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LUST FOR MANGO
Quantitative description of Land Use Systems and Technology for mango in Guanacaste, Costa Rica (PART A)

MANGO YIELDS IN RELATION TO DIFFERENT MANAGEMENT ASPECTS - a literature study (PART B)

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CENTRO AGRONOMICO TROPICAL DE INVESTIGACION Y ENSEÑANZA (CATIE)

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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.

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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 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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ABSTRACT

The research described in this thesis was conducted within the Atlantic Zone Project (AZP) in Costa Rica in 1995. The program developed the USTED (Uso Sostenible de Tierras En el Desarollo; Sustainable Land Use in Development) Methodology (Stoorvogel et al.,1995) which supports regional land use planning agricultural lands. The approach followed by the AZP uses the term LUST (Land Use System and Technology). This form of describing land use includes a quantification of the technology.

The objective of this study was to describe activities in the production of mango *(Mangifera indica)* in Guanacaste and to quantify the corresponding inputs and outputs. The aim was to describe at least two LUSTs, based on a cluster analysis of the data. The required data were gathered by doing a questionnaire among twenty-four mango cultivators in the study area.

Data were gathered about general aspects of the plantation (such as area and age of the plantation), sowing, irrigation, weeding, pruning, flower induction, fertilization, harvesting and controlling pests and diseases. Of all these aspects, data about hours of labour, time of the year, equipment used, products used and amount of inputs had to be gathered. These were necessary for describing LUSTs.

A statistical cluster analysis (Ward method) was used to make four groups of mango plantations which each represent a LUST.

The group with the most extensive management consists of five fields and was given number one in the cluster analysis.

The group with number two is less extensive than cluster one. Sometimes the fields are a bit neglected, but occasionally the management is quite intensive without, for instance, intensive irrigation. Often capital is lacking.

Fields that are in group three have intensive management and belong to the largest cluster.

Fields with number four have the most intensive management. There are only three cases of this catagory in this study and they all belong to the same company.

In general, it becomes clear that the acreage increases per cluster. Cluster one has an average of 10 hectares, cluster two of 29 hectares, cluster three of 41 hectares and cluster four of 473 hectares. Cluster one contains the only farms with varieties that are only suitable for the local market and there is hardly any flower induction or irrigation. In the other clusters, there is always flower induction and from cluster two to four, the type of irrigation becomes more capital intensive.

ACRONYMS

AUW	Wageningen Agricultural University
AZP	Atlantic Zone Project
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
GIS	Geographic Information System
LP	Linear Programming
LU	Land Unit
LUS	Land Use System
LUST	Land Use System and Technology
LUT	Land Use Type
MAG	Ministerio de Agricultura y Ganadería
MODUS	MOdules for Data management in USTED
UPGMA	Unweighed Pair-Group Method using arithmetic Averages
UNED	Universidad Estatal a Distancia
USTED	Uso Sostenible de Tierras En el Desarollo (Sustainable land use in development)
SPSS	Statistical Package for Social Sciences

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FOREWORD

This study for the Msc thesis 'Land Use Systems and Technology for mango' was conducted in Costa Rica, in the Province of Guanacaste. The study took place within the Atlantic Zone Project, which is a collaboration of the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE, Turrialba), the Ministerio de Agricultura y Ganadería of Costa Rica (MAG) and the Agricultural University of Wageningen (AUW, the Netherlands). I stayed in the Atlantic Zone Project from May till the end of August in 1995.

CHAPTER 1: INTRODUCTION

1.1 The Atlantic Zone Project

The research described in this thesis was conducted within the Atlantic Zone Project (AZP) in Costa Rica in 1995.

The AZP in Costa Rica is a result of an agreement for technical cooperation between the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE, Turrialba), the Ministerio de Agricultura y Ganadería of Costa Rica (MAG) and the Agricultural University of Wageningen (AUW, the Netherlands). The program started in April 1986.

The program developed the USTED (Uso Sostenible de Tierras En el Desarollo; Sustainable Land Use in Development) Methodology (Stoorvogel et al.,1995) which supports regional land use planning of agricultural lands.

The framework of USTED consists of the following modules:

1. A linear programming (LP) model, to calculate optimal land use given a goal, a set of constraints and a series of technical coefficients reflecting the options for land use. Goal and constraints can include socio-economic and biophysical aspects, including sustainability indicators.
2. A geographic information system (GIS), to facilitate storage and analysis of spatial data, including geographical distribution of soil types and their characteristics; and to visualize model outputs in maps.
3. A data management tool (MODUS: MOdules for Data management in USTED, to facilitate data transfer with USTED; and to calculate the technical coefficients for the LP model.

1.2 Land Use System and Technology (LUST)

The FAO introduced some guidelines on what aspects to include in describing land use, and how to differentiate various aspects of land use, separating Land Unit (LU) from Land Use Type (LUT). Hereby LUTs are described with as much detail and precision as the purpose requires. Land Use System (LUS), being the combination of LU and LUT, can be used to describe land use on LU level (Jansen and Schipper, 1994).

The approach followed by the AZP uses the term LUST (Land Use System and Technology). This form of describing land use includes a quantification of the technology. Each LUST is described in an individual database. The body of each description of a LUST is formed by a chronological and quantitative description of a particular operation sequence, that comprises at least one full crop cycle, and might contain rotations. LUST descriptions quantify all inputs and outputs. However, information on prices, nutrient contents and toxicity is stored separately from the LUSTs descriptions in so-called attribute databases. Users of LUSTs descriptions need to develop customized procedures to extract information from the LUST descriptions and the attribute databases, and to convert this information into coefficients for further analysis (Jansen and

Schipper, 1994). This way, calculations, for example about sustainability, can be made. Unique identifiers and a clear definition of the data are required.

Automation of data flows to the LP model is via the customized software MODUS (MOdules for Datamanagement in USTED; Stoorvogel et al., 1995), requiring a specific structure of the LUST description. The FAO FARMAP coding system (FAO, 1986) is used to generate unique identifiers for the various entries in the different databases.

1.3 Objective of the study

The objective of the AZP is to extend the methodology to a national and subcontinental scale of observation. First, a comparative study of two ecologically and economically contrasting areas within Costa Rica, the Atlantic Zone and the Guanacaste area will be made. Land use planning on a national scale requires consideration of processes outside the scope of the regional planner. Finally, an attempt will be made to link the regional models with global models of world vegetation and land use on the basis of similar climatic and biophysical constraints used in the smaller scale farm and (sub-)regional simulations, to predict the impact of global changes of land use. (Alfaro et al.,1994, Chapter 16).

The effort of AZP in the Guanacaste area will focus on a low data-input validation of the USTED methodology. In order to be of practical use, the methodology should also function in cases where only limited data can be available in a short time.

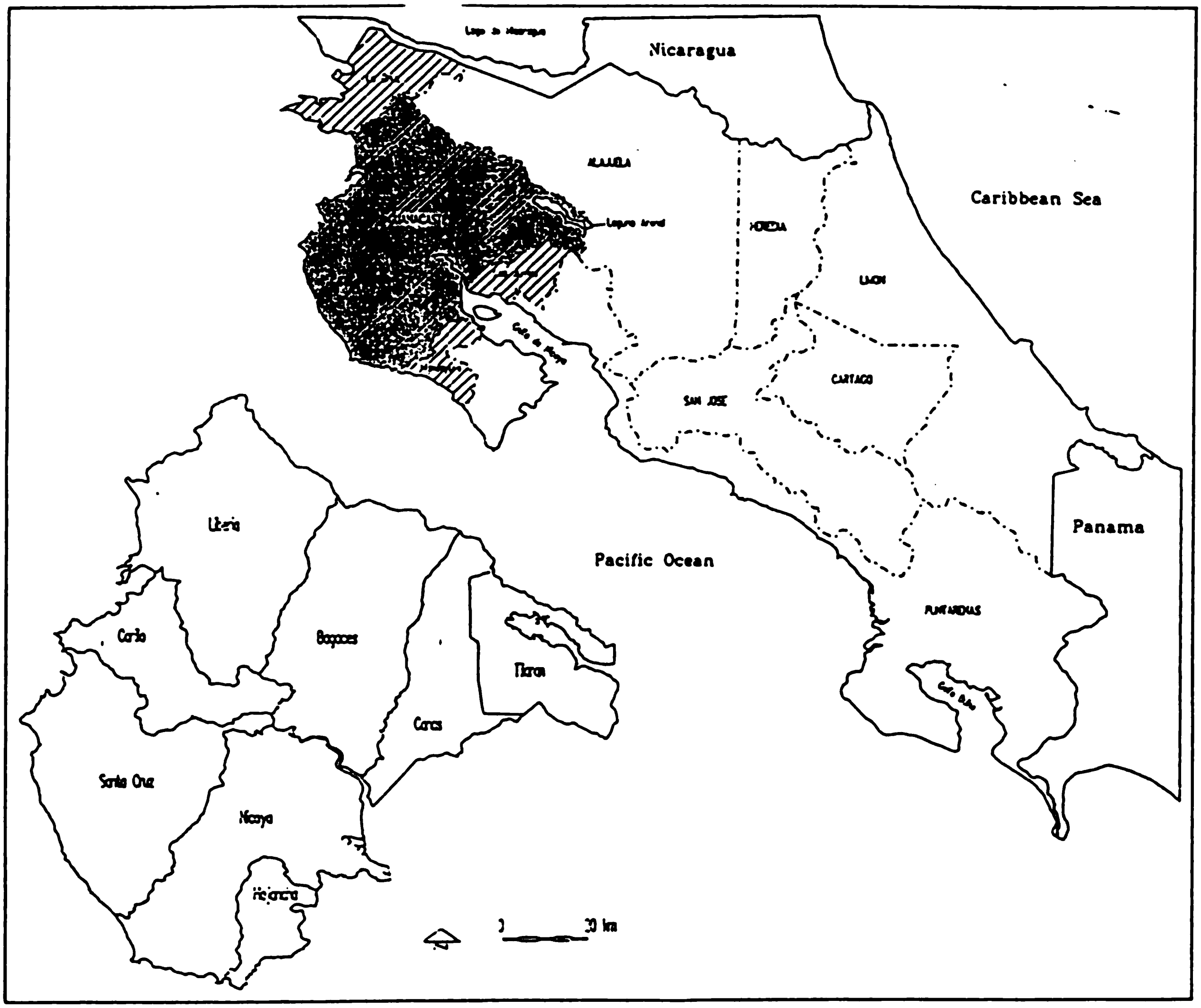
The objective of my study is to describe production-activities of mango *(Mangifera indica)* in Guanacaste and to quantify the corresponding inputs and outputs. The aim is to describe at least two LUSTs, based on a cluster analysis of the data. The required data were gathered by doing a questionnaire among mango cultivators in the study area.

The Guanacaste area is described in Chapter 2. Chapter 3 gives a description about mango, generally in Costa Rica and more particularly in Guanacaste. The methodology is explained in Chapters 4 and 5, the result of the cluster analysis is given. Finally, Chapter 6 contains the conclusions of the study and a discussion of the methodology.

CHAPTER 2: THE GUANACASTE AREA

The study area is situated in the province of Guanacaste (Figure 1). This province is bordered by Nicaragua in the north, the Cordillera de Guanacaste in the east, the Pacific Ocean in the west and the Golf of Nicoya and part of the Peninsula of Nicoya in the south. The province includes 12 cantons, but for the study area, three cantons are excluded: Abangares, Nandayure and La Cruz. The remaining 9 cantons are found in Figure 1. The area covers 7649 km^2 and had 160000 inhabitants in 1984. The most important income sources are agriculture and tourism (DGEC, 1987).

Figure 1. Maps of Costa Rica and the Guanacaste Study area.



The climate is subhumid/semi-arid with a mean annual precipitation ranging from 1200 to 2900 millimeters per year. There is a dry season of five to six months, from November to May/April and a second rainfall minimum in July/August. The mean year temperature is 27°C (Herrera, 1985).

Guanacaste has seven different life zones as described by Holdridge (1971) ranging from Tropical Dry Forest to Lower Montane Forest. The Tropical Dry

Forest has been extensively cleared and recurrently burnt for shifting cultivation and pastures. This has resulted in large range lands in the greater part of Guanacaste (Hartshorn et al., 1982).

Some soil types in Guanacaste are Andisols, Inceptisols, Mollisols, Alfisols, Vertisols and Entisols. The first three are the most common. Andisols, Mollisols and Alfisols are suitable for mango. Inseptisols and vertisols are not suitable. Alluvial soils are also found in the province and those soils are marginal for mango. It was estimated by Efdé (personal communications, 1997) that 60 per cent of the total area is suitable for the cultivation of mango.

As is found in Table 1, the most important crops in Guanacaste are rice (*Oryza sativa*), sugar cane (*Saccharum* cvs.) and (sweet) melon (*C. Melo, Citrullus lanatus*) (Hartshorn et al., 1982). Mango and coffee are cultivated on a relatively small scale. The dominant land use is extensive grazing (Eding and Suchy, 1994).

Table 1. Area and productivity of different crops in Guanacaste in 1984.

crop	area (ha)	productivity (t/ha)
rice	41,169.9	2.96
sugar cane	18,828.6	64.25
maize	8,425.1	0.90
beans	5,845.7	0.37
coffee	1,791.0	4.30
platano	410.4	2.52
orange	329.7	31.59
banana	225.5	2.39
yucca	216.0	6.09
avocado	206.9	14.79
cocos	55.8	4856.63 pieces/ha
pine apple	87.6	114.16 pieces/ha
mango	1428.0	8-10 (fresh fruit)

Source: DGEC, 1987

CHAPTER 3: DESCRIPTION OF MANGO

3.1 General aspects of mango

The botanical name for the mango plant is *Mangifera indica*. It belongs to the Anacardiaceae family. Cashew nut is another example of a crop that belongs to this family. It is most likely that the origin of mango lies in the Burma-Malaysian region. However, the fruit has been cultivated in India for more than four thousand years. From there it has been spread to other regions. Persian sailors took it to East Africa and South America. Since then, the mango has been introduced into every tropical and subtropical country in the world. It is cultivated up to 800 meters above sea level. The crop requires an average annual precipitation between 1000 and 1500 mm. The optimum daily temperature ranges between 20 and 26°C and night temperature should be between 12 and 20°C. Mango cannot tolerate frost (Samson, 1986).

