Crop and Soil Variability in Traditional and Modern Mayan Maize Cultivation of Yucatan, Mexico

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Conducted as part of a DAAD-funded cooperation between the Faculty of Ecological Agricultural Sciences at the University of Kassel (Germany) and the Universidad Autonoma de Yucatan at Merida (Mexico). This research aimed at documenting the present state of a millennia old shifting cultivation system on fragile tropical soils.

The maize-bean-squash ‘milpa-system’ of the Yucatan peninsula has undoubtedly been a mode of ecological and economical sustainable land use as long as population pressure was low enough to allow prolonged fallow periods. In the ruins of the Mayan temples there is ample evidence that it also has been the basis for the rise and fall of great cultural achievements. Commonly known as ‘slash-and-burn’ agriculture its consequences on the global atmosphere have, as elsewhere in the world, recently come under heavy criticism and political and economic measures are being taken to discourage its use ever since. Sophie Graefe’s work provides good evidence of the particularities of the Mayan version of shifting cultivation on the predominantly shallow, calcareous soils of the Yucatan peninsula in Southern Mexico. Furthermore, it points to some of the forgotten negative consequences of the relatively recent global phenomenon of abandonment of marginal soils. Regardless of whether it may be in the Peruvian Andes, the highlands of Afghanistan, central or southern Mexico, Europe or North America, intensive farming increasingly concentrates on fertile soils or areas with good access to markets. Globally the ecological consequences of this bi-polarisation of agricultural land use are still poorly understood. While this trend may help to relieve pressure of some ecosystems and thus increase their sustainability in the short term, there is convincing evidence that it may decrease overall biodiversity in the long run. As “a managed mosaic” the ecologically and culturally complex milpa-land use system of Yucatan is currently at the verge of extinction showing various stages of severe degradation. This case study therefore also pays tribute to farmers who still conscientiously care for their land and live in a system that may, if practised properly, be more efficient and environmentally friendly than it is commonly perceived.

Andreas Buerkert
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"Y del maíz se hizo el hombre,
y del maíz su carne
y de maíz su alma.....

.....Y llegará el dia en que las milpas
serán pisoteadas y arrasadas por animales,
Y el hambre rondara sus estomagos y corazones...."

Popol Vuh

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1 Objectives of the study

The main focus of this study was on the milpa system which consists of a complex shifting cultivation of maize (*Zea mays* L.), squash (*Cucurbita* spp.) and beans (*Phaseolus* spp.). This system covers extended areas of the Yucatan Peninsula in south-eastern Mexico and forms a fundamental part of the "family production unit" of Mayan subsistence farmers who realise more than 95% of the agricultural production in this region (Cuanalo and Arias, 1997).

Due to its adaptation to the marginal edaphic conditions found in Yucatan, the milpa system survived three millennia, including 500 years of colonisation (Teran, 1992). This agricultural system presents a high degree of diversification in terms of production strategies. Traditional Mayan farmer may carry out several agricultural activities besides the "milpa" in a more narrow sense, which refers to a field were maize production is carried out. A great diversity of crops can be found in homegardens, but milpa fields form the principal part of the Mayan peasant farming, providing the major components of the families' diet. Maize is the single most important food crop of Central America (Wilken, 1975), and Mexico is located within the primary centre of origin and diversity for maize, beans and squash, leading to a long history of co-evolution connecting plants and mankind (Hernandez X., 1985). The availability of vast plant genetic resources represented one of the most important contributions to the power of this system which was the basis of the ancient Mesoamerican agriculture (Teran et al., 1998).

However, diversity of crops, varieties and management practises are influenced by many components of modern agriculture. Milpa production and productivity has been strongly affected by population increases on the Yucatan Peninsula which has led to a doubling of the population density in the last 30 years (Cuanalo and Arias, 1997), going along with a profound transformation process leading to a loss of the capacity of family self-sufficiency. This may have strengthened two common prejudices against shifting cultivation, which are low productivity and destructivity (Remmers and Ucan, 1996).

The basic hypothesis of this study was that despite the widespread degradation of the traditional milpa cultivation system in Yucatan some traditionally operating farmers could still be found. It was further hypothesised that their cultivation was characterised by a spatially and genetically divers milpa system that allows to adapt to spatial differences in the edaphic conditions within and between fields. This cultivation system with a high degree of diversification should be strongly location specific thus making better use of differences in soil productivity and satisfying different household needs. But this mode of operation would be vigorously threatened by a in the short run more productive, genetically less divers modern maize production system that partially overrides edaphic limitations by a more intensive use of external inputs.

These hypotheses were tested by a survey in the central part of Yucatan, which comprised the maize cropped fields of six farmers in three villages, regarded as "case studies". While the small sample size within the survey and its limitation to a single cropping season from April to October 2000 certainly precludes more general conclusions, the approach allowed to visualise the dynamic process of change currently occurring in the milpa production system of Yucatan.

