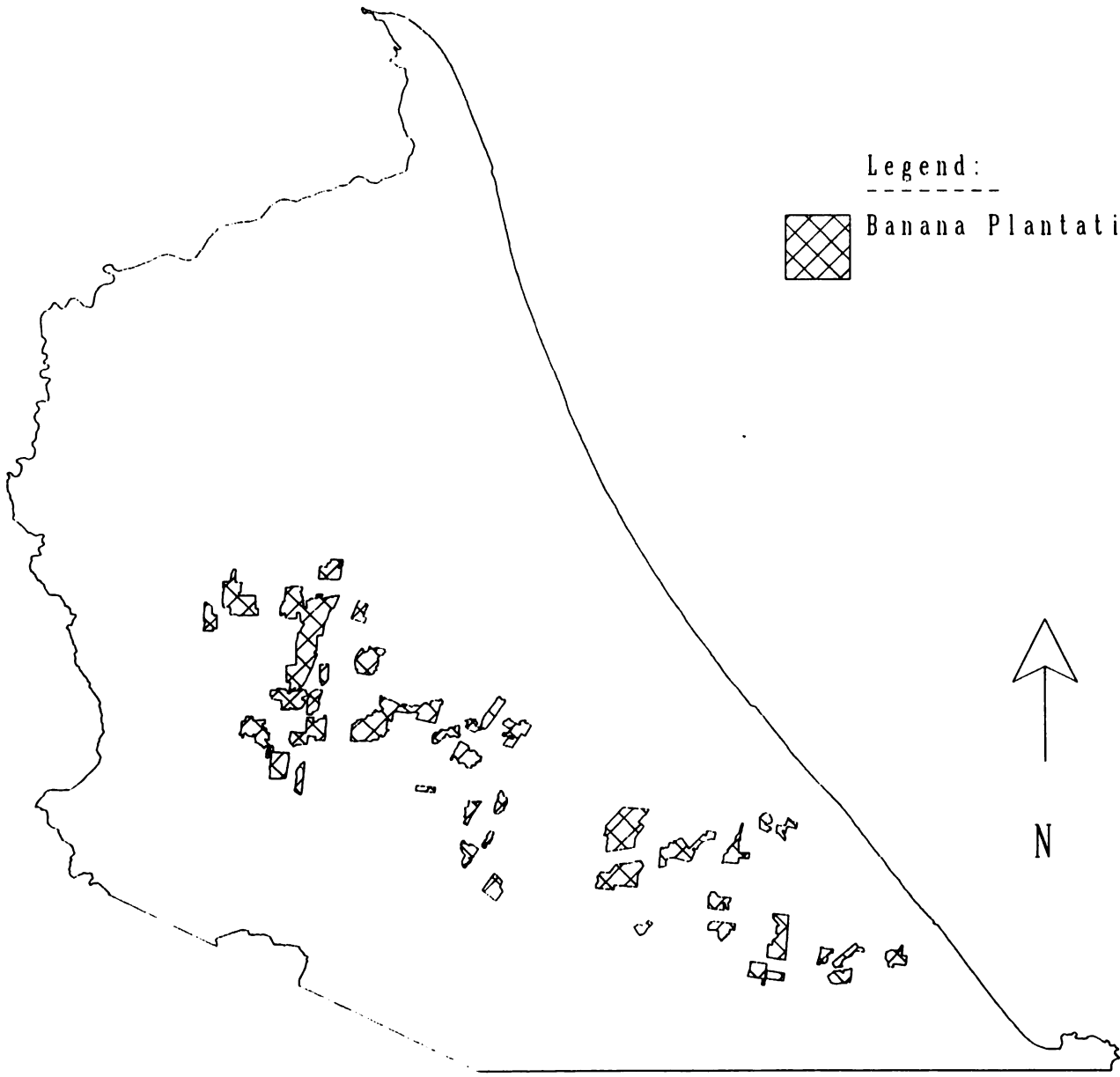
ASSO. ASSOCIATIONS

- ASSO1** Association of banana and wooded area.