Mango forms an erect, well-branched evergreen tree with a dense crown. The leaves are spirally arranged and come out in reddish flushes that initially hang straight down. Later they take on a more horizontal position and turn green. They stay on the tree for one to three years. There are two to five flushes a year, depending on the climate. The inflorescence is a widely branched panicle, 10-60 cm long, with a thousand or more male and hermaphrodite flowers. The proportion of bisexual flowers ranges from 1-100 per cent, depending on cultivar, climate and weather. The flowers are small, 5-8 mm, usually with five sepals, petals and stamens (only one of which is fertile) and a pistil with an oblique style. The fruit is a fleshy drupe with edible pulp (mesocarp) and a woody stone (endocarp) around the seed. Fruits weigh from 100 grams to 2 kilograms (fresh weight). There are mono-embryonic and polyembryonic cultivars. It is possible to propagate mango vegetatively by seed. All varieties of the mango can be classified under two categories: the seedling races, both wild and cultivated ones, and the horticultural varieties, which are propagated asexually (Samson, 1986).

Mango makes no high demands on the soil. It can be sandy or loamy, lateritic or alluvial, as long as it is deep and free-draining. Very poor, shallow, rocky and alkaline soils should be avoided. The tree needs good drainage since it has a medium tolerance to waterlogging. The minimum required ground water depth is 60 cm and the minimum rooting depth is 75 cm or more.The pH should be between 5.5 and 7.5. A light slope furthers drainage but steep slopes are unsuitable (Samson, 1986).

Mango requires high nitrogen (N) fertilization in the first years to obtain good vegetative growth, but after they begin to bear fruits, the fertilizer gift should be higher in phosphate (P) and potassium (K) Fertilizer formulas vary with the soil. In sandy acid soils, excess N contributes to 'soft nose' breakdown of the fruits (Morton, 1987). This can be counteracted by adding calcium (Ca) which is also reported in Childers (1966). Ca can be maintained by either applying the N as $Ca(NO_3)_2$ or as limestone or gypsum. The following figures are an estimate of the nutrients extracted by the crop (in kg/t fresh fruit): N 6.5, P 0.75, K 6.2, Ca 5.5 and Mg 2.9. The fruit contains much potassium and this should be balanced by adequate Ca en Mg levels to avoid physiological disorders in the fruit (Verheij and Coronel, 1991).

Some diseases that reduce the yields of mango are Anthracnose, caused by the fungus *Glomerella cingulata,* powdery mildew (*Oidium mangiferae),* and *Elsinoe mangiferae.* A bacterial disease caused by *Erwinia* sp. affects the mango production in Costa Rica and may produce losses above fifty per cent of the harvested fruits (Coto and Wang, 1995). Major pests are fruitfly (*Anastrepha obligua* in Costa Rica, the larvae of which render the fruit useless for human consumption), aphids, thrips (*Selenothrips* sp.) and scales. Also nematodes can damage the crop.

Mango belongs to the freely branching fruit trees. For this group of fruit trees, not a lot is known about yields, growth and development. The yield levels of this group are often much below those of the single-stemmed plants such as pine apple, papaya and banana, and the yields vary so much from tree to tree and year to year that it is difficult to set normative figures (Verheij and Coronel, 1991). Yields for mango are especially erratic as there is also biennial bearing, leading to bumper production in one year and a low production in the other. The industry is plagued by this inconsistent production with annual yields fluctuating by up to 150 per cent) (Schaffer and Andersen, 1994).

There are many ways to induce flowering, such as cinturing the trunk or branches, root pruning, exposing the roots a few weeks by removing the topsoil, applying salt in a furrow around the tree and smoking the orchard for several weeks with fires. This way, growers hope to get a better yield as well as advance harvesting. There is evidence that ethylene is the active ingredient inducing flowering. However, spraying potassium nitrate (KNO_3) has superseded smudging as it is a simple and reliable method. The way in which this product work remains obscure (Verheij and Coronel, 1991).

Planting material is very important for the productivity of mango. Small-scale growers commonly use seeds from mangoes they eat to obtain seedlings. However, vegetative propagation is the crucial step towards the improvement of the productivity. This is because the juvenile phase is eliminated or greatly reduced and the most fruitful trees can be selected for propagation. The reduction through early fruiting also has the advantage that more trees can be planted per hectare. Besides, managing the trees becomes easier. Rootstocks can be used with resistance to pests and diseases.

3.2 Mango in Costa Rica

Mango was introduced in Costa Rica in 1796 by the Spaniards. The tree was used in gardens and public places as a provider of shade and fruit (Gonzales, 1993). The cultivation of mango started its development in Costa Rica, since the fifties and sixties, as a product without many opportunities for expansion. There were only smallholders cultivating mango without commercial goals who received little agronomic assistance and for whom the cultivation of Mango was considered a secondary source of income. The production was only for national use and the fruits were obtained from trees sowed in homegardens and living fences of farms. These factors contributed to low yields, bad quality and a disorganization of producers (Saénz and Murillo, 1989).

The good conditions of the national and international markets later on made farmers consider the cultivation of mango as a new alternative of production and income. At the end of the seventies this impulse led to plantations with new varieties and a better management of plantations already existing. With the commercialization of the national market the requirements changed, but not substantially. The consumers demanded better taste, colour and appearance of the fruit. The commercialization of the international market had more effects. This process took place in the year 1981 when mango was exported for the first time. This was to Europe to explore the potential market for mango (Gonzales, 1993). With the international commercialization, the requirements for mango changed more drastically. Because of the long and expensive transportation and high demands of consumers, nowadays only fruits of the right size, colour, texture, internal sanity and appearance are being bought. The European consumers make higher demands than the national consumers. Actually, Costa Rica exports for a great deal to Europe, especially to Germany, where mango of Costa Rica has gained great acceptation.

Today, the area in Costa Rica planted with mango covers more than 6000 hectares, divided over: Alajuela (36.5 per cent), Puntarenas (25.8 per cent), Guanacaste (23.8 per cent) and San José (13.9 per cent) (Anonymous, 1994). In 1988 the average production per year was estimated between 8000 and 10000 kilograms of fresh fruit per hectare. This is considered very low compared to countries such as India, Israel and Mexico where, under less favourable climatic conditions, but assisted by better technologies, productions up to 30000 or 40000 kilograms per hectare are obtained (Sáenz and Murillo, 1989).

The regions Guanacaste and Puntarenas have a dry period which causes poor agricultural activity and few opportunities for employment. Taking into consideration that mango needs these climatic conditions, its development in these regions is justified in an ordered way. There have to be financial services, availability of resources, research and transfer of technologies, commercialization, organization of the producers, etceteras. In the period of 1988 till 1993, there was great interest of the private enterprises and MAG to encourage the cultivation of mango. The latter developed a National, Sectorial Program for mango. The primary goal is "to consolidate and to regulate the commercial development of mango for export and internal consumption to benefit the producer and to improve the economic situation of the country" (Sáenz and Murillo, 1989).

Table 2. Amounts of mango exported to Europe in 1995. (Programa Nacional de Mango, MAG, 1996)

COONAPROSAL	228688	kg (and 380000 to the USA)
Mango Tiko and Manga Rica SA	720706	kg
Finca La Flor	212966	kg
Tikosol SA	474172	kg
TOTAL	2016532	kg

Although Costa Rica already has created a market for mango in Europe, it wants to explore orther markets to avoid too much dependency on the European market and to prevent that the same thing will happen as with the export of bananas. The unification of the countries of Europe and the protection of the ex-colonies is a threat to the Costarican export. With the opening of new markets this danger could be reduced. Besides, Costa Rica has the capacity to expand the supply of mango and, under favourable conditions, to obtain fruits of a high quality. Because of this, Costa Rica has searched for a market in the United States. It is only recently that the high fytosanitary criteria of this market have been overcome. The amount of mango exported to Europe and the USA is found in Table 2. Only the company COONAPROSAL has the hydrotermic treatment needed to export to the USA.

3.3 Varieties of mango used in Guanacaste

Many commercially important varieties are grown in Guanacaste of which the most relevant are given below.

Tommy Atkins: This is the latest variety. The fruit has an ovoid form and has a medium to big size. The colour is green, orange to intense red. Because the peel is thick, it is not easily damaged and very suitable for export. The pulp contains small fibers, has a firm texture and an agreeable taste. The weight is between 450 and 750 grams. The tree has a close, round canopy with good growth. New shoots have a very light green colour. The production level is medium. In Guanacaste this is the most important variety for export. This is because of the red colour, which is preferred in Europe. Tommy Atkins has some problems with flowering and, if rains start early, also with *Anastrepha obligua*..

Haden Rojo: The fruit has an oval form. The peel can be reddish yellow with orange patches or orange with red patches. The white lenticulas give the fruit an attractive appearance. The pulp contains little fiber and is juicy. The seed is small. A fruit weighs between 250 and 650 grams. Growth of the tree is vigorous and the canopy is rounded and extended. This is a very old variety which has gained high esteem among the Costaricans because of the good qualities. Naturally, it is an early variety for harvesting, between January and June. This makes it a good variety for export, because of the better prices earlier in the season. Also in the international market it is a very accepted variety.

Haden Amarillo: Most producers use this name, although there are some doubts as to the correctness of the name. Some producers call it Mulgoba. The tree as well as the fruit and its taste are very similar to Haden Rojo. But, because it matures yellow, this is an unattractive variety for the European market.

Irwin: This is an old variety. The fruit has an intense red colour with white, enlarged lenticulas. It has an intermediate yield and the fruits mature a little after Haden Rojo. They have an oval, narrow form and very good taste. The weight varies between 300 and 500 grams. The pulp is without fibers and the seed is small. The tree has limited growth and is expanded. New shoots have a reddish-purplish colour. A problem for this variety is that it does not resist the hydrotermic treatment required for exportation to the USA.

Keitt: This variety is next to Kent and Tommy Atkins very popular. It has a big fruit with an ovoid but broad form and a greenish-yellow colour with a touch of pink. It has the disadvantage that it produces late in the season. The weight is 400-800 grams, but sometimes it reaches a kilo per fruit. The big ones are not suitable for export. The seed is small. It is a typical tree with numerous and extended branches which gives the impression that the tree is very open. However, the tree is not big.

Kent: Kent produces big fruits with a form as in Keitt and yellow-green and red sides. The pulp is juicy with good taste, a moderate quantity of fibers and a small seed. It weighs between 350 and 800 grams. Production is late. The trees have a moderate growth and are straight with a small canopy. Young shoots have a violet colour.

Palmer: The fruit has an enlarged form and the colour is orange-yellow with some patches of red and many lenticulas. It weighs 350 up to 700 grams. The pulp has a medium sized seed, contains little fiber and has a very good taste. The tree does not grow fast and is extended.

Smith: The form of the fruit is enlarged and big with a weight of 450 up to 900 grams. The colour is orange-yellow with patches of dark-brown scarlet. It has a late production. The tree grows fast and the canopy is vertical.

Many other varieties are grown, but mostly with little economic importance for the fruits. Jamaica, Papa, Criollo, Mecha and Caribe are varieties that are generally used as rootstocks in which other varieties are grafted. (Gonzales, 1993).

CHAPTER 4: METHODOLOGY

4.1 The questionnaire

First, a literature study about mango in general was done. With the help of a questionnaire of a previous study about pineapple in the Atlantic Zone and the available literature the draft questionnaire was made. Because of the lack of literature about the cultivation of mango in Guanacaste the need was felt to test this questionnaire in the field first. Nandayure, which is just outside the research area, was chosen. There, three farmers with mango plantations were interviewed. A mango-expert of the MAG told a lot about the management of mango in Guanacaste and gave a very useful tip about a "día de campo" (field day) in Liberia that week. This also helped in getting a better picture of the cultivation of mango and problems in the area. One of the participants worked in San José at the UNED (Universidad Estatal a Distancia) and later provided a list of mango farmers in Guanacaste and their location.

With all this extra information the questionnaire could be improved significantly as it was more adapted to the situation in Guanacaste now. The questionnaire consists of questions about management activities, period, labour, inputs (type and quantity), equipment and other measures (see Annex 1). These data are necessary to describe a LUST.

As mango is a perennial crop, this aspect had to be incorporated in the questionnaire. In practice, this was a major problem during the inquiries. Even when a farmer was closely involved with all his field practices, he could seldom remember details from the past such as planting and fertilizing in the first years. This was particularly true for plantations that had been established many years before. Besides, a lot of proprietors had appointed a caretaker. This was not really a problem as mostly the caretaker, who was closely involved in the management , was interviewed instead of the proprietor.

The locations of the plantations were identified with the aid of the list from the MAG. The farmers themselves also gave some other locations of plantations. Altogether, 24 persons were interviewed. The last person represented farm 24 and 25 because they belong to the same company. The locations and management, however, were different.

When a farm had different types of management for cultivating mango, every part, homogeneous in management, was called a field. Different types of management were considered different types of irrigation, different types of fertilization etceteras. Logically, young trees receive less fertilizer than old trees. This does not mean, however, that the type of management is therefore different. In most of the cases, different parts of the plantation with trees of different ages were considered as having the same type of management, even when they received a different amount of fertilizer in that year.

4.2 Data input

For every subject in the questionnaire one file was made in Quattro Pro. The information gathered had to be made useful for statistical analysis and other computations. All data had to be made numeric, so codes were applied. The codes are put in a codebook (see Annex 2). If data are unknown, the number -9 is used.

The files have one general structure with farmnumber, field and year as the constant frame. The number of fields and the age of the trees on them are the crireria that determine the number of rows assigned to that particular farm. For example, a farm with two fields, one of which has five-years-old trees and the other one trees of six years old, is assigned eleven rows.

4.3 Statistical analysis

To differentiate groups of farms with different type of management, criteria have to be chosen to decide in which group a certain farm belongs. More is explained about those criteria later on.

There are different ways to make groups (or clusters). It is possible to make clusters without statistical analysis. However, this is a very subjective appraoch and not a method preferred for this study. Instead, a statistical cluster analysis was chosen. There are different clustering methods:

- One of the simplest clustering methods is Single Linkage. At every step the distance between two clusters is calculated as the distance between their two closest points.
- The Complete Linkage method takes the two furthest points.
- The Average Linkage Between Groups method (UPGMA = unweighed pair-group method using arithmetic averages), defines the distance between two clusters as the average of the distances between all pairs of cases in which one member of the pair is from each of the clusters. Thus, it uses information about all pairs of distances.
- Average Linkage Within Groups method takes the distance between two clusters as the average of the distances between all possible pairs of cases in the resulting cluster.
- There is also the frequently used Ward's method. For each cluster the means of all variables are calculated. These distances are summed up for all of the cases. At each step, the two clusters that merge are those that result in the smallest increase in the overall sum of the squared within-cluster distances.

(SPSS chapter 3: cluster analysis).

After experimenting with the different methods, the Ward's method was chosen. In Annex 3, the results of the following clustering methods are given; the Average Linkage (Within Group), the Single Linkage, the Complete Linkage and the Ward Method. On personal grounds (own observations in the field), the Ward Method was chosen because of the 'more realistic' outcome of the clusters it gives. It was considered the better choice in spite of these subjective motives.