2 Introduction to the study area

2.1 Environmental conditions

2.1.1 Geographical location and climate

The Peninsula of Yucatan forms the most eastern part of the Mexican territory. The state of Yucatan is located in the northern part of the peninsula between 19°15' and 21°37' N and 87°30' and 90°26'W and borders with the states of Campeche and Quintana Roo (Figure 1). It has a triangular shape and comprises 39,34 km² or 28% of the Peninsula and a little less than 2% of the Federal territory (Duch, 1991).

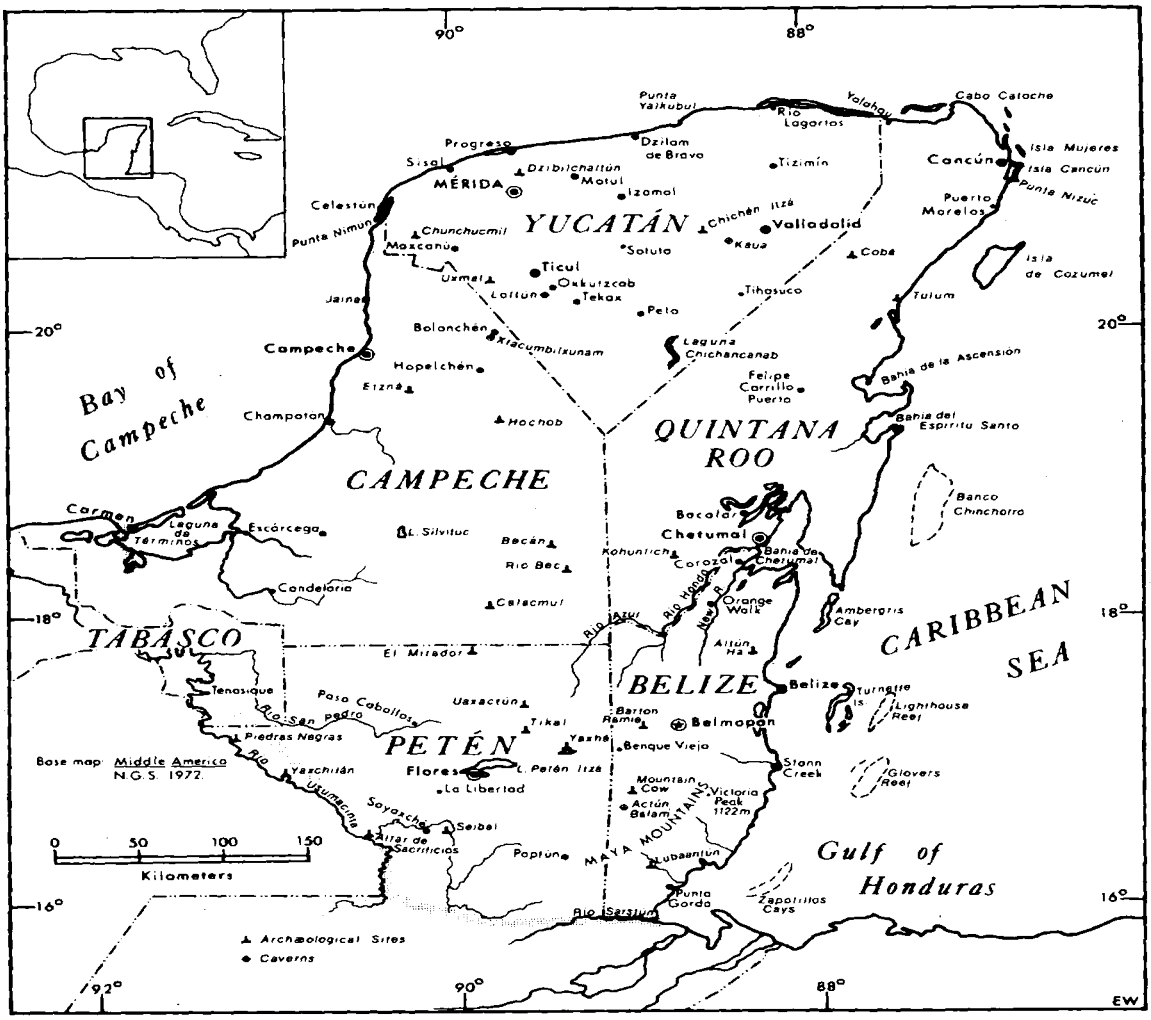

Figure 1. Peninsula of Yucatan
Source: Wilson (1980)

Through its geographical location south of the Tropic of Cancer and within the intertropical belt, Yucatan is characterised by a hot subhumid climate with summer rain and an average annual temperature of 26°C. According to the classification of Koeppen, the climate of Yucatan can be grouped within the *Aw* climates (hot subhumid) with a small part of *BS* climate (hot semiarid) in the extreme north-west (Figure 2). Three subtypes of the *Aw* climate can be distinguished according to the level of humidity (Aw^0= less humid, Aw^1 = intermediate and Aw^2 = more humid). Aw^0 is the driest of the hot subhumid climates and the dominating type within the state of Yucatan. A remarkable decrease of rainfall from southeast (up to 1200 mm/year) to northwest (500 mm/year) can be found, corresponding to the main direction of the wind (Hernandez X. et al., 1994) and the location of the Peninsula within the trade wind belt, the southern part being closer to the intertropical convergence zone (Wilson, 1980).