NC. NOT CLASSIFIED







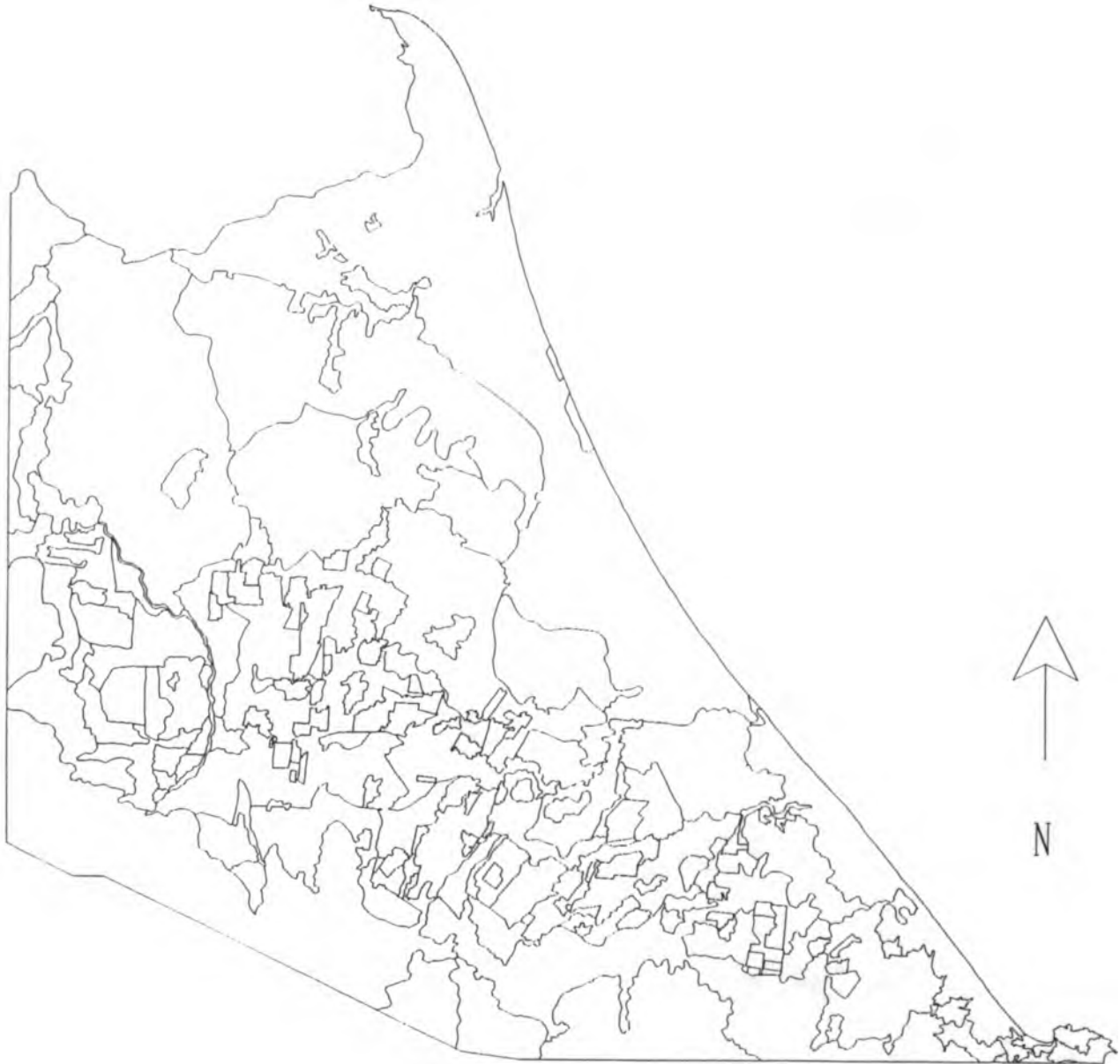