A lot of time was spent on experimenting with different variables or criteria. Eventually, the following variables were selected to be included in the cluster analysis:

- Total hectares of mango ('hatot')
- Type of irrigation ('tiri')
- Flower induction ('fi')
- Planting type ('plty') (means the production purpose, see Table 1)

Other variables such as labour, fertilization and disease control were not used. For some farms these variables were missing values, which would make the cluster analysis invalid.

Total hectares of mango ('hatot') indicates the acreage of the total mango plantation. The acreage was not split for the different fields, because this would give a false impression for management. Total acreage gives a better indication for management than the acreage per field.

The fourteen varieties that are cultivated in Guanacaste were classified into two groups for the cluster analysis, mango for export and mango for the local market in Costa Rica (see Table 3). As mango for export requires higher standards of management, a score is given five times higher (10) than the score for mango for the local market (2). The clustering done by the statistical program is based on the scores of the variables.

Table 3. Production purpose ('plty') and score for cluster analysis

- mango for export	10
- mango for local market	2

Type of irrigation and flower induction are management activities and thus give a direct impression of management of the total farm. Irrigation was classified into five groups as is displayed in Table 4. The higher the score, the higher the level of management.

Table 4. Type of irrigation ('tiri') and score for cluster analysis

- no irrigation	0
- gravity irrigation	2
- pipe irrigation	4
- with tractor and tank	6
- sprinkle irrigation	8

Flower induction, as explained in Chapter 3.1, was divided as no (0) or yes (1).

The variables have different scales. The score of 'hatot' is the same as the amount of hectares. This can give a very high score and therefore, 'hatot' was divided by ten. The scores of 'tiri' range from 0-8 and to give 'tiri' more importance in the analysis, it was multiplied by ten. It was given more importance as this variable is a very relevant variable to ascertain the intensity of management.

4.4 Describing the clusters

To be useful for the USTED-model, the different clusters have to be described. The data are quite complicated and quite a few data are missing. This makes calculations difficult and less realistic. Therefore, it was decided to choose a representative case in every cluster to describe the total cluster. Criteria for choosing a certain field were completeness of the data, representativeness within the cluster and reliability of the answers given by the respondent. Although this choice is subjective, it was thought that it would give a more realistic view of a farm. The different phases are also taken into account. Phase 1 is the unproductive phase, from planting till year five. Year five and higher are the productive phase.

While describing the clusters, the structure of the questionnaire is used as much as possible. For the description of the clusters data about labour, equipment, input, output, time of application and type of activity are used. See Table 5 for all the data that are used in the description of the clusters. As an extra, the future perspective of the farmer on the cultivation of mango in Guanacaste and problems he encounters are dealt with. These factors are not used in further analysis, but merely give a more personal perspective.

Table 5. Data used for describing the clusters

plantation: variety acreage planting density planting model type of labour	***fertilization:*** fertilizer amount of fertilizer months labour equipment
sowing: type of soil preparation month labour equipment	***weeding:*** herbicides quantity of product month labour equipment
plagues: type of plagues type of combat product quantity of product months labour equipment	***diseases:*** type of diseases type of combat product quantity of product months labour equipment
flower induction: type of flower induction year month(s) labour equipment	***harvest:*** year of harvest months of harvest yield buyer price labour equipment refuse fruit
irrigation: type of irrigation year quantity of water months labour equipment	***pruning:*** type of pruning year month labour equipment remains of pruning

CHAPTER 5: RESULTS

5.1 The clusters formed

The clusters are ranked from extensive to intensive management, or from low input to high input level. Which field belongs to which cluster can be found in Table 6. Number 5.1 in the table means farm five field one. If the name of a farm is not known, it is assigned the number -9.

The group of the most extensive management consists of five fields and was given in the cluster analysis the number one. The group with number two is less extensive than one. Sometimes the fields are a bit neglected, but sometimes the management is quite intensive without for instance intensive irrigation. Often capital is lacking. Fields that are given number three have intensive management and belong to the largest cluster. Fields with number four have the most intensive management. There are only three cases in this cluster and they belong to the same company.

Table 6. The four clusters with their fields and the names of the farms

CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4
1.1 -9	2.1 La Flor	2.2 La Flor	25.1 Manga Rica
5.1 Carolina	11.1 Carrizal	3.1 Las Trancas	25.2 Manga Rica
18.1 Las Tecas	14.1Fruta de Oro	4.1 Catsa	25.3 Manga Rica
20.1 -9	17.1 El Molino	6.1 El Gavila	
22.1 Fondagro	19.1 Colegio	7.1 La Troja	
	23.1 La Victoria	8.1 INA	
		9.1 Agropecuari	
		9.2 Agropecuari	
		10.1 Espavelar	
		12.1 Agropact	
		13.1 El Rincon	
		13.2 El Rincon	
		15.1 UCR	
		16.1 Montegrande	
		21.1 Las Botas	
		24.1 Mango Tiko	

Table 7. The values of the variables used in the cluster analysis per cluster.

CLUSTER	No. OF FARMS	PLTY	FI	TIRI	HATOT RANGE	HATOT AVERAGE
1	5	2 or 10	0 or 1	0	0.3-35.0	10.4
2	6	10	1	0 or 4	1.25-154.0	28.5
3	16	10	1	6, 8 or 10	1.4-154.0	41.3
4	3	10	1	8	473.0	473.0

In Table 7, the values of the variables used for the cluster analysis are displayed. One must keep in mind that during the statistical calculations for the cluster analysis, the values of hatot were divided by ten and those of tiri were multiplied by ten as was earlier explained in Chapter 4.3. The scores in the table were also explained in the same part and the Tables 3 and 4.

In general, it becomes clear that the acreage increases per cluster. Cluster one has an average of 10.4 hectares, cluster two of 28.5 hectares, cluster three of 41.3 hectares and cluster four of 473 hectares. In cluster one, also are the only farms that have varieties that are only suitable for the local market and there is hardly any flower induction or irrigation. In the other clusters, there is always flower induction and from cluster two to four, the type of irrigation becomes more capital intensive.

In Annex 3, the results of the cluster analysis can be found with a comparison of the Average Linkage (within group) Method, the Single Linkage, the Complete Linkage and the Ward Method and an Agglomeration Schedule of the last-mentioned method.

5.2 Description of the clusters

First, the clusters will be described. The type of activities and labour hours spent will also be summarized in Table 8, at the end of this chapter. Sometimes it was hard to make quantitative descriptions or it was unreliable. In that case these figures were not put in the Table. Year one in the descriptions is the year in which the trees were planted.

There are several planting models of which are:

- Tres Bolillo: Next to the first row, trees are planted at half the distance of two following trees in the first row. All trees have equal space.
- Marco Real (or perfect square): The distance between rows is equal to the distance between trees. This system makes agronomic practices in different directions easier.
- Rectangular. The distance between rows is not equal to the distance between trees and the pattern is rectangular.

cluster 1:

Farm 18 is chosen to describe a farm with a very low input level.

It has 15 hectares of a combination of ten varieties of mango. Most of the trees were Tommy Atkins next to Haden Rojo, Irwin, Keitt, Kent, Palmer, Filipino, Smith, Edward and Popo. The trees were planted in July 1980.

The plant density is 138 trees per hectare. The planting model is perfect square (also called Marco Real). There is only one temporary worker and it is unknown in which months and how much time he works.

Before planting the trees, the field was cleaned and mowed. Then the field was harrowed with a disc plough. It was not remembered how the plantholes had been made and filled nor could one indicate the labour hours spent on the preparations.

During sowing, 500 grams per tree of N-P-K 10-30-10 were applied manually. After that, little is known about fertilization. In the beginning it was done more frequently than later on. Especially Nitrogen is applied, but there has not been fertilization every year. It is known, however, that during the seventh year N-P-K 10-30-10 and NH_4NO_3 were applied in July and September. This was also done manually and it took 4 hours per hectare.

The farmer does not use flower induction and has never done so.

Neither has he ever irrigated.

Normally the trees are not pruned. However, there has been formation pruning about which no more details are known.

Weeding is done in November with a mower and machete.
There is no control of plagues nor of diseases.
From year six on harvest has taken place in March, April and May. There are no figures about yield and labour. The crop is mainly for own family consumption. Fruits that are not used are left in the plantation to rot.

There was no perspective of changing management. It would be too expensive to make improvements because yields and the resulting income are low.

cluster 2:

Farm 23 is grouped in cluster 2. There are four hectares of Tommy Atkins and one hectare of Haden Rojo which are both suitable for export. The trees were all planted in July 1991.

The plant density is 120 trees per hectare with Tres Bolillo planting model.

There is one person looking after the plantation and sometimes also a temporary worker is hired. It is not known when and how long this person works on the plantation.

The field was cleaned with a chemical in a manual knapsack sprayer (two hours of labour per hectare) before making the plantholes with a spade and sowing. The last two preparations together took 60 hours.

During planting 150 grams per tree of N-P-K 10-30-10 were applied, in August and October 120 grams of NH_4NO_3 and in September 120 grams of Urea. In the following year 250 grams of N-P-K-Mg-Ca 18-5-15-6-2 were given in August, September and October. With a manual knapsack sprayer multiminerals were sprayed in the same months. This took 4 hours per hectare and manual application 8 hours per hectare. The same was done in year three, four and five, but with different amounts. The amounts are only known for year four. At that time, 500 grams of N-P-K-Mg-Ca 18-5-15-6-2 per tree per application were given.

In year five KNO_3 was sprayed with a manual knapsack sprayer to induce flowering. In December two times the same product is sprayed with eight days in between. This, like fertilization, took four hours per hectare per application.

In the years two, three and four there was irrigation in the months January, February, March and April. The water was taken from the river and supplied using two portable pumps, a tractor with a tank (800 liters) with two exits. There were four applications per month which took two hours of labour per hectare per application. The maintenance of the furrows cost 20 hours per hectare in January. The trees were given 10 liters per tree per application.

The first three years the trees were pruned for formation. This was done in June with pruning shears. It took fifteen hours per hectare. To protect the wounds, copper paste was used. Pruning material is left under the trees.

In year five, weeding was done in May with a machete, in July with the chemical Glifosate using a manual knapsack sprayer (two hours per hectare), in August once with the mower, in September with Paraquat (manual knapsack sprayer), in November again with Glifosate and in December with the mower.

The plague *Anastrepha obliqua* was controlled in year five, in the months of February and March with Malathion. This was sprayed twice a month with a manual knapsack sprayer (4 hours per application per hectare). *Selenothrips rubrocintus* is controlled with Metasystox, Diazinon and/or Lannate in January and February with the same equipment, but with only one application per month. Ants were controlled with Tamaron or Diazinon, also with a manual knapsack sprayer. This is controlled whenever it occurs.

The disease Antracnosis (*Collectotrichum gloeosporioides Penz*) is controlled with Benlate once or twice in January and March. In December *Erwinia sp.* is controlled by pruning (using copper paste) as well as by spraying Kilol (a natural fungicide made out of grapefruit peels), copper based fungicides and $CaSO_4$.

The first harvest took place in year five in the months of April and May. There was one cut per month. Tiko Sol bought the harvest which was 300 kilograms per hectare. About 75 per cent was for export and 25 per cent for the local market.

The field has no windbreak and there has been some damage due to storm. Round the stem some organic material is applied. In the winter the owner also grows some beans and maize and after that he sometimes lets cattle graze the pasture in the plantation (40 cows on five hectares). The owner, who is also an expert in mango and works for the MAG, is positive about the future possibilities for mango in Guanacaste. He would like to improve his management, but faces some problems with regard to credit. He does not have good equipment and cannot easily get credit to improve this.

cluster 3:

Farm 9 field 2 will describe cluster 3. On this field (30 hectares) Tommy Atkins is grown for export. The trees were planted in May 1989 in a rectangular pattern. There are 100 trees per hectare. There are approximately three permanent workers on this field who work here full time and there are two temporary workers of whom it is not known in which months they are hired and for how long. One mango expert is hired for this field throughout the year for 21 hours per month.

The field preparation before sowing consisted of harrowing with a disc plough, making plantholes with a spade and for planting, a tractor with trailer was used and again the spade. Harrowing took one hour per hectare and the total number of labour hours was 24 hours per hectare.

During planting 250 grams of N-P-K 10-30-10 was applied with a spade which took 8 hours per hectare. In the second year 200 grams of N-P-K-Mg-Ca 18-5-15-6-2 was applied in June and August, also with a spade. Besides, Kresko (multiminerals) was sprayed with a tractor and tank plus sprayer. This took half an hour per hectare and it was repeated every year with increasing amounts till in year seven 1000 grams per tree per application was given. For the Kresko no amounts are given.

From year five on, flower induction is used. In November, KNO_3 is sprayed three times with a tractor and sprayer, taking half an hour per hectare.

In years two and three, irrigation took place in the months of January, February, March and April. Groundwater was pumped up and applied using a tractor and tank with two exits. Application took place every eight to ten days. In following years there was only irrigation in very dry years. It is known that in year five the trees were irrigated in January and February, every three to four days. In January furrows had to be made/restored which took 8 hours of labour per hectare. Application took three and a half hours per hectare.

During the first three years, trees are pruned for formation. Maintenance pruning is done in the month of June with pruning knives and pruning shears. This took 24 hours per hectare in the last year (year seven).

In June of year seven Glifosate was sprayed once with a manual knapsack sprayer, taking six hours per hectare. Once it was mowed (unknown in which month) taking half an hour per hectare.

Anastrepha obliqua was controlled in year seven in April with Ambush (permitrina) and/or Metacide. This was done once or twice a month using a tractor with tank and sprayer (half an hour per hectare). In May, *Selenothrips rubrocintus* is controlled with two sprays of an unknown product.

The disease *Erwinia sp.* was controlled with three sprays of Fiton 27 in May and June. A tractor with tank and sprayer was used. In May, *Pestalotia sp.* was controlled with Benlate and Gitan (once or twice).

The first harvest was in year five. Harvesting takes place in April using cutting knives and poles with a knife and bag to catch the fruit. In the last year the yield was 30 kilograms per tree. About 23 per cent of the harvest was for the local market and 5 per cent was lost and fed to the cattle. The rest of the crop was bought by Delmonte and Tiko Sol. There have been considerable fluctuations in yield over the years.