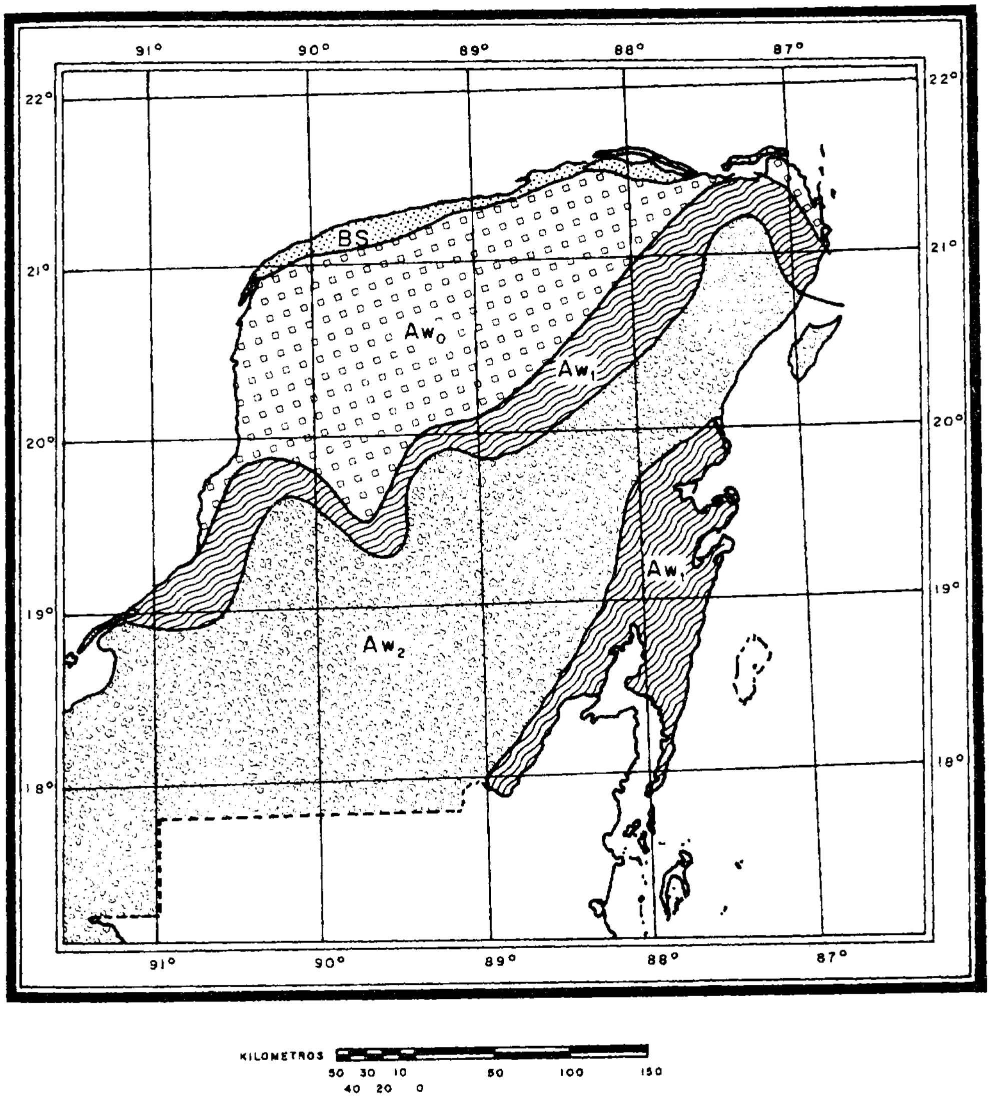

Figure 2. Climates of the Yucatan peninsula. Koeppen system modified by Garcia.
Source: Hernandez X. et al. (1994)

Between 70 and 80% of the total rain falls within the rainy season, which lasts from May until October (Figure 3). The wettest month is September with a total rainfall of at least 150 mm, the driest months are March and April with 20 to 30 mm. Between July and August a dry period, locally called *canícula,* occurs, which is a major concern to the campesinos as it may coincide with the flowering time of maize. Although there exists a well defined wet season, its unpredictable distribution throughout the year creates a certain risk for the campesinos with respect to the success of their rainfed agriculture (Teran and Rasmussen, 1992).