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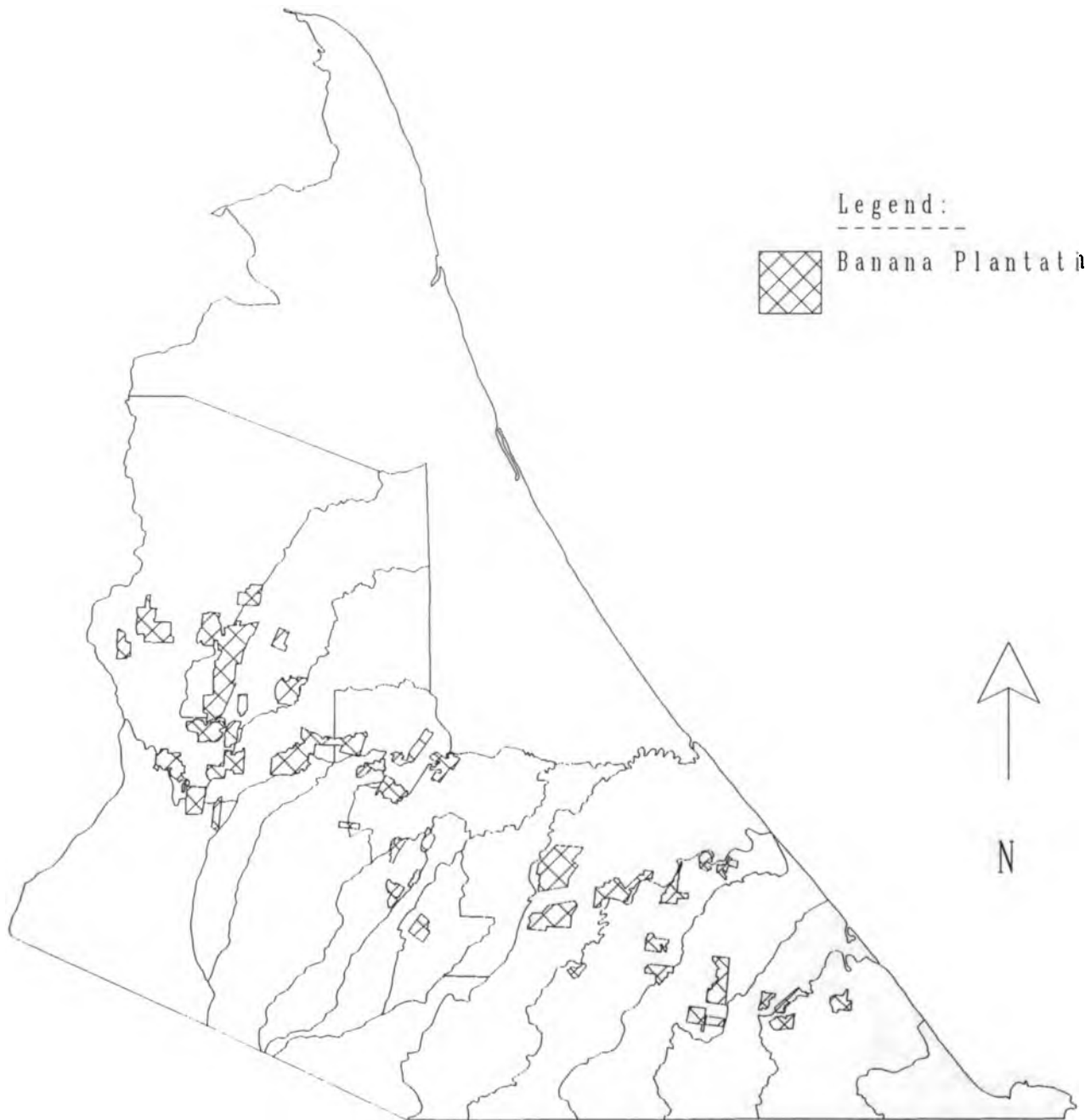