There is a natural wind shield to protect the trees. In the plantation food for cattle is grown and harvested with machines. The owner is positive about the cultivation of mango, but the success depends on the market which is not well developed yet. He holds the view that maintaining a mango plantation is relatively inexpensive.

cluster 4:

Field 1 of farm 25 is chosen, because it is the oldest of the fields of this farm. It has 71 hectares of Tommy Atkins (planted in May), 99.3 hectares of Haden Rojo (planted in July) and 17.7 hectares of Keitt (planted in June). All were planted in the year 1990 in a perfect square model with a plant density of 143 trees per hectare. There are about nine permanent workers and 160 temporary workers (it is not known in which months they are hired) and four experts in mango (in the field of controlling pests and diseases and nutrition of the trees) for this field.

The field was mowed (one hour per hectare) before making plantholes with a 'tornillo sin fin' (a machine boring holes in the soil). After planting, gaps were closed using a spade.

With planting 200 grams of N-P-K 10-30-10 per tree were applied manually and in the same year there was fertilization in September and October with a tractor with tank and sprayer. In the second year N-P-K-Mg-Ca 18-5-15-6-2 was applied in January and February using the irrigation system, which is sprinkle irrigation and a tank where the fertilizer is added to the water. Of the years three and four, details of fertilization were not available. For years five and six 1500 grams of NH_4NO_3, 2100 grams of K_2O, 700 grams of P_2O_5, 400 grams of MgO and 300 grams of K_2SO_4 were given via the irrigation system. The amounts mentioned are per tree.

To induce flower setting, KNO_3 is used in December and NH_4NO_3 in January. It is applied using a tractor with tank and sprayer.

This company uses a sprinkle installation to irrigate the plantation. Groundwater is pumped up using electric pumps. Irrigation is used every day in the months of February up to May. There are drainage canals which took 1000 hours to construct spread over the months of June, July and October.

Five months after sowing, formation pruning was used and this was repeated in the first three years in May and June. Pruning shears were used. It took two hours per hectare. Every year, the canopy is kept open using chain saws. This takes place in May and June and took 50 hours per hectare with trees of Mango

Tiko when they were twelve years old. Sanity pruning takes place to control *Erwinia sp*. This is done in May, June and October, depending also on the rate of infection. This takes two hours per hectare. The pruning material is taken outside the field and burned.

From May to December of year six the field was mowed monthly (taking two hours of labour per hectare every time). In May, August and October, Glifosate and Paraquat were sprayed using a tractor with tank and sprayer.

Anastrepha obliqua is controlled with sterile males. In year six Malathion was sprayed once in May and once in June using tractor with tank and sprayer. *Selenothrips rubrocintus* was controlled with Malathion and Orthene in January. Once or twice a month this is sprayed on the trees.

The disease Antracnosis is controlled in April and May with Dithane, Derosal and $CuSO_4$, depending on the rains about two times per month. This is done with a tractor with tank and sprayer. *Erwinia sp*. is sprayed with $CuSO_4$ in April and November. In May, June and November sanity pruning to control this disease takes two hours of labour per hectare. There was also a disease for which no fungicide was known, named *Botryodiplodie sp*. (Stem Rot). This was the number one enemy of the crop. They tried to control it by pruning.

In year four, the first crop was collected. Harvesting takes place in April and May with pruning shears and the knives on the poles with a bag. The trees are still young so there is an upward trend in the yield. The Mango Tiko company has its own plant to select the fruit. It also buys the produce of other farmers and sells to Delmonte, Chiquita and X-Fruit. Then the fruit is exported to Europe. Refuse fruits are buried to prevent pests and diseases from spreading.

The area is very windy, owing to which seven to eight per cent of the yield is lost. There are natural windshields of various tree species. An experiment was performed with a shield of densely planted mango trees. The advantage is that they have some yield and also protect the trees inside the plantation. The trees are planted in lines that follow the prevailing wind direction, so less damage occurs. A disadvantage is that pest and diseases can easily develop in the densely planted trees. It is harder to control this. The manager of the company was not very positive about the perspectives of mango in Guanacaste. Both yields and prices are low, but labour is expensive. This is especially true for the small producers. He found it hard to compete with the larger scale farms in Brazil.

Table 8. Activities and labour (if known in hours/hectare) per month per cluster (Cl1, 2 or 3) for year one (yr1) and Phase one (year 1-5) or two (year >5) (Ph 1 or 2).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cl1 yr1							Cl Mo Pl Hr Fe					
Cl1 Ph1												
Cl1 Ph2			Ha	Ha	Ha		Fe 4		Fe 4			
Cl2 yr1							Wc 2 Pl60 Fe	Fe	Fe	Fe		
Cl2 Ph1	IR 8 MF20	IR 8	IR 8	IR 8		Pf15		Fe 4 Fe 8	Fe 4 Fe 8	Fe 4 Fe 8		
Cl2 Ph2	Cp 4 Cd	Cp 8 Cp 4	Cp 8 Cd	Ha	Wm Ha		Wc 2	FE 4 FE 8 Mo	FE 4 FE 8 Wc 2	FE 4 FE 8	Wc 2	Fi 8 Mo Cd
Cl3 yr1					Hr 1 Pl23 Fe 8							
Cl3 Ph1	Ir Mf 8	Ir	IR	IR		Fe 8 Fe.5 Pf		Fe 8 Fe.5				
Cl3 Ph2	Ir Mf 8	Ir		Cp 1 Ha	Cp 1 Cd	FE 8 FE.5 PM24 WC 6 CD		FE 8 FE.5	Wm .5?		Fi 1.5	
Cl4 yr1					Mo 1 Pl Fe				Fe	Pf		
Cl4 Ph1	Fe	Fe Ir	Fe Ir	Fe Ir	Fe Ir Pf 2 Pm Ps	Fe Pf 2 Pm Ps	Fe	Fe	Fe	Fe Ps	Fe	Fe
Cl4 Ph2	Fe Fi Cp	Fe	Fe	Fe Cd Ha	Fe Pm Ps Mo 2 Wc Cp Cd Ha	Fe Pm Ps Mo 2 Cp	Fe Mo 2	Fe Mo 2 Wc	Fe Mo 2	Fe Ps Mo 2 Wc	Fe Mo 2 Cd Ps	Fe Fi Mo 2

Codes in the table:

Cd= controlling diseases
Cp= controlling pests
Fi= flower induction
Hr= harrowing
Mf= maintaining furrows
Pf= formation pruning
Pm= maintenance pruning
Wc= chemical weeding
Cl= cleaning
Fe= fertilizing
Ha= harvesting
Ir= irrigating
Mo= mowing
Pl= planting
Ps= sanity pruning
We= mechanical weeding

CHAPTER 6: CONCLUSIONS AND DISCUSSION

6.1 Conclusions

As expected, the farms in cluster one have a very low input level. There is hardly any fertilization. However, fruits are taken outside the field so there is a loss of nutrients in the field. On the other hand, there is hardly any use of chemicals in this cluster which makes the system more sustainable than the other three with regard to toxicity.

Farms in cluster two and three are largely comparable, but in general farms in cluster three are bigger and belong to a company that is also involved in other activities. Farmers in cluster two more often encounter credit problems. Also the average farm size is bigger. However, they all try to follow a certain management program for the plantation to obtain high yields. There has been a stimulation program of the MAG for better management of mango as some potential is seen in this crop. It is possible for farmers to get good information for proper management. Nevertheless, a lot of variation is seen in type of management. This makes it hard to make generalizations. The same can be said about the control of pests and diseases. A large variety of chemicals is being used by different farmers. It seemed that there was not much knowledge about pests and diseases, especially at the smaller farms.

Cluster four represents one company which is called Mango Tiko. It concerns two farms, Mango Tiko (see cluster three) and Manga Rica. The latter is younger and much bigger (96 hectares in Mango Tiko against 525 hectares in Manga Rica). The management is more advanced as there is a sprinkle installation which is also used to fertilize. A lot of fertilizer is applied as compared to farms in the other clusters. Another example of a diverging type of management is the use of sterile males to control *Anastrepha obliqua.* There are also mango experts working in the company, for example for the nutrition of the trees. Mango Tiko owns a facility to sort, wash and pack the fruit. It buys mango from other farms and sells to big companies as Chiquita.

Besides chemical control of plagues, also biological control is used on some farms. Unfortunately there are no examples in one of the four descriptions of the clusters. With a view to sustainability, it is an important aspect to keep in mind. Some farmers use traps to control *Anastrepha obliqua*. These traps can be very simple, just half a plastic bottle in the tree with an attracter and poison or just a sticky fluid. This plague is also controlled with sterile males. One farm used traps with lamps and Pheromones to catch the adults of a larvae that attacked the roots of the trees.

It is hard to make predictions for mango as a future important cash crop in Guanacaste. Lately there have been considerable investments in mango orchards. This is an indication of the positive view that the cultivators generally have with regard to mango. However, some farmers were quite pessimistic about the future of mango in Guanacaste. Some of them because they lack credit, good equipment and knowledge about some pests and diseases, and some because they fear the competition with large scaled farms in for example Brazil. With regard to the market, the biggest constraint is that export to the USA is still quite difficult owing to the high fytosanitary criteria and the relatively poor quality of the fruits that Costa Rica still supplies. Recently, a facility for hydrotermic treatment has been built by COONAPROSAL to overcome this problem and now mango is exported to the USA. It is to be expected that other companies will follow this example.

6.2 Discussion on the methodology

Data turned out to be very complicated and unreliable as farmers do not remember so much about management activities in the past. A lot of data are not available due to this. On top of that, most data are available only about the previous year. This makes it hard to average data. Also, labour figures were hardly registered by the farmers.

It is difficult to make generalizations for these LUSTs as there is so much variation within one LUST and some LUSTs that were described represent only a few cases. It is important to keep that in mind when using the LUSTs with land use planning.

To get more detailed information, it would help to do some extra research in the field. Yields can be weighed and the use of inputs can be measured. Especially measuring hours of labour for the different activities would be useful as it is expected that this is nearly the same for every plantation if one uses the same equipment. This information would be useful in describing LUSTs for other crops as well.

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ANNEXES

Annex 1. Questionnaire: 'Cultivation of mango in Guanacaste'.:

ENTREVISTA SOBRE EL CULTIVO DE MANGO

Información general:

Fecha entrevista :
Región :
Localización del terreno :
(Nombre del productor) :
Nombre de la finca y lugar:
Area total :
Area de mango :
Cuáles otros cultivos :
Edad de la finca :
Edad del huerto de mango :
Cuántas variedades :
Cuántos tipos de suelos :

Información sobre el cultivo de mango:

1 Suelos
En qué tipos de suelos cultiva Ud. Mango?
- fértil si... no...
- bien drenado si... no...

Textura: limoso/ limoso-arcilloso/ franco/ franco-arcilloso

2 Preparación del terreno
Su terreno es: plano ... quebrado ...
Cómo preparó Ud. su terreno antes de sembrar?
Hacer huecos ... Nivelar ... Limpiar ... Otro ...

Cuál equipo:
Mano de obra:

Hay diferente preparación en diferente suelos?

Alrededor del tronco hay diferente preparación?

3 La siembra
Cuándo Ud. ha sembrado este mango? .. ... 19.. Cuántos árboles?
Ud ha resembrado mango? sí... no... Cuántos árboles?
Cuándo?
Cuál equipo usó Ud.?
Mano de obra:

Qué usó Ud. para sembrar? árbol injertado si... no...
Cuál tratamiento recibió el árbol?
De qué variedad es el patrón? -Jamaica... Criollo...
-Papa ... Caribe ...
De dónde?

4 Variedades

Variedad	Ha	Años	Por qué?	De dónde?	Densidad
Tommy Atkins					
Haden amaril					
Haden rojo					
Irwin					
Keitt					
Kent					
Palmer					
Mora/Smith					

Por qué usó Ud. esta densidad?
Qué modelo? -Marco Real ... Rectangular ...
-Tres Bolillo ... Quinto al centro ...

5 Fertilización
Cuál fertilizante usa Ud. y cuánto? Cuántas aplicaciónes?
Año: 1 2 3 4 5 6 Enero
-
*
Febrero -
*
Marzo -
*
Abril -
*
Mayo -
*
Junio -
*
Julio -
*
Agosto -
*
Septiembre -
*
Octubre -
*
Noviembre -
*
Deciembre -
*

- = fertilizante * = cantidad

Equipo:
Mano de obra por aplicación:

Cómo sabe Ud. si hay deficiencias de nutrientes?
-tomar muestras de hojas
-tomar muestras de suelo
Hay diferente fertilización en diferentes suelos?

6 Inducción de la floración
Qué usa Ud. para inducir la floración?

-Flowerkem	...	-anillar tronco/ramas	...
-Flowerset	...	-KNO_3	...
-podar	...	-otro:	...

Año:	1	2	3	4	5	6
Cuántos litros? -						
Cuándo? (mes) -						

Equipo: -equipo estacionario
-equipo con motor mochila

Mano de obra:

7 El riego

Ud. usa riego? frecuencia cuanto

Año:	1	2	3	4	5	6
Enero -						
Febrero -						
Marzo -						
Abril -						
Mayo -						
Junio -						
Julio -						
Agosto -						
Septiembre -						
Octubre -						
Noviembre -						
Deciembre -						

Qué tipo?
Cuál equipo:
Mano de obra:
Mano de obra de instalación:
De dónde es el agua?
Tiene que pagar el agua?
Si tiene bomba, cuál fue la mano de obra de la instalación?
Cuántos años funccione la bomba?
Cuál es la mano de obra del mantenimiento por año?

Ud. tiene drenage? si... no... Cuál tipo?
Cuándo hizo este y cuál fue la mano de obra?

8 La poda

Tipo de poda	Cuándo	Equipo	Mano de obra	Cada año?	Adonde va desmocho
formación					
raleo					
mantenimien-to					
sanidad					
renovación					

9 Malezas

Cuáles malezas de suelo hay?

Cómo combate Ud. estas malezas?
Equipo: -chapeadora ... herbicida (glifosfato,oxifluorfen) ...
-rastra ... herbicida (paraquat,paraquat con diurón)..
-manual ... otro: ...

Cuándo (por cada aplicación):

Cada año ?
Cuánto por aplicación?
Mano de obra por aplicación:

Cuáles malezas de árbol hay?

Cómo combate Ud. estas malezas?
Equipo:

Cuándo?
Cada año?
Cuánto por aplicación?
Mano de obra por aplicación:

10 Plagas

Plagas	%	Combate	Equipo	Mano	Cuándo	Cuánto
Mosca de la fruta						
Escamas						
Afidos						
Trips						
Comejen						
Zompopa						
Combinación						

11 Enfermedades

Enfermedad	%	Combate	Equipo	Mano	Cuándo	Cuánto
Antracnosis						
Mildiu Polv-oso						
Erwinia						
Bacteriosis						
Sarna o Roña						
Combinación						

12 La cosecha

Cuándo cosechó Ud. el mango por primera vez?
Cuándo cosecha Ud. el mango? Cuántos dias dura este? Es temprano o tardío?
Equipo:
Mano de obra:

Cuántos kilogramos por hectárea/ por árbol produce el mango?
Año 1 2 3 4 5 6 7 ..