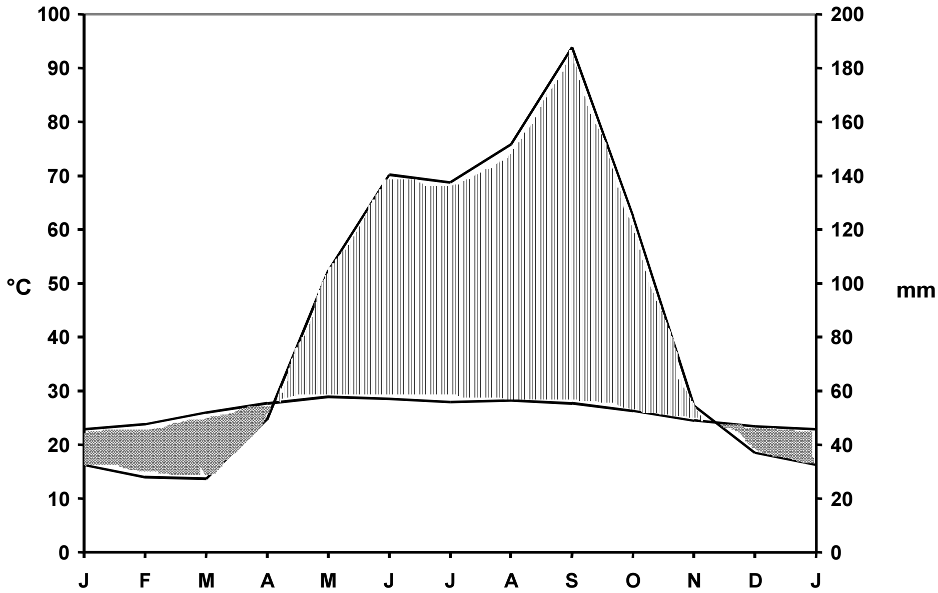

Figure 3. Climatic diagram of Peto, Yucatan
(Means of the 1961-1999 period)
Source: Comision Nacional del Agua (2000)

The main wind direction in Yucatan is from east to west and has a beneficial effect in particular to maize, because it brings along humidity, that is above 70% all over the year. Only the extreme north-west is influenced by north-easterly winds, which is responsible for the low precipitation and xerophile vegetation in this area (Hernandez X., 1959). From August through October hurricanes may originate from the Caribbean and have destructive effects on cultivars (Wilson, 1980).

2.1.2 Geology and topography

One of the primary geological features of the Peninsula is the extensive and deep limestone and dolomite platform that emerged 25 to 6 million years ago in the Tertiary and Quaternary period from the sea-bottom to the surface gradually in a northerly direction (Duch, 1991). This physiographical unit also includes the Peten lowlands of Guatemala and the northern lowlands of Belize, largely occupied by limestone and unconsolidated old fluvial sediments (FAO, 1975).

As the geological age of the bedrocks decreases from south to north, the State of Yucatan occupies the youngest part of the Peninsula. Yucatan's soils have been formed from whatever shallow-water coastal drift materials happened to lie on the hard crust immediately prior to uplift (Duch, 1991). The limestone is composed of calcium carbonate ($CaCO_3$) and calcium-magnesium carbonate ($CaMg(CO_3)_2$, dolomite) (Wilson, 1980). During one of the periods of uplift, the sea must have contained a large proportion of volcanic ash in suspension. After uplift this gave rise to red clay soils which still show traces of a volcanic origin (FAO, 1975).

The majority of the state presents an ondulated and little elevated relief that forms a great plain. Only in the south some mayor elevations can be found due to a folding of the limestone platform in the Tertiary.

The solid limestone is locally called CHALTUN with a calcareous, friable and whitish layer underneath, known as SAHKAB, which is able to store infiltrated water. Limestone on the soil surface is easily cracked and penetrated by plant roots, which explains the abundance of stones (Duch, 1994).

2.1.3 Soils

Yucatan is characterised by a mosaic of different soils, which can be found within small distances (DUCH, 1991). Limestone as parent material and the limited weathering explain the shallowness and stoniness of Yucatan's soils, which hamper the introduction of mechanisation and irrigation at a large scale. Additionally, due to the calcareous origin, carbonates occupy 95% of the substratum, whereas those of volcanic origin are only of minor importance (Pool, 1986). Solely in the south on the flanks of the "Sierrita", deep soils developed through erosion and allow mechanisation.

Despite the relative homogeneity with respect to the chemical and physical properties of the soils in Yucatan, a great morphological variation can be observed which is strongly reflected in the Mayan terminology (Table 1, Figure 4). The Mayan classification system describes factors like soil colour, its location, depth, fertility, water economy, the content of stones, their size and distribution. Some terms are used to identify a distinct soil type, whereas others just serve to describe a characteristic feature of the soil. This terminology is widely used by Mayan campesinos, and expresses the importance of the soil in Mayan culture. The traditional edaphical knowledge represents an important contribution to the scientific understanding of the use and conservation of Yucatan soils (Duch, 1991, 1994).

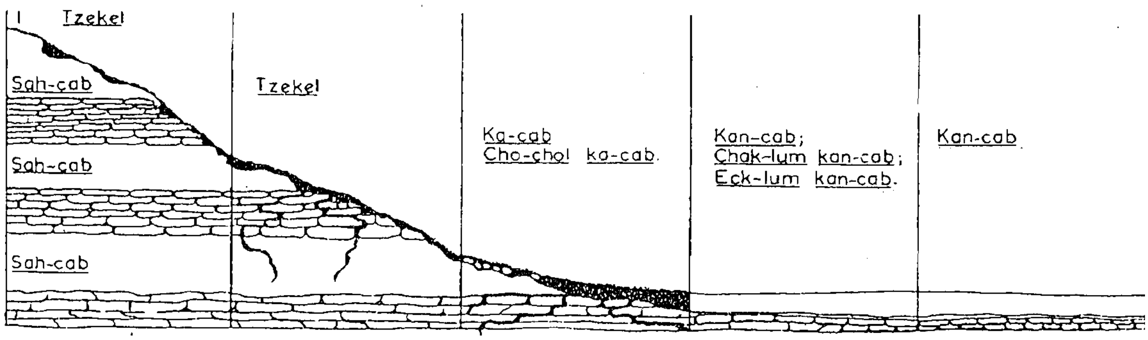

Figure 4. A general profile of Yucatan soils
Source: Hernandez X. (1959)