Banana Plantation

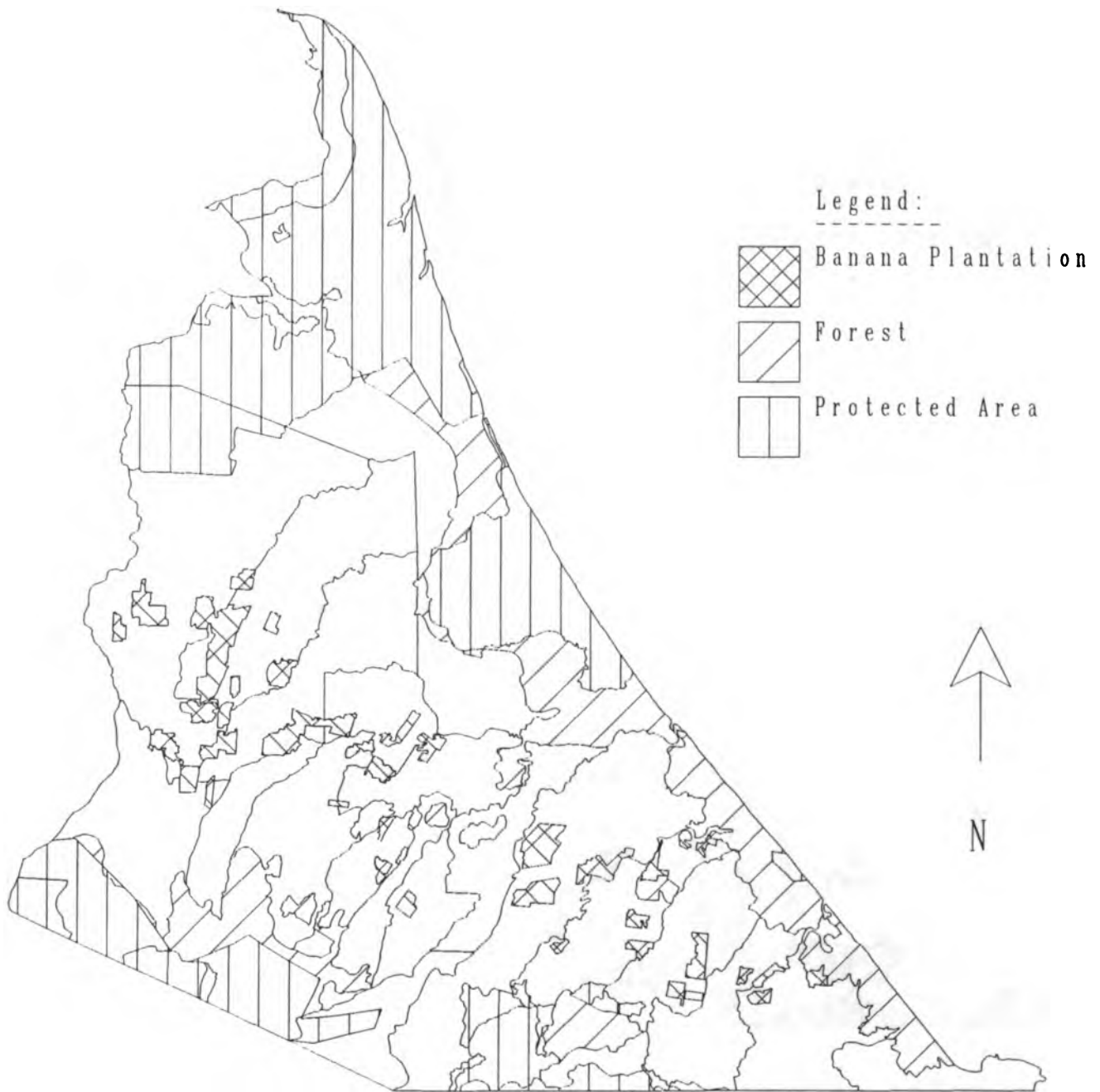