Cuánto es para -exportación:
-uso local:
-botar

Cuánto dan por un kilogramo? -exportación:
-uso local:

Quién compra las frutas?
Ud. tiene que transportar el mango? Costos:
Hay un comerciante que compra el mango?
Ud. tiene que pagar para el transporte? Cuánto?

Hay mucha alteranción?
Por qué?
Dónde bota Ud. su Mango? Fuera de su finca?

13 Otras medidas:

Medida	Cuándo	Equipo	Mano	Cada año?	Costos
Rompeviento					
Hueco para botar mango					
aplicar m.o. a la corona					

Hay/hubo una asociación con otros cultivos?
Qué?
Cuándo?
Por cuántos años?
Cuánto fue la producción por año?
Mano de obra en el tiempo:

14 Mano de obra
Cuántas personas trabajan para Ud.?

-familiares: edad
Cuánto tiempo en la semana/mes/año?

-alquilado : Ud. contrata peónes? si... no...
Ud. contrata expertos? si... no...
-permanente tiempo completo:
-permanente tiempo parcial :
-ocasional:

15 El futuro
Ud. va cambiar la manera de producción?
Cuándo?
Cómo?
Cómo es la perspectiva para su mango/mango en general en este area?

Cuáles otras observaciones/ problemas tiene Ud. en el cultivo de mango?

Annex 2. Codes for the Questionnaire.

SPREADSHEET 1: \QPRO\LINDA\ALG.WQ

* Farmnumber: 1...24
* Name of farm:
* Coordinate X:
* Coordinate Y:
* Total area: ha
* Area of mango: ha
* Field relief: 1- flat
  2- undulating

SPREAD-

SHEET 2: QPRO\LINDA\VARIETIES

* Variety:
  1- Tommy Atkins
  2- Haden Rojo
  3- Haden Amarillo
  4- Irwin
  5- Keitt
  6- Kent
  7- Palmer
  8- Mora
  9- Papa
  10- Criollo
  11- Caribe
  12- Smith
  13- Edward
  14- Popo
  15- Combination of many varieties

* How many hectares per variety:
* Month of planting: 1 2 3 4 5 6 7 8 9 10 11 12
* Year of planting:
* Density: trees per ha.
* Which planting model: 1- Marco Real (perfect square)
  2- Tres Bolillo
  3- Rectangular
  4- Fifth in the middle
  5- At random
  6- Irregular rows
* Resowing: y/n

SPREADSHEET 3: QPRO\LINDA\SOWING

* How did you prepare the field before sowing?
  1- Cleaning/ mowing
  2- Ripping
  3- Plowing
  4- Harrowing
  5- Making plantholes
  6- Sowing
  7- Grafting

* Equipment:
  1- mower
  3- machete
  4- ripper
  5- disc plough
  6- harrow
  7- tornillo sin fin
  8- spade
  11- knapsack sprayer, manual
  25- tractor with trailer
  29- grafting knife
  30- axe

* Labour: hours/ha.

SPREADSHEET 4: QPRO\LINDA\FERTILIZATION

* Months of fertilization:
* Year of fertilization:
* Fertilizer:
  1- 10-30-10
  2- 12-24-12
  3- 18-46-0
  4- 18-5-15-6-2
  5- 18-5-4-3-2
  6- 20-5-15-4-5-2
  7- 20-3-20
  8- Uria
  9- NH_4NO_3 (Nutran)
  10- $CuSO_4$
  11- KCl
  12- K_2O
  13- K_2SO_4
  14- $CaCO_3$
  15- P_2O_5
  16- MgO
  17- Nitrofoska
  18- Kresko
  19- Multiminerales
  20- CaMg
  21- Copper
  22- Bo
  23- Zinc
  24- K-Mag
  25- KNO_3
  26- 18-5-20-4-1-2

* Amount of fertilizer: gram per tree
* Equipment:
  9- tractor with tank and sprayer
  10- central tank and irrigation
  11- knapsack sprayer manual
  12- knapsack sprayer with motor
  8- spade
  26- manual

* Labour: hours/ha.
* Taking samples of leafs: y/n
* Taking soil samples: y/n

SPREADSHEET 5: QPRO\LINDA\FLOWER

* What is used for flower induction?
  0- nothing
  1- not yet reproductive
  2- KNO_3
  3- ringing
  4- NH_4NO_3

* Years of flower induction:

* Month of flower induction:

* How many applications per month:

* Quantity per hectare: l

* Equipment:
  9- tractor with sprayer
  11- knapsack sprayer, manual
  12- knapsack sprayer with motor
  16- tank with pump and pipe
  18- knife

* Labour: hours/ha*application

SPREADSHEET 6: QPRO\LINDA\IRRIGATION

* Type of irrigation: 0- no irrigation
  1- gravity
  4- pipe
  5- sprinkle irrigation
  6- with tractor and tank

* Watersource: 1- spring
  2- river
  3- groundwater

* In which months irrigation is used?
* Quantity of water applied: l/ha*application
* Frequency: applications/month 50 = every day of the month
* Equipment: 8- spade
  9- tractor with tank and sprayer
  14- sprinkle installation
  15- pump
  31- tractor with tank and two exits
  32- pump and pipe
  33- pipe

* Labour per application: hours/ha.
* Labour of maintenance: hours/ha.
* Labour of installation: hours/ha.
* In which month:

SPREADSHEET 7: QPRO\LINDA\PRUNING

* Type of pruning: 0- no pruning
  1- formation
  2- maintenance
  3- sanity
  4- flowering

* In which month pruning is done?
* Year of pruning: 50= every year

* Equipment 1 & 2: 17- pruning knife
  19- saw
  20- chainsaw
  3- machete
  21- pruning shears

* Labour: hours/ha
* Remains of pruning: 1- everything stays on the field
  2- large parts stay on the field
  3- everything leaves the field

SPREADSHEET 8: QPRO\LINDA\WEEDS

* Months of weeding:
* Equipment to combat weeds : 1- mower
  2- hand mower with motor
  3- machete
  5- plough
  6- harrow
  9- tractor with tank and sprayer
  11- knapsack sprayer, manual
  12- knapsack sprayer, motor
* Labour: hours/ha.
* Herbicides: 1- Glifosate (Round-up)
  2- Paraquat (Gramoxone)
  3- 2,4-D

* How many applications per month:
* Amount of herbicide per application: l/ha.

SPREADSHEET 9: QPRO\LINDA\PLAGUES

* Which plagues are combatted?
  - 0- No combat
  - 1- Anastrepha obliqua
  - 2- Selenothrips rubrocintus
  - 3- Ants
  - 4- Mites (Phyllophaga)
  - 5- Larvae in the roots
  - 6- Wasps
  - 7- Locust
  - 50- Combination

* Months of combat: 50= continuously
* Type of combat: 2- biological
  3- chemical
* Product of combat:
  - 1- Malathion
  - 2- Decis
  - 3- Benlate
  - 4- Dithane
  - 5- Orthene
  - 6- Folidol
  - 7- Ambush (permitrina)
  - 8- Tamaron
  - 9- Lorsban
  - 10- Metacide
  - 11- Metasystox
  - 12- Perfecthion
  - 13- Diazinon
  - 14- Lannate
  - 15- Cymbush
  - 29- Buminal
  - 30- Mosc

* Equipment:
  - 9- tractor with tank and sprayer
  - 11- knapsack sprayer, manual
  - 12- knapsack sprayer with motor
  - 22- bottles as tramps

  - 41- steriel males
  - 42- parasitoids
  - 43- tramps with attracter (Buminal)
  - 44- ,, ,, ,, ,, Mos/mox
  - 45- ,, ,, lamps

* Quantity of product per application: l/ha.
* How many applications per month:
* Labour: hours/ha * application

SPREADSHEET 10: QPRO\LINDA\DISEASES

* Which diseases are combatted?
  - 0- No combat
  - 1- Colletotrichum gloeosporioides Penz (Antracnosis)
  - 2- Erwinia sp.
  - 3- Oidium mangiferae (Mildiu Polvoso)
  - 4- Pestalotia sp.
  - 50- Combination

* Months of combat: 50= continuously
* Type of combat: 1- cultural
  3- chemical

* Product of combat:
  - 2- Decis
  - 3- Benlate
  - 4- Dithane
  - 14- Lannate
  - 15- Derosal
  - 16- Cobre
  - 18- Cobre bordeles
  - 21- Carbolina

22- Trimiltox
23- Kilol
24- Fiton 27
25- Zinc
26- Bo
27- Chlorotanoil
28- Gitan

* Equipment: 9- tractor with tank and sprayer
11- knapsack sprayer, manual
12- knapsack sprayer with motor
17- pruning knife
21- pruning shears
34- brush

* Quantity per application: l/ha.
* How many applications per month:
* Labour per application: hours/ha.

SPREADSHEET 11: QPRO\LINDA\HARVEST

* Year of first harvest: 0= not yet
* Year of latest harvest:
* Months of harvest 1 & 2:
* Cuts per month:
* Equipment 1 & 2: 18- cutting knife
23- pole with knife and sack
21- pruning shears

* Labour per cut: hours/ha
* How many kilos per ha. are for exportation?
* ,, ,, ,, ,, ,, ,, ,, Costarican market?
* ,, ,, ,, ,, ,, are lost?
* Who is buying the fruits for exportation?
1- Mango Tiko
2- Tiko Sol
3- Conaprosal
4- Pindeco
5- Merchant
6- Delmonte
7- La Flor
8- The producer himself
9- Merchant who also harvests
10- Merchant who comes and buys

* Price per kilo? ¢
* Who is buying the fruits for the Costarican market?
The same as for exportation.
* Price per kilo? ¢
* What is the destiny of the refuse fruits?
0- is left under the trees
1- is given to the animals
2- on the refuse dump
3- buried

SPREADSHEET 12: QPRO\LINDA\OTHER

* Damage because of wind: 0- no damage
1- little damage
2- main cause of loss of production

* Windbreak: 0- not
1- natural
2- planted, mango
3- planted, other species

* Is there an association with other land uses?
0- no
1- pasture with cattle

2- maize

* How many cows per ha.?
* Month:
* Year:

SPREADSHEET 13: QPRO\LINDA\LABOUR

* Numbers of family members working in the mango:
* Number of months of labour of family members:
* Labour per person per month: hours
* Number of permanent labourers:
* Labour: 1- full time
  2- part time
* Number of temporary labourers:
* In which months:
* Labour per person per month: hours
* Number of hired experts:
* Number of months of labour:
* Labour per person per month: hours

SPREADSHEET 14: QPRO\LINDA\FUTURE

* How will the management change in the future?
  0- not
  1- along with new technologies
  2- more inputs
  3- less inputs

* Perspective for the future: 0- no idea
  1- bad future
  2- will stay the same
  3- good future

* Other land uses 0- Non
  1- Cattle
  2- Sugar cane
  3- Maize
  4- Rice
  5- Beans
  6- Lemon
  7- Orange
  8- Forest (Melina, Pochote, Ronrón, Teca)
  9- Esparago
  10- Water melon
  11- Avocado
  12- Pejivalle
  13- Tamarindo
  14- Platano
  15- Combination

```
data list free file='irclu.geg'/
    farm veld year
    have plde plty fi tiri hatot.
*missing value hatot to fi (-9.00).
*missing value hatot to fi (-9.0) .
*missing value hatot to fi (-9) .

if (year le 4) fase=1.
if (year ge 5) fase=2.
title 'oorspronkelijke file'.
---------------------------------------------------------------------------
-Page   2   oorspronkelijke file
10/1/96

*descriptives /variables have plde plty fi tiri hatot.
*frequencies /variables have plde plty fi tiri hatot.
compute fave=farm*10+veld.
sort cases by farm veld.
The raw data or transformation pass is proceeding
    220 cases are written to the compressed active file.
The file to be sorted contains 220 cases of 112 bytes each.
At least 35,376 bytes of memory are available to the sort.
12,784 bytes is the minimum in which the sort will run.
35,372 bytes would suffice for an in-memory sort.
The data were already sorted.
---------------------------------------------------------------------------
-Page   3   oorspronkelijke file
10/1/96

This procedure was completed at 15:05:28
*list farm veld fave have plde plty fi tiri hatot.

aggregate outfile= *
    /presorted
    /break=farm veld
    /mfave mhave mplde mplty mfi mtiri mhatot
    =mean(fave have plde plty fi tiri hatot).
     30 cases are written to the compressed active file.

A new (AGGREGATED) active file has replaced the existing active file.
It contains   12 variables (including system variables).
---------------------------------------------------------------------------
-Page   4   oorspronkelijke file
10/1/96

This procedure was completed at 15:05:28

compute mfave=trunc(mfave).
set results = 'w:rob.prc'.

write farm veld mfave mhave mplde mplty mfi mtiri mhatot.
The raw data or transformation pass is proceeding
     30 cases are written to the compressed active file.
---------------------------------------------------------------------------
-Page   5   oorspronkelijke file
10/1/96


WRITE has generated Procedure Output File:  w:rob.prc

  2 records have been written for each case.

              Record
  Variable    Number  Columns    Format

  FARM             1    1 -  8   Numeric
  VELD             1   10 - 17   Numeric
```

FOREWORD

The report 'Mango yields in relation to different management aspects' is a literature study about yield levels of mango under different management practices. It is done in two weeks in July, 1997 at Wageningen Agricultural University, The Netherlands.

ACKNOWLEDGEMENTS

For helping me to compile this report, I would like to thank dr. ir. S. Efdé and dr. ir. E. Westphal from the department of Agronomy. I also thank dr. E.M.W. Verheij who gave me some suggestions for the literature search.

SUMMARY

The aim of this study was to give some more insight in the yield levels of mango. This was done through a literature study. The data and the relations which will be presented in this literature study can be of use for the description and quantification of alternative production technologies of mango. It was tried to find the following relations:

- yields and planting material and growth-controlling chemicals (growth-defining factors),
- yields and fertilizer use (growth-limiting factor),
- yields and use of chemicals to control pests and diseases (growth-reducing factors).

Analysing the differences between potential and actual yield levels enables the development of new production technologies and input-output combinations which can be used in explorations of options for sustainable agricultural production systems (Ittersum and Rabbinge, 1997).