Table 1. Main soil groups and their correspondence to the international classification system

EDAPHIC FEATURES	SOIL TYPE ACCORDING TO FAO/UNESCO CLASSIFICATION	ASSOCIATED TERMINOLOGY IN MAYAN LANGUAGE
deep sandy coastal soils	Regosols	-
halomorphic soils of swampy areas	Solonchaks Histosols	-
shallow stony soils	Litosols Rendzinas Cambisols	TSEK'EL BOX-LU'UM; PUSLU'UM CHAC-LU'UM; K'ANKAB
red clayey deep soils, free of stones	Luvisols Nitosols	K'ANKAB (red) EK-LU'UM (dark brown)
dark clayey, often inundated soils	Gleysols Vertisols	AK'ALCHE YAAX-HOM

Source: FAO (1975) and Duch (1991)

The state of Yucatan presents a remarkable predominance of stony soils, which form groups with different soil types according to the region (Figure 5). Most of the soil types belong to stony Lithosols (TSEK'EL) and shallow Rendzinas (CHALTUN) in the north and west, and to Cambisols (K'ANKAB) and Luvisols in the east and south which can be of brown-red or black colour. Because of the abundance of stones and good drainage, these soils are favourable to the traditional subsistence-oriented shifting-cultivation system. Generally the incidence of stones and the proportion of K'ANKAB soils increases from north to south.

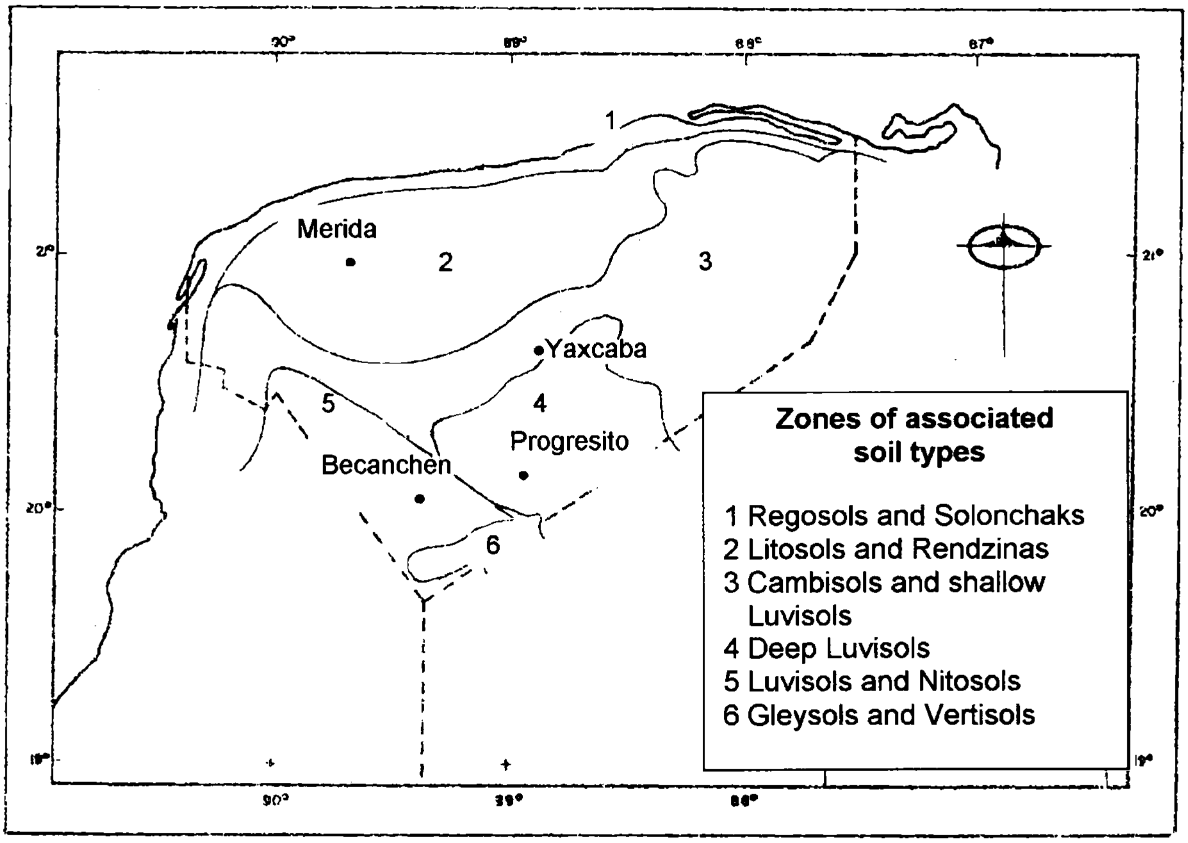

Figure 5. Distribution of associated soil types in the Yucatan state
Source: Duch (1991), modified

More developed soils such as Luvisols, Nitosols and Vertisols appear around the "Sierrita" in the south-east of Yucatan and permit the cultivation of cash-crops. Despite the content of clay they show good drainage. They are hard when dry and sticky when wet. Additionally some Gleysols (AK'ALCHE) with poor drainage and excess of water in the subsoil during the greater part of the year can be found in the extreme south. They are subjected to frequent inundations and of only limited use for agriculture.