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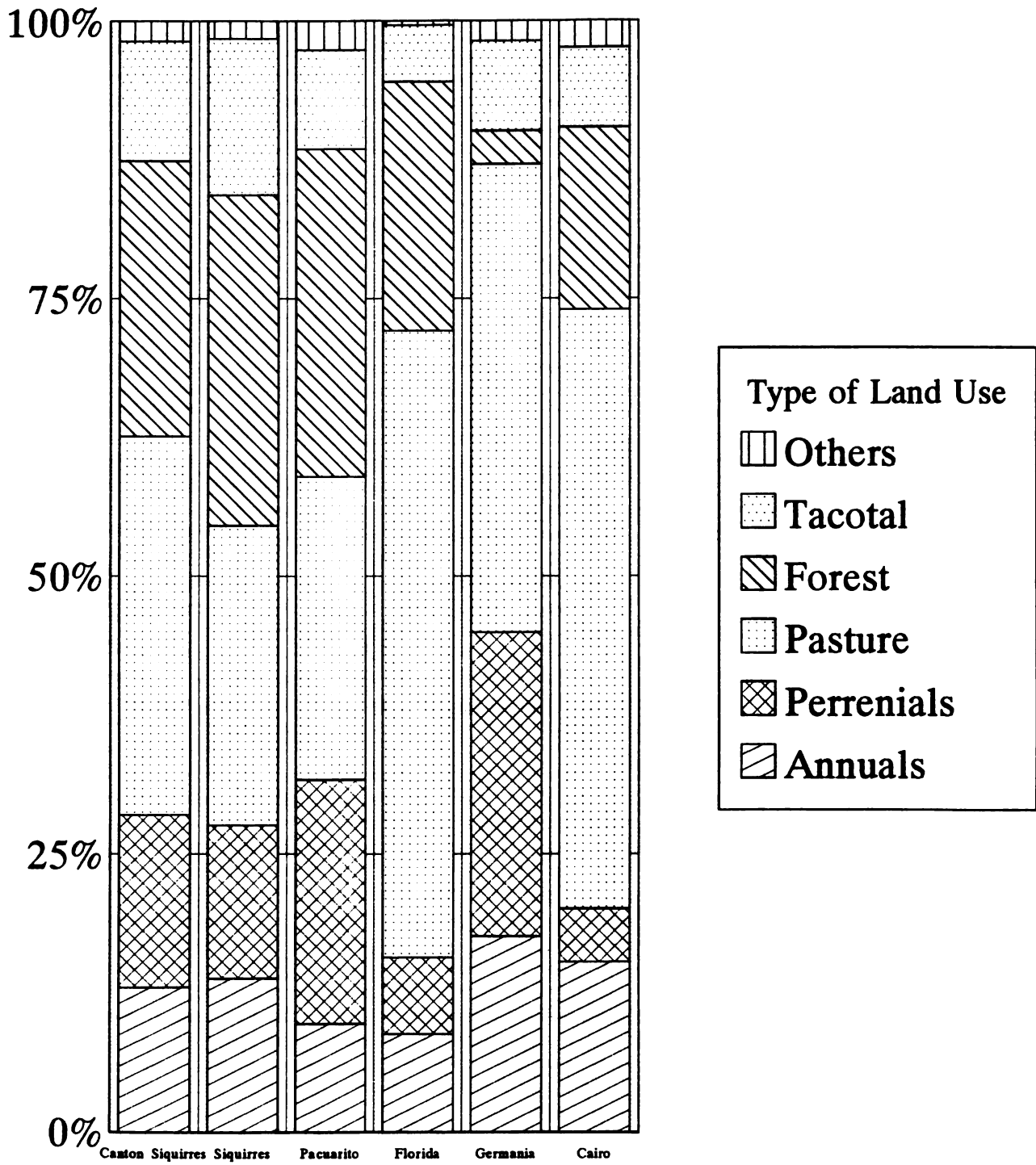