The yield varies, among other factors, with the cultivar and the age of the tree. Yields for mango are especially erratic as there is also biennial bearing, leading to bumper production in one year and a low production in the other. There is an increase of yield from the third to the tenth year. After that, the yield stabilizes somehow. For tropical high-quality cultivars 10 t/ha is considered a reasonable annual yield. In the subtropics, 10-30 t/ha is aimed at, depending on the cultivar (in particular its tendency to biennial bearing) (Verheij and Coronel, 1991). Based on the available literature, best mango yields are obtained in Florida, depending on cultivar, followed by Australia and India.

Most of the commercial mango cultivars are vigorous. There are four approaches towards control of tree vigour: genetic (dwarf cultivars and hybrids), rootstock and interstock, chemical and physical. The last one, pruning, has not been found useful for controlling tree vigour in mango (Kulkarni, 1991). In mango most of the fruits are produced from buds in the periphery of the canopy. As a result, a smaller percentage of the total canopy is available for production in each successive fruiting cycle. The tree becomes very massive, but inefficient as a production unit. Therefore, dwarfing is a desired characteristic for mango (Maldonado et al., 1988). A trial described by Ram and Sirohi (1991) about plant density related to production confirms a positive relation between yield and high planting density.

Rootstock effects on scion are dependable on rootstock variety and specific rootstock/scion combinations should be better for various varieties. An observation of the relationship between canopy volume and yield efficiency shows that large canopies such as 'Palmer' on 'Julie' are associated with low yield efficiency. Evidently in programs of rootstock evaluation and selection, yield efficiency should be one of the most important criteria, since high yield efficiency permits high outputs per unit of land area used.

Cultar is a growth controller that contains paclobutrazol, a gibberellin synthesis inhibitor. Exogenous applications of gibberellins can inhibit flowering in mango. Cultar is a growth retardant with reduced internode extensions as the main morphological effect. The yield

is increased. Fruit numbers are increased significantly. Fruit size is usually not affected or increased.

Depending on climatic limitations and cultivar sensitivity the following cropping patterns can be achieved with Cultar treatment:

- off-season bearing
- early season bearing
- staggering of cropping
- regular cropping of shy-bearing or biennial cultivars. (Voon et al., 1991).

In fruit where Cultar has been in commercial use, one factor that has limited continuing high yields has been nutrition. Where high yields have been generated during the first season and inadequate compensation to the nutritional status has resulted, yields in subsequent crops have suffered.

Fertilizer gift recommendations vary widely over the world. It is clear that a sensible fertilizer program can only be arrived at after the analysis of soil and leaves is known. Mango requires high nitrogen (N) fertilization in the first years to obtain good vegetative growth, but after they begin to bear fruits, the fertilizer gift should be higher in phosphate (P) and potassium (K). A yield of 16 t fresh fruit/ha was found in Venezuela to remove (in kg): N 104, P12, K99, Ca 88 and Mg 47, and (in g): Fe 976, Mn 871, Cu 435, Zn 375 and B 174 (quoted in Samson, 1986). Application of 20 kg of N, P, K and Mg fertilizers in the ratio of 6-3-10-3 compensated for the losses due to the removal of one t fresh fruit of the variety Dashehari in Saharanpur in 1962 (Bose, 1985).

Insect pests are highly injurious to the mango industry. Besides causing economic loss through direct and indirect damage (blemishes and sooty mould), they also affect access to interstate and overseas fresh fruit markets. Current mango pest management is largely dependent on pesticides. Two examples, one of a disease and one of a pest, of chemical control and one chemical control recommendation of the Northern Territory in Australia are given:

- A bacterial disease caused by *Erwinia* sp. affects the mango production in Costa Rica and may produce losses above fifty per cent of the harvested fruits. The best results were obtained with Bordeaux Mixture and the chemical Phyton-27.
- Singh (1991) studied the mango fruitfly (*Dacus* sp.) in Pantnagar, India. This fly is occasionally a serious pest in this area. The most toxic insecticide was found to be Aldrin (applied to the soil as 5% dust).

CONTENTS

LIST OF TABLES AND FIGURES

1 INTRODUCTION

Mango (*Mangifera indica* L.) belongs to the freely branching fruit trees. For this group of fruit trees, not a lot is known about yields, growth and development. The yield levels of this group are often much below those of the single-stemmed plants such as pine apple, papaya and banana, and the yields vary so much from tree to tree and year to year that it is difficult to set normative figures. Yield indications are often based on incidental observations and can not be generalized (Verheij and Coronel, 1991). Maximum mango yields (33 t/ha) are also low compared to other tree fruit crops such as apple (112 t/ha), pear (90 t/ha), orange (80 t/ha), peach (56 t/ha) and prune (45 t/ha). Yields for mango are especially erratic as there is also biennial bearing, leading to bumper production in one year and a low production in the other. The industry is plagued by this inconsistent production with annual yields fluctuating by up to 150%) (Schaffer and Andersen, 1994).

The important mango-producing countries are India, Mexico, Pakistan, Thailand, China, Brazil, Indonesia, the Philippines, Haiti and Zaire (Schaffer and Andersen, 1994). The major markets are in South-East Asia, Europe, the United States and Japan. The volume of world trade was approximately 90000 t only in 1985, but international trade is increasing fast (Verheij and Coronel, 1991).

Planting material is very important for the productivity of mango. Small-scale growers commonly use seeds from mangoes they eat to obtain seedlings. However, vegetative propagation is the crucial step towards the improvement of the productivity. This is because the juvenile phase is eliminated or greatly reduced and the most fruitful trees can be selected for propagation. The reduction through early fruiting also has the advantage that more trees can be planted per hectare. Besides, managing the trees becomes easier. Rootstocks can be used with resistance to pests and diseases.

I performed two studies where I investigated mango. One was in Costa Rica in 1995. The aim was to quantify all inputs and outputs for mango plantations. I collected the data through a formal survey among the mango cultivators. I found out that it was very difficult to get good data for the yields. Another thing I found out was that production varied very much between the plantations. All by all, it was very hard to say something about yields and productivity of mango (Ligt, 1997a). The second study was in Machakos, Kenya in 1996/97. Here, I visited small-scale farmers who also were growing some fruit trees on their plots. There were no plantations in the area. The same problems arose as was the case in Costa Rica. Yields were low (also compared to Costa Rica) and erratic, especially as also serious drought occurred (Ligt, 1997b).

1.1 Scope of the study

The crop production level stands for the level of desired, primary output per unit area. In production ecology three groups of production levels are distinguished (van Ittersum & Rabbinge, 1997):

(1) The potential yield level is determined by growth-defining factors, i.e. incoming solar radiation, temperature and the characteristics of the crop; the crop is optimally supplied with water and nutrients and is completely protected against growth-reducing factors.

(2) The water-limited and the nutrient-limited yield level is lower than the potential, due to a suboptimal supply of water and/or nutrients, respectively.

(3) The actual production level is determined by lack of water and nutrients, and by incomplete protection of the crop against growth-reducing factors.

The actual yield level can be improved by the farmer to attainable levels by yield protecting and yield increasing measures (see Table 1). Yield increasing measures are related to non-substitutable inputs like water and nutrients, whereas inputs related to growth-reducing measures are often substitutable up to a certain extent: e.g. labour, mechanisation and pesticides. Given a certain location and plant species, the growth-defining factors and thus the potential production level can only be influenced indirectly via breeding and planting date.

Table 1. Yield levels and measures and growth factors.

yield level	yield measure	growth factors	handled in this study
potential	increasing	defining	plant material, chemical vigour control
attainable	increasing	limiting	nutrients
actual	protecting	reducing	pests and diseases

Analysing the differences between potential and actual yield levels enables the development of new production technologies and input-output combinations which can be used in explorations of options for sustainable agricultural production systems (Ittersum and Rabbinge, 1997). It is interesting to know the relation between inputs and outputs in respect to sustainability. In the case of this study, the following inputs are considered: fertilizer use, use of chemicals to control pests and diseases, planting material and chemical growth controllers. The output is the yield. For ecological sustainability there has to be a balance in the production system between inputs and outputs. Inputs like pesticides you want to minimize. For economical sustainability, the economic returns have to be as high as possible through the years. In an orchard, production starts only from the third or fourth year on. A farmer may not want to invest in expensive fertilizers if the returns are not high enough.

1.2 Objective

The aim of this study is to give some more insight in the yield levels of mango. This is done through a literature study. The data and the relations which will be gathered in this literature study can be of use for the description and quantification of alternative production technologies of mango. It will be tried to find the following relations:

- yields and planting material and growth controlling chemicals (growth-defining factors),
- yields and fertilizer use (growth limiting factor),
- yields and use of chemicals to control pests and diseases (growth-reducing factors).

In the available literature, most can be found about planting material-yield relations, less about fertilizer effects on yields and hardly anything about the direct relation between pesticide or fungicide use and yields.

2 MANGO YIELD LEVELS

The yield varies, among other factors, with the cultivar and the age of the tree. Yields for mango are especially erratic as there is also biennial bearing, leading to bumper production in one year and a low production in the other. At 10-20 years, a good annual yield may be 200 to 300 fruits per tree. At twice that age and over, the yield can be doubled. Some cultivars in India bear 800 to 3000 fruits in 'on' years and, with good cultural attention, yields of 5000 fruits per tree have been reported (Morton, 1987). Assuming a planting density of 75 trees/ha and a mean fruit weight of 200 g, this means yields from 12 to 75 t/ha.

For tropical high-quality cultivars 10 t/ha is considered a reasonable annual yield. In the subtropics, 10-30 t/ha is aimed at, depending on the cultivar (in particular its tendency to biennial bearing) (Verheij and Coronel, 1991). In Table 2, yields are given for some production areas. Florida gives the best yields, depending on cultivar, followed by Australia and India. The figures calculated by Verheij and Coronel (1991), Das and Ghose (1996) and Donadio (1990) are the total production of a country divided by the total area under mango. The figures by Morton (1987) and Anonymous (1994) are estimates for plantations by an expert. The figures of Laroussilhe (1980) are obtained from experimental stations.

Table 2. Production areas and their (estimated) yield levels (in t/ha or kg/tree).

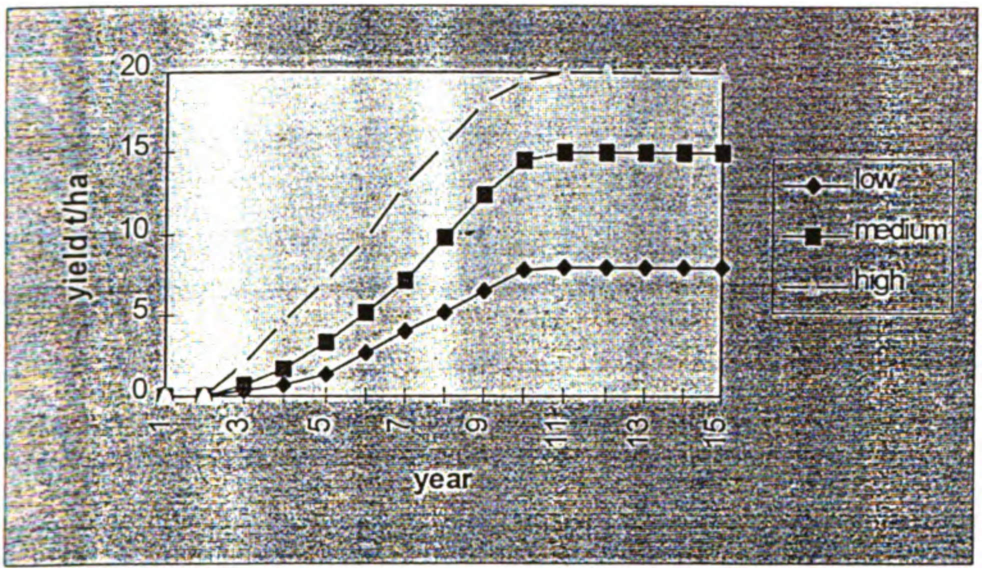
AREA	*T/HA*	*KG/TREE*	*VARIETY*	*SOURCE*
Philippines	5.8	-	-	Verheij and Coronel, 1991
Peninsular Malaysia	3.5	-	-	Verheij and Coronel, 1991
Thailand	2.2	-	-	Verheij and Coronel, 1991
São Paulo (Brazil)	-	76.1	-	Donadio, 1990
Andhra Pradesh (India)	12	150	Banganpali Bangalora	Das and Ghose, 1996
India	12-75	160-1000	-	Morton, 1987
Congo	45-60	-	Alphonso, Brooks, Kent	Laroussilhe, 1980
Guinée	<30	-	Palmer	Laroussilhe, 1980
Florida	29-31	-	Keitt, Tommy Atkins	Morton, 1987
Florida	22-27	-	Irwin, Fascell, Kent, Palmer, Sensation	Morton, 1987
Florida	8-9	-	Haden	Morton, 1987
Northern Territory (Australia)	8 low level 15 medium 20 high	80 150 200	Kensington Pride	Anonymous, 1994

- If no data are filled in, data are unknown.

In Andhra Pradesh, India, a well maintained orchard has about 75 mango trees/ha, yielding on average 600-800 fruits/tree, (150 kg/tree) or 11.0-12.0 t/ha. Two varieties are grown mostly of which Banganpali is the most profitable (earlier and better quality), and Bangalora is grown with almost no maintenance and minimum input costs (Das and Ghose, 1996).

In Figure 1, it is seen that there is an increase of yield from the third to the tenth year. After that, the yield stabilizes somehow. The study is about the variety Kensington Pride, planted at a density of 100 trees per hectare and three estimated yield levels, based on observations in the field. The same curve can be found for the three yield levels. This curve will be taken as a model for yield growth in this study. It does not take into account biennial bearing, however.

Figure 1. Estimated yields in t/ha and age for three yield levels (low, medium and high) Northern Territory, Australia. Trees planted at 100 trees/ha. (Anonymous, 1994).



Yields also vary with variety. Therefore, a few examples of yields for different varieties are given. In Figure 2, the curves are not like in Figure 1. Probably this is due to biennial bearing for which no account is taken in Figure 1. The high yields in Congo (Figure 2) are obtained at an experimental station under very favourable conditions (Laroussilhe, 1980). Only in year five there was a drought in Guinée which caused an 'off' year in year six. The same is seen in Figure 3 (Laroussilhe, 1980), where more varieties are shown. The low yields in year eight are also due to a drought. Year nine is a good year again, especially for Palmer, Irwin, Smith, Keitt and Kent. In Figure 4, their large yield increase compared to year seven can be seen. In this Figure, year eight is taken as the average of year seven and nine to make the trends more clear.

It must be kept in mind that with mango, yields normally vary tremendously per year so that no consistent conclusions concerning yield levels of different varieties can be given. The fact that Palmer performed best in year nine in Figure 3 and 4, does not mean that it will also be the best performer the next year. The good performance of Brooks, Alphonso and Kent in year eight in Figure 2 is not a guarantee for a good performance in year nine. The yields could be half due to biennial bearing. However, the Figures show that there are important differences in yields for the different varieties under different conditions. A farmer will have to seek the most successful variety or choose for a combination of varieties. He can also choose for using rootstocks and interstocks which will be handled in Chapter 2.