The coastline is characterised by sandy Regosols, Histosols with a high content of organic matter and Solonchacs which are rich in salt (Duch, 1991).

2.1.4 Hydrology

Yucatan does not have superficial water sources. The permeability of limestone and the plain relief effectively prevented the formation of rivers. The filtration of water led to a carstified subterranean network of waterbodys, of which the ground-water level gets deeper from the north to south, with a depth not exceeding 27 m (Wilson, 1980) These limestone caverns occasionally breach to the surface and create natural wells, that are known as *Cenotes* (DZONOT). They consist of holes of different size, which are a result of the dilution of $CaCO_3$. They have been the main access to groundwater during a long period in the history of Yucatan and the basis for human settlements (Hernandez X., 1959).

Sartenejas (HALTUN'OB) are hollows in the limestone, in which water accumulates that may serve as water supply for domestic as well as wild animals and irrigation at a small scale. But only voluminous *Sartenejas* will conservate water during the dry season. Like *Cenotes* they have been an important source of water supply in the past (Flores, 1983).

2.1.5 Vegetation

Annual precipitation, the change of wet and dry seasons, drainage and human land use are the principal factors which determine the vegetation distribution in the Peninsula (Wilson, 1980). Duch (1991) mentioned the climate as the most evident determinant for the occurrence of distinct vegetation types in Yucatan. There is a gradient of vegetation corresponding to changes in rainfall and soil depth and type which goes in general from south-west to north-west.

Corresponding to the types of climate the following vegetation groups can be distinguished according to Hernandez X. et al. (1994):

- *Tall to medium semi-evergreen forest*

This type of vegetation covers areas with an average annual rainfall exceeding 1200 mm. A characteristic feature of this forest type is that 20-50% of the trees loose their leaves in the middle of the dry season. The height of the trees is 25 to 30 m.

- *Tall to medium deciduous forest*

75% or more of the trees composing the forest loose their leaves in a pronounced dry season. A predominating species is *Vitex gaumeri* Greenman (YAX NIK in Mayan language), that is associated with different species according to the soil type. The annual rainfall ranges between 1100 and 1200 mm and the trees grow to between 25 and 30 m. Deciduous forests reduce the loss of transpiration, but still have to absorb a certain amount of water from the soil during the dry season. Therefore a condition for the existence of deciduous forests is the capacity of soils to store water during the wet season to prevent them from parching during the dry months (Walter, 1990).

- *Transitional forest*

This forest is a mixture of the tall to medium and the low deciduous forest and occurs at an average rainfall of around 1000 mm, leading to trees of 15 to 20 m height. Due to a rather high density of population in this region of Yucatan, this natural vegetation is strongly influenced by man.

- *Low deciduous forest*

This forest occurs in areas with 700 to 1000 mm of annual rainfall and a longer dry season when most trees shed their leaves. The original vegetation with a height of 15 to 20 m has been reduced to secondary shrubs, with spinous leguminosae dominating their composition.

In reality the original vegetation has been reduced through agricultural activities to just a few patches on ranches, by the wayside or in very isolated places. The secondary vegetation that covers the surface of Yucatan emerged mainly through shifting cultivation. The vegetation re-develops during the fallow period on the basis of sprouts, that are developing from stumps, due to the habit of the campesinos to cut the trees down to a height of 0,5 to 1,0 m. Many of the wooden species are fire resistant and sprout again easily (Hernandez X. et al., 1994). Rather than being separate categories of vegetation, fields and mature forest patches are different stages of the cyclical process of shifting agriculture (Gomez-Pompa et al., 1993). In the Mayan language different types of secondary vegetation are classified according to their age as well as the composition of species. A typical vegetation type to be found is called HUB'CHE, which refers to vegetation with two to three years of regrowth (Duch, 1991).

Burning of the vegetation provokes significant changes depending on the edaphic characteristics. During burning immediate losses of organic matter and microbial activity in the upper centimetres as well as a rapid mineralisation through high temperatures occur. Cambisols (CHAK LU'UM) and Luvisols (K'ANKAB) reduce their moisture retention.

Symptoms of dryness in maize turn up earlier. Soil layers that accumulated during fallow periods tend to erode particularly on slopes (TSEK'EL) through heavy rainfall. But apart from this, in the Yucatan context, the stoniness may protect the soil against water erosion (Duch, 1994).