Land Use in Siquirres in 1984

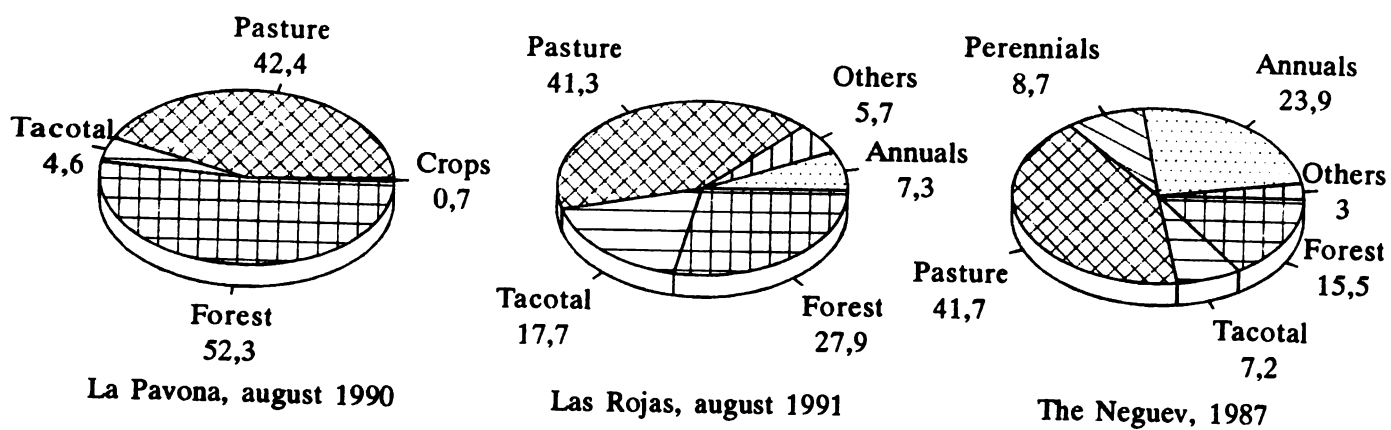
According to Districts



Districts per Canton

Source W. Brooijmans, 1992.

Land Use in different Ida settlements



FIELDWORK WITH A GPS IN COSTA RICA

Introduction

The long-term objective of the Atlantic Zone Program is to analyze and improve the land use in the Atlantic Zone in Costa Rica. A methodology for land use planning on a sustainable basis is developed. This methodology includes the development of crop growth simulation models, a linear programming model and a Geographical Information System (GIS).

For this reason a land use map (situation in 1984) has been created (Chapter 2). Land use is dynamic, with the land use map of 1984 as a basis the present land use and its dynamic characteristics can be analyzed. This is however only possible if the land use map can be updated on a regular basis.

In the northern part of the Atlantic Zone the area covered by banana plantations is rapidly increasing. No recent aerial photographs, topographic maps or satellite images were available to update the land use zone map. A Global Positioning System (GPS) seemed a usable tool for quick updating of the geometrical description of the land use zones in areas with rapid change.

Global Positioning System

On the most recent topographic maps available at the Atlantic Zone Program, banana plantations dating from 1985 or later are not present. Before banana plantations came to the northern part of the Atlantic Zone, the area was mainly covered with natural rain forest and roads hardly existed.

Lacking recent aerial photographs a GPS (a NAVSTAR borrowed from the IUCN) was used to locate new banana plantations which are in construction or have just started producing. To check the GPS accuracy, checkpoints were measured on cross-roads which were also present on the rail and road map. The rail and road map was digitized from the 1984 aerial photographs by the Department of Surveying and GIS in Wageningen.

Nearly all the measured checkpoints proved to be inaccurate, with a maximum error of two kilometres in the field. The errors of the measured points differed in size and direction, no systemacy could be observed. How the inaccuracies could occur is not known and it is not possible to detect the reasons at this time. The data (rail and road map and the measured points) were lost during transportation from Costa Rica to Holland).

There are several possible reasons that could have lead to the errors, namely:

- *the weather conditions*, this can never be the cause of errors of two kilometres.
- *the type of GPS*, the GPS type used was surely not the most accurate type. This may explain minor errors, but errors of two kilometres are not likely to be explained by the use of a 'cheap' GPS.
- *human failure*, the most likely reason.

Human failure could have had one or more of the following reasons:

- *identification errors* of the measured checkpoints on the topographic map and/or rail and road map. This might have been the case if some of the measured points had been false, but nearly all the points had a more than acceptable error.
- *inaccurate reference geometry* of the rail and road map. This is very unlikely.
- *wrong projection*. The most acceptable reason, but not traceable.

Even at the scale the Program uses for its land use research (1:200.000), the GPS errors are too large. However, an indication of the location of the new plantations and their approximate size were extracted from the GPS measurements. No information at all was available up to that moment on the increase of banana planted areas since 1984. Therefore the GPS measurements were not totally useless.

At present aerial photographs of 1992 are available for the identification of the accurate locations of the banana plantations.