Figure 2. Yields in t/ha per year for four varieties planted at 100 trees/ha in Loudima, Congo. Trees planted in 1953. (Laroussilhe, 1980).

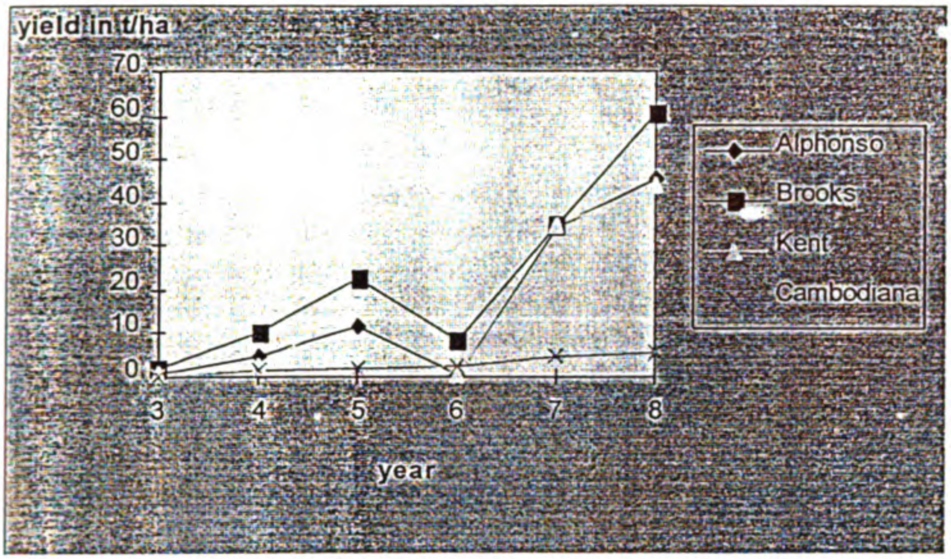
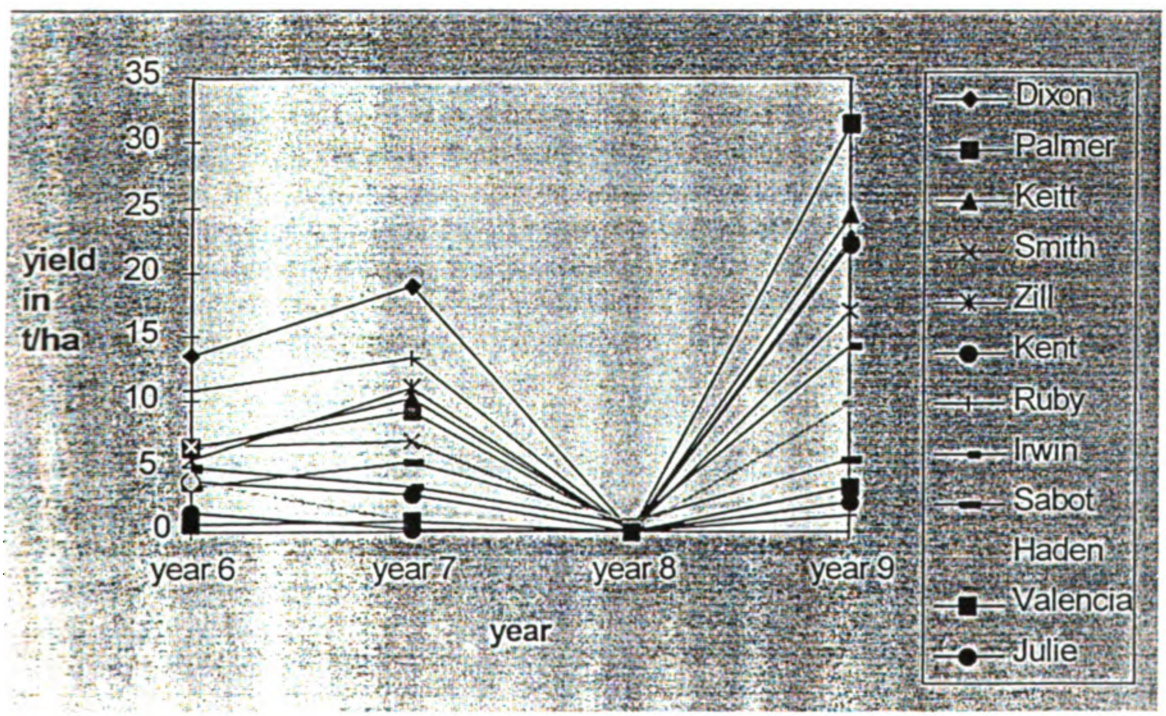


Figure 3. Yields in kg/tree for different varieties planted in 1950 at the station of Foulaya (Guinée) including the year of drought (year 8). (Laroussilhe, 1980).



3 YIELD RELATED TO PLANT MATERIAL AND VIGOUR CONTROL IN MANGO

Most of the commercial mango cultivars are vigorous. There are four approaches towards control of tree vigour: genetic (dwarf cultivars and hybrids), rootstock and interstock, chemical and physical. The last one, pruning, has not been found useful for controlling tree vigour in mango (Kulkarni, 1991).

3.1 Dwarf cultivars and hybrids

In mango most of the fruits are produced from buds in the periphery of the canopy. As a result, a smaller percentage of the total canopy is available for production in each successive fruiting cycle. The tree becomes very massive, but inefficient as a production unit. Therefore, dwarfing is a desired characteristic for mango (Maldonado et al., 1988). Phenotypic factors which indicate dwarfness are precoecity, production of fewer number of growth flushes, short internodes and early branching. Kulkarni (1991) found that the dwarf cultivar Rumani is a useful donor. Two hybrids with Rumani parentage are:

- Manjerra (Rumani * Neelum): precoecious, high yielding, moderate fruit quality and transportability.
- AU Rumani (Rumani * Yerra Mulgoa): heavy flower and fruit drop (due to post-bloom vegetative growth), better fruit quality, but incidence of mango malformation (also in Amrapali).

However, he also found that grafts on own rootstocks were vigorous, attained larger canopy and commenced yielding earlier than grafts on dwarfing rootstock. The most important reason for the limited success of the dwarf hybrids is the consumer preference for the conventional cultivars (Kulkarni, 1991).

A trial described by Ram and Sirohi (1991) about plant density related to production confirms the positive relation between yield and high planting density. The trial was done with Dashehari veneer grafts, planted at two planting densities: 3 * 2.5 m (1333 trees/ha) and 12 * 12 m (69 trees/ha) in August 1976. After year ten, in the high density orchard, ¾ of the canopy of the trees were pruned in July 1987 and the remaining trees in July 1988. The yield of fruit per tree was similar in both densities in 1985, but after that the yield per tree was higher in the low density orchard because of the bigger trees as compared to the high density orchard. However, greater number of trees/ha in the high density orchard were responsible of an approximately 14 times higher cumulative yield after 12 years (the cumulative yield was 82.8 t/ha vs. 6.0 t/ha in the low density orchard). In the years 11 to 12, yields per hectare were 10 times higher in the high density orchard.

3.2 Rootstock/interstock effects

At the Fortuna Research and Development Center near Ponce in Puerto Rico, a trial with four rootstocks and three scions has been done (Maldonado et al., 1988). The climate is sub-humid with an annual rainfall of 1020 mm. Drip irrigation was applied. The planting density was 120 trees/ha. The four rootstocks were Julie, Malda, Manzano, Tetenene and Eldon and the scions Edward, Palmer and Irwin.

Eldon induced the most prominent dwarfing effects, most effectively in reducing the height of Palmer and Irwin. Only Julie significantly reduced the height of Edward. Eldon reduced canopy volume the most on Irwin and Palmer, Julie did so on Edward.

The term 'Yield efficiency' is used to indicate the number of fruits per tree divided by the canopy volume. The canopy volume = $4/3\ \pi\ a^2 b$ with a= 1/2 canopy width and b= 1/2 tree height. Using this term, Irwin was the most 'efficient' producer, especially when grafted on Manzano and Malda. Palmer was the least efficient. With Palmer, significantly higher yields (kg/tree) were obtained when it was grafted on Julie and Manzano.

Table 3. Number of fruits produced per tree per year (means of 8 years, starting the third year from planting), 120 trees/ha. (Maldonado et al., 1988).

rootstock / scion	*Edward*	*Palmer*	*Irwin*
Julie	190b*	200b	381a
Malda	190b*	134b	364a
Manzano	203b	195b	311a
Eldon	169b	119b	190b

* *Means followed by the same letters do not differ significantly at the 0.05 probability level.*

However, the number of fruits per tree do not differ significantly for the three scions grafted on the different rootstocks. Only Irwin produced significantly less fruits per tree when grafted on Eldon (Table 3). This shows that yield efficiency can be a more useful concept than yield per tree. Evidently in programs of rootstock evaluation and selection, yield efficiency should be one of the most important criteria, since high yield efficiency permits high outputs per unit of land area used.

The results indicate that effects on scion are dependable on rootstock variety and that specific rootstock/scion combinations should be better for various varieties. An observation of the relationship between canopy volume and yield efficiency shows that large canopies such as Palmer on Julie are associated with low yield efficiency.

3.3 Chemical control of tree vigour

Cultar contains paclobutrazol, a gibberellin synthesis inhibitor. Exogenous applications of gibberellins can inhibit flowering in mango. Cultar is essentially a growth retardant with reduced internode extension as the main morphological effect. In a number of plant species flowering is either induced or intensified. This increases the yields. Fruit numbers are increased significantly. Fruit size is usually not affected. Fruit size is more related to the fruit load on the tree then to the direct effect of Cultar. Depending on climatic limitations and cultivar sensitivity the following characteristics can be achieved with Cultar treatment (Voon et al., 1991):

- off-season bearing
- early season bearing
- staggering of cropping
- regular cropping of shy-bearing or biennial cultivars.

Table 4 shows that 2 to 5 gram of active ingredient of Cultar per tree have the most positive effect on yield of the three varieties Harumanis, Keowsawoey and Chounsa in Indonesia, Thailand and Pakistan, respectively. Applications are to the soil.

Table 4. Effect of Cultar on yield (kg/tree or fruits/tree) (Voon et al., 1991).

gram AI per tree*	*kg/tree (1)*	*kg/tree (2)*	*fruits/tree (3)*
0	148.7	25	20.75
1	-	-	70.00
1.25	206.7	-	-
2	237.88	-	133.80
3.73	283.98	-	-
4	-	-	206.75
5	180.01	45	-
8	-	-	103.75
10	170.98	41	-
20	187.78	-	-

** AI: Active Ingredient*
(1) Cultivar Harumanis, Indonesia 1988. Soil treatment.
(2) Chounsa, Pakistan 1988. Soil treatment.
(3) Keowsawoey (KSW), Thailand 1986. Soil treatment.

Kulkarni (1991) also indicated that paclobutrazol has given good results in control of tree vigour of mango. Soil application reduced internodal length, shoot length and height increments in Alphonso and Dashehari and also caused early, profuse flowering and cauliflory. The results of the trial are shown in Table 5.

Table 5. Effects of Paclobutrazol in two mango cultivars on shoot growth, flowering shoots and yield per tree in year 5 and 7 (Kulkarni, 1991).

treatment	variety	year	shoot length of new growth (cm)	proportion of flowering shoots (%)	yield (number of fruits/tree)
7.5 gr/tree*	A	7	5.2	95.5	248
0.0 gr/tree*	A	7	23.8	22.6	46
5.0 gr/tree*	A	5	8.9	73.5	198
0.0 gr/tree*	A	5	24.8	19.2	31
7.5 gr/tree*	D	7	5.5	96.0	466
0.0 gr/tree*	D	7	21.6	27.2	118
5.0 gr/tree*	D	5	10.2	70.8	75
0.0 gr/tree*	D	5	23.7	31.6	30

A= Alphonso D= Dashehari

Borundkar and Gunjate (1991) found that treatment of 16 year old trees of Alphonso (distinctly alternate bearing, in off year and under uniform cultural operations) with paclobutrazol had results as shown in Table 6. It was applied twice as foliar spray (500, 1000, 2000 ppm) or through soil application (5 and 10 g active ingredient per tree) at 15/7 and 15/8 in 1987 and 1988. Soil application of 10 and 5 g active ingredient paclobutrazol or foliar application of 1000 ppm were found to be significantly effective in giving consistently higher yields.

Table 6. Effect of soil and foliar application of Paclobutrazol on fruiting behaviour. Variety Alphonso, 16 years old, planted in 1987. (Borundkar and Gunjate, 1991).

treatment	mean weight of fruit (g) year 1	year 2	No of fruits /tree year 1	year 2	weight of fruits (kg/tree) year 1	year 2
500 ppm[1]	292.8	236.0	93.3	153.0	27.3	35.5
1000 ppm	238.3	232.3	258.3	194.0	61.5	44.9
2000 ppm	258.6	258.6	188.5	167.0	48.7	43.0
5 g a.i.[2]	231.7	228.2	331.8	214.5	76.9	48.9
10 g a.i.	245.9	238.0	277.8	259.0	68.3	61.7
control	285.4	243.3	46.6	125.0	13.1	30.2
SE of mean	9.6	N.S.	18.1	12.4	5.0	3.1
CD at 5%	29.0	N.S.	54.7	37.5	15.1	9.4

1-foliar application 2-soil application

4 YIELD RELATED TO FERTILIZER USE

Fertilizer gift recommendations vary widely over the world (see Table 7). It is clear that a sensible fertilizer program can only be arrived at after soil and leaf analysis are known. This study will, however try to come to some general conclusions about fertilization and yield.

Table 7. Fertilizer recommendations per area. Different sources.