The composition of species within the secondary vegetation depends upon the species composition before the clearance and the length of the fallow period. In general there are only few leguminosae and on deeper soils gramineae are widespread. The longer the cultivation and the shorter the fallow period, the higher the incidence of annual weeds and the lower the occurrence of shrubs. The main effect of a longer fallow period is the eradication of annual species and a forest consisting mainly of trees and shrubs which are easier to slash down for the campesinos. Due to the fact that the soils will be cultivated again after a certain fallow period, the secondary forest does not have time to re-establish its original structure (Hernandez X., 1959).

2.2 Milpa as a shifting cultivation system

2.2.1 General concept of milpa farming and its significance in ancient times

The *milpa* (COL in Maya) is the field that the Mayan farmers cultivate for several years with maize as the main species, associated with various other crops. They clear a piece of forest sized between one and two ha by the slash-and burn method, after which a fallow period is allowed to restore soil fertility.

According to Teran and Rasmussen (1995), the milpa was the dominant productive system in pre-Columbian times and structurally very similar to today's traditional agriculture. It was capable of maintaining a high population, even in time of crisis. Hernandez X. (1959) emphasized that the ancient maize cultivation has been the basis for the development of the Mayan culture. Maize has been the basic food, medium of exchange, basis of ancient cultural prospering and a motive of faith and rituals (Hernandez X., 1994).

The basic milpa structure is characterised by a high diversity of genetic resources. Teran and Rasmussen (1995) mentioned four elements as essential to understand the milpa system:

1. Cultivation of various fields
2. Cultivation of various species
3. Cultivation of short-term and long-term varieties, especially of maize
4. Various productive activities related to the milpa

All mentioned aspects secure production and apart of (4.) reduce the risk of loosing the harvest in critical years. This explains the system's great persistence over centuries. Until today around 45 000 Mayan campesino families in Yucatan cultivate maize as the principal element of their daily diet within the milpa (Hernandez X., 1994).

The milpa system includes a wide range of agricultural and silvicultural activities, providing important parts of the diet, construction material for housing and firewood. Therefore it has to be considered as a general system of production. In addition to firewood and construction material, the forests (HUB'CHE) are used for various products like the manufacture of working implements, gathering of fodder, medicinal plants and tanning agents, construction of fireplaces to obtain charcoal and lime, hunting and the exploitation of non-renewable resources like stones and SAHKAB, with the aim of domestic use. Another activity is the commercial apiculture. Most of these activities depend upon the availability of extended fallow periods, nowadays comprising a span of six to ten years, which is less than those guaranteeing an *ad infinitum* course of the system with more than 17 years of fallow (Hernandez X., 1994).

The most important crop of the milpa is maize (*Zea mays* L.), followed by squash (*Cucurbita pepo* L. and *C. moschata* (Lam.) Duch. ex Poir.) and beans (*Phaseolus vulgaris* L. and *P. lunatus* L.). In parts of the milpa small patches are dedicated to horticultural species like chillie (*Capsicum annum* L.), tomatoes (*Lycopersicum esculentum* L.), water-melon (*Citrullus lanatus* (Thunb.) Matsum. et Nakai), jícama (*Pachyrrhizus erosus* (L.) Urban), manioc (*Manihot eculenta* Crantz), sweet potatoe (*Ipomea batatas* (L.) Poir.), xcucut makal (*Xanthosoma yucatanense* Engler) and cucumber (*Cucumis sativus* L.) (Hernandez X., 1994). These patches are often selected to provide favourable soil conditions for particular crops and complement the complex of “maize-bean-squash”. They are known as PACH PAKAL. The traditional crops of the milpa are composed of local genotypes, which show a big variation within the species and are well adapted to the climatic conditions and soils (Arias, 1994).

2.2.2 Seasonal activities in the milpa

A new milpa cycle typically starts with the deforestation of a an area of 30 to 300 mecates (1 mecate = 0,04 ha). The first task for the campesino is to select a suitable area within the boundaries of the *ejido*[1] . It belongs to the farmer’s basic knowledge to judge upon the age of the HUB’CHE and to evaluate the soil, relief and existing vegetation, which allows an estimation of its overall productivity. When cutting the trees, the campesino usually spares useful species like ramón (*Brosimum alicastrum* Swartz, Moraceae), nance (*Byrsomina crassifolia* (L.) H.B. & K., Malpighiaceae), guano (*Sabal mexicana* Mart. and *S. yapa* C. Wright ex Beccari, Palmae), cocoyol (*Acrocomia mexicana* Karw. ex Wart., Palmae) or zapote (*Manilkara achras* (Mill.) Fosberg, Sapotaceae). The working time of slashing comprises 1.2 mecates/person/day.

The burning (TOOK) takes place at the end of the dry season during the month of March or April, when the slashed vegetation has dried and the beginning of the rain is forthcoming. It is very important to choose the right timing of the fire, as it has a direct impact on future yields. A sunny day around midday with the highest solar radiation and south-easterly winds is a favourable moment. The fire will be initiated with a torch every two meters on the windward border of the field. The whole lighting process does not last longer than 20 to 30 minutes.