AREA	FERTILIZER FORMULA	RATE OF APPLICATION	SOURCE
Florida	N-P-K-Mg 2-4-2-1 Zn-Mn-Cu	1.6 kg N/year for fruit-bearing trees	Samson, 1986
French Antilles	N-P-K-Mg 12-15-18-5	0.5 kg/tree for each year of age (up to 6 kg at 12 years)	Geus, 1973
Florida	N-P-K 5-8-10	0.9-1.8 kg/tree per year of age	Morton, 1987
India	N-P-K 4-1-4	0.75 kg/tree for 12-year old trees	Geus, 1973
South Africa	225-675 g N 175-350 g P_2O_5 400-550 g K_2O	for mature trees	Geus, 1873
Cuba	N-P-K 5-10-10	7.5-12.5 kg/tree	Geus, 1973

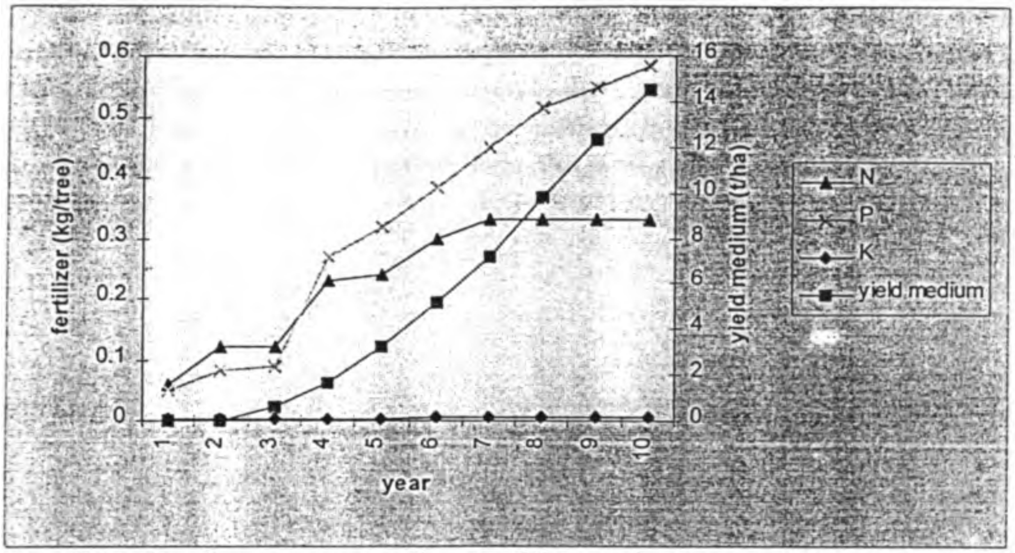
Mango requires high nitrogen (N) fertilization in the first years to obtain good vegetative growth, but after they begin to bear fruits, the fertilizer gift should be higher in phosphate (P) and potassium (K) (Morton, 1987). This is confirmed by the study done in Australia. In Figure 1, Chapter 2, three yield levels are estimated for Kensington Pride in the Top End of the Northern Territory, Australia. Figure 4 gives the fertilizer gift as is used to obtain the medium yield level of 15 t/ha (Anonymous, 1994). It shows that the gift of P increases more rapidly than N after the third year.

Poor flowering in 'off' years results from poor growth in 'on' years and heavy flowering in 'on' years results from heavy and early shoot development in 'off' years. Summer growth can be obtained even in the 'on' year by additional N fertilization (Geus, 1973).

Fertilizer formulas vary with the soil. In sandy acid soils, excess N contributes to 'soft nose' breakdown of the fruits (Morton, 1987). This can be counteracted by adding calcium (Ca) which is also reported in Childers (1966). Ca can be maintained by either applying the N as $Ca(NO_3)_2$ or as limestone or gypsum.

On organic soils, N may be omitted entirely. In India, fertilizer is applied at an increasing rate until the tree is rather old, and then it is discontinued. Ground fertilizers are supplemented by foliar nutrients including zinc (Zn), manganese (Mg) and copper (Cu). Iron (Fe) deficiency is corrected by small applications of chelated iron (Morton, 1987).

Figure 4. Fertilizer gift and yield per year of Kensington Pride (100 trees/ha). Northern Territory, Australia.



The following figures are an estimate of the nutrients extracted by the crop (in kg/t fresh fruit): N 6.5, P 0.75, K 6.2, Ca 5.5 and Mg 2.9. The fruit contains much potassium and this should be balanced by adequate Ca en Mg levels to avoid physiological disorders in the fruit (Verheij and Coronel, 1991). A yield of 16 t fresh fruit/ha was found in Venezuela to remove (in kg): N 104, P12, K99, Ca 88 and Mg 47, and (in g): Fe 976, Mn 871, Cu 435, Zn 375 and B 174 (quoted in Samson, 1986). Application of 20 kg of N, P, K and Mg fertilizers in the ratio of 6-3-10-3 compensated for the losses due to the removal of 1000 kg fresh fruit of the variety Dashehari in Saharanpur in 1962 (Bose, 1985).

In fruit where Cultar has been in commercial use, one factor that has limited continuing high yields has been nutrition. Where high yields have been generated during the first season and inadequate compensation to the nutritional status has resulted, yields in subsequent crops have suffered. See Table 8 for the estimated nutrient removal per tree. Nutrients commonly involved have been N and K although other nutrients such as Zn, Cu and sulfur (S) have also been implicated. (Hillier and Rudge, 1991).

Table 8. Relation of estimated nutrient removal per tree with different rates of Cultar per tree. (Effect of first year's crop load on nutrient removal during the second year).

Cultar rate (ml/tree)	yield (kg/tree)	K (g/tree)	Ca (g/tree)	Mg (g/tree)
0	0.3	0.4	0.02	0.02
4	9.8	11.7	0.7	0.8
8	11.5	13.7	0.8	0.9
16	20.2	24.0	1.4	1.7
32	28.4	33.8	2.0	2.3

It is difficult to relate fertilizer gift directly to yields as not a lot of research has been done, but also because the data vary so much from area to area. However, evidence of the positive relation between fertilizer gift and yield is abundant. Fertilizer recommendations are based on the reality in a certain situation. Through analysis of soil and leaf samples a farmer can find out the nutrient requirements of the mango crop to sustain the yield level he has in mind to make the enterprise profitable through the years. The above mentioned nutrient contents of the crop can help finding out how many nutrients to apply to keep the system sustainable.

5 YIELD RELATED TO CHEMICAL USE IN CONTROLLING PESTS AND DISEASES

Insect pests are highly injurious to the mango industry. Besides causing economic loss through direct and indirect damage (blemishes and sooty mould), they also affect access to interstate and overseas fresh fruit markets. Current mango pest management is largely dependent on pesticides (Cunningham, 1991). One example of the control of a disease and one of a pest will be given.

A bacterial disease caused by *Erwinia* sp. affects the mango production in Costa Rica and may produce losses above fifty per cent of the harvested fruits. This is described in Coto and Wang (1995). Five chemical treatments were evaluated in Turrabares (100 m a.s.l.) on variety Tommy Atkins (six years old) at planting density 204 trees/ha. It is a preharvest disease that, besides infecting the fruit, also attacks the trunk, the branches and the inflorescences. It is spreading by rain, wind, insects and infected cuttings. Starting before bloom, nine foliar sprays (at 2-week intervals) were applied to the trees with Kilol L DF-100, Bravo C/M, Phyton-27 and Bordeaux Mixture. Four sprays of Agrimycin 500 were followed by five sprays of Daconil 500 F at rates as in Table 9.

Table 9. Chemical product description and dose in ml or g per liter water. An average of four liters of spray per tree was applied.

commercial name		*dose used*
Kilol L DF-100	Seedextract of citrus (110 g a.i./L)	2.5 ml/L
Bravo C/M	27% clorotalonil + 45.8% oxicloruro de cobre + 5.4% maneb	11.4 g/ L
Agrimycin 500	1.8% sulfato de estreptomicina + 0.18% oxitetraciclina + 42.4% sulfato de cobre tribasico (cobre metalico equivalente)	2.0 g/L
Phyton-27	21.4 % sulfato de cobre pentahidratado	0.5 ml/L
Daconil 500 F	% clorotanonil	5.0 ml/L
Bordeaux Mixture	80% sulfato de cobre neutralizado con cal apagada $Ca(OH)_2$	5.0 g/L

The best results were obtained with Bordeaux Mixture (incidence of 23.5 % of fruits with the bacterial disease) and Phyton-27 (24.0% incidence), in comparison with the control (46.3% incidence). The other treatments had no effect on controlling the disease (Table 10).

Table 10. Chemical treatment and effect on *Erwinia* sp. incidence.

chemical treatment	incidence (%)*
Control	46.3ab
Bravo C/M	47.5a
Kilol L DF-100	36.7abc
Agrimycin 500 + Daconil 500 F	30.2bc
Phyton-27	24.0c
Bordeaux Mixture	23.5c

**The same letters mean that there is no significant difference according to the Chi-quadrate at 90%.*

Singh (1991) studied the mango fruitfly (*Dacus* sp.) in Pantnagar, India. This fly is occasionally a serious pest in this area. Table 11 shows the mean percentage of fruit of the Dashehari variety damaged in relation to date of picking. The later the picking, the more damage the insect causes. Damage is caused by the maggots that eat through the fruit. In fully ripe, dropped fruits the damage ranged from 10 to 25 per cent from 24 June to 13 July.

Table 11. *Dacus* sp. damage to physiologically mature fruits of Dashehari mango on different dates in 1988. (Singh, 1991).

date of picking	*17/6*	*22/6*	*28/6*	*8/7*	*13/7*
mean % of fruit damaged	3.6	4.6	4.3	4.7	10.0

Efficiencies of insecticidal dusts and sprays were recorded by mixing them in the soil in specially prepared rings and releasing ten larvae into them. Residual toxicity of seven insecticides belonging to different chemical groups were studied. Their toxicity was tested after 0, 1, 3, 7, and 15 days after application and mixing in the soil to the last larvae of *D. dorsalis*. Table 12 indicates that the most toxic insecticide initially was Aldrin (76.7%). However, after 15 days after application, toxicity of Aldrin was reduced to 23.5%. Other treatments were almost ineffective at that time. Thus, it was concluded that Aldrin 5% dust in the soil was the best insecticide against falling pupating larvae of *D. Dorsalis*.

Table 12. Residual toxicity of the insecticides to the last larvae of *Darcus* sp. Mean per cent mortality. (Singh, 1991).

days after application	0	1	3	7	15
Carbaryl 5% dust	35.2	32.7	28.0	20.3	2.0
Aldrin 5% dust	76.7	75.6	68.0	51.0	23.5
BHC 10% dust	55.6	51.8	41.5	28.2	15.6
Methyl parathion 2% dust	25.6	25.1	18.8	10.5	0.0
Malathion 5% dust	24.1	21.1	13.2	04.5	0.0
Quinolphos 0.05% spray	55.6	50.0	41.5	28.3	11.8
Carbaryl 0.1% spray	30.4	26.9	18.8	11.3	0.0
Endosulfan 0.07% spray	57.4	53.9	45.2	33.9	15.6
Control	10.0	13.3	11.7	11.7	15.0
S.Em	1.4	1.5	1.3	1.4	2.0
C.D. (5%)	4.2	4.6	3.8	4.1	6.1

An example of a pest control program as used in the Northern Territory Top End at the medium yield level (see Figure 1 of Chapter 2) of 15 t/ha is given in Table 13. It is not given which pests are controlled.

Table 13. Pest control chemicals and rates of year one to ten in the Nortern Territory, Australia. (Anonymous, 1994).

pest control	rate	1	2	3	4	5	6	7	8	9	10
Rogor	L/ha	0.6	1.2	2.4	3	4	4	4	4	4	4
Summer Oil	L/ha	0	0	0	0	37.5	37.5	37.5	37.5	37.5	37.5
Carbaryl	L/ha	0	0	0	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Mirant1	tu/ha	6	6	6	6	6	6	6	6	6	6
Agral	L/ha	0.3	0.3	0.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6

6 DISCUSSION AND CONCLUSIONS

It was found in Chapter 2 that actual yield levels are under 12 t/ha. These figures were found by Verheij and Coronel (1991) and Das and Ghose (1990). These low yield levels of mango could be due to the fact that in the past breeding in the tropics has concentrated on fruit quality. As it was a crop especially for the upper class, and large areas could be devoted to mango production, high productivity was not an aspiration. Attainable yield levels were estimated in Morton (1987) and Anonymous (1994) to lay between 8 and 31 t/ha. These estimations are based experiences at plantations and not, like the actual levels, by dividing total area under mango by production of mango. Potential yield levels were found by Morton (1987) and Laroussilhe (1980) to lay between 60 and 80 t/ha. This is under favourable conditions in experimental stations and in 'on' years. It is uncertain if these yield levels really could be maintained through the years.

Very few breeding programs have been undertaken with the objective of dwarfing. It takes a long time to get results. The focus is more on the use of rootstocks with a dwarfing effect. This has the advantage that the unproductive phase is reduced. Besides, the cultivator can use a scion with desirable characteristics (such as good fruit quality) which is much more difficult with breeding. Using rootstocks and interstocks seems to be more effective as also resistance against pests and diseases can be built in. It can be concluded that, although no yield figures are available, using good rootstock (interstock) and scion combinations seems to be the way to higher productivity without the fruit quality having to collapse. However, using a rootstock affects growth from the nursery stage and in the concept of high density orcharding, rapid early growth followed by retardation after the trees fill the allotted space is desired. Rootstocks with an adventitious root system will pose the additional problem of lack of proper anchorage in the absence of a tap root. If this is the case, using chemicals to control tree vigour can be a solution. Paclobutrazol has proven to be effective in mango. Productivity increased, but it is important to keep the nutrient level high enough to continue this higher production.

What the potential yield level is for the different varieties and combinations of rootstock/interstock scion is not known. All the trials done are not under perfect conditions. They do indicate, however, which combinations have a higher yielding potential compared to other combinations. In the case of chemical control of tree vigour the potential yield level is also increased. If the potential yield level increases, yield-limiting factors become relatively more important. The limiting factor studied in this report is nutrients.

It was found that, based on this literature study, a positive relation between fertilizer gift and yield is proven. Figures are given about nutrient extraction with the removal of the crop. It is clear that this yield-increasing measure is needed to come to the attainable yield level.

Growth-reducing factors in mango are pests and diseases. Through yield-protecting measures, these factors are tried to be minimised. Some examples of control of a disease and a pest are given. The measures taken have a positive impact on the production, so that the actual yield level is improved. Quantification of yield level increase through these measures was not possible.

For ecological sustainability there has to be a balance in the production system between inputs and outputs. This emphasizes again the need to give sufficient nutrients to maintain the desired production level. Inputs like pesticides and fungicides have to be minimized in the perspective of ecological sustainability. There are alternative ways to control pests and diseases in mango, like biological control, Integrated Crop Management (ICM) and Integrated Pest Management (IPM) which has the objective of using as few pesticides as possible, but does not exclude it. Also the use of resistant root- or interstocks reduces the need to use chemicals.

For economic sustainability, the economic returns have to be as high as possible through the years. In an orchard, production starts only from the third or fourth year onwards. A farmer may not want to invest in expensive fertilizers if the returns are not high enough. Biological pest and disease control and IPM may also be attractive in a economic sense as inputs are reduced. As long as good yields are maintained, this is an attractive option.

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