The burning of the vegetation has the following effects:

- it clears the field of logs and undergrowth
- it helps to prepare for sowing without a modification of the soil profile
- it allows a fast regeneration of the HUB'CHE on the basis of offshoots and fire resistant species, which is important for the course of the rotation cycle
- it eliminates harmful insects

(Arias, 1994)

In milpas of the second year (milpa caña), offshoots and climbing plants which are developing after the weeding of the first year have to be cut down. The sowing starts with the beginning of the rainy season in the month of May or June. A stick is used to make holes to 10 cm into the ground for seeds of maize, squash and beans, that are selected and mixed together previous to sowing. The campesino puts around three to four seeds of maize in each hole, together with a smaller quantity of squash and beans. In general he sows from the peripheries to the centre of the milpa, mecate by mecate. In soils of the type TSEK'EL with a predominating rocky surface, adequate pieces have to be selected where the soil layer is deep enough for proper seedling growth.

Around July, when the crops are starting to develop, a strong competition with weeds begins, which requires time consuming hand weeding. Those farmers who do not have the time for hand weeding apply herbicides which depending on their mode of application and product type may have a negative effect on the crops associated with maize. Previous to the elimination of weeds on the ground, the shoots from the stumps have to be cut.

During the month of September and October when the maize approaches maturity, the crop is bend individually at the nodes below the cob, with the intention to a) protect the cob from bird attacks b) in case of an already happened bird damage to prevent the penetration of water; c) accelerate the process of dehydration and d) facilitate the entering of sunlight to associated crops on the ground to allow their continued growth. Campesinos who intend to harvest the maize immediately after physiological maturing do not practise the bending. But a bended milpa functions like a granary. Maize can be harvested from September onward to

1 Ejidos are peasant communities under the form of collective ownership, which were created by the land reform

February according to demands of the household. Cops that will serve as seed for the next year will be separated from maize for household uses, and damaged cops will be sorted out to be consumed first. They will be stored in granaries next to the field or at home, made on pales and with a roof of the leaves of the guano palm.
(Arias, 1994)

2.2.3 Milpa in today's context

Historically the milpa was characterised through a sustainable use of natural resources and self-sufficiency. It was able to sustain family needs of staple crops and extended fallow periods allowed to restore the forest vegetation.

The milpa agriculture that is still found in parts of Yucatan today is basically similar to the pre-Columbian milpa system, but less productive. The fallow periods are too short and forests can not recover between milpa cycles. The system can be characterised as a reduced maize-bean-squash mixed cropping. Today farmers have lost a lot of traditional knowledge about the milpa. Teran and Rasmussen (1995) describe the milpa of today as "only a vague shadow of yesterday's well-functioning system". Not always does it cover family needs for staple food, with the consequence of a lower level of self-sufficiency in rural communities.

Apart from this, the demand of today's market does not anymore correspond to the output of the milpa, which provides small amounts of a diversified production (Neugebauer, 1986). Instead campesinos have developed different strategies to generate income, such as growing of cash-crops, manufacturing of handicraft or temporal out-migration (Guendel, 1997).

Today only one-third of the State of Yucatan is dedicated to milpa production. During the 1800s a great part of the countryside was converted into sisal plantations which are now abandoned and for the last 50 years, an increasing part of the forest has steadily been converted into extensive cattle ranches and citrus-plantations, considered to be more productive. As a whole the state of Yucatan has lost its ability to be self-sufficient in food. (Teran and Rasmussen, 1995)

of 1917 following the peasant-led revolution of 1910 (de Janvry et al., 1995).

3 Methodology

3.1 Method of investigation

To document and compare “traditional“ and “modern“ milpa cultivation systems with each other, six case studies were conducted. Through an informal survey a total of six farmers in three villages have been identified, of whom three practised “traditional“ and three “modern“ maize cultivation. Semi-structured interviews (Martin, 1995) were used for getting extensive responses about the farmer’s cultivation system and to find out comparable pairs in each village. The interviews were guided by a checklist of topics that helped to classify his mode of cultivation as modern/traditional.
Topics covered on this checklist concentrated on:

- mixed cropping *versus* monocrop cultivation
- local *versus* high-yielding varieties
- low *versus* high external input (e.g. use of herbicides, mineral fertiliser)

The general impression of the farmer’s mode of operation has been a decisive selection criterion as was his openness and willingness to participate in the study. The first interviews were accompanied by a Mexican counterpart speaking the local language Maya, with the purpose to initiate the conversation and to establish a basis for confidence. This first process of identification required a few days up to six weeks dependent on location.

The six selected farmers were visited at regular intervals of approximately two weeks during the cropping cycle from late April to early September 2000. During individual stays of several days in the villages and accompanying the farmers to their milpas, information could be gathered with the help of participant observation (Martin, 1995), more intense interviews and quantitative measurements (see next passage). This allowed to see how the farmers put their knowledge into practise and to observe changes that came with the season. Interviews were held in Spanish, as most Yucatecan villagers are bilingual. For talks with non-Spanish speaking persons, members of the family were helpful with translating. Local names of species were translated into the scientific nomenclature based on existing literature (Sosa et al., 1985).

3.2 Fields of investigation

Investigations were carried with respect to the following soil and plant parameters:

- differences in land quality within the milpas were documented with the help of GPS-based and hand-drawn maps, according to own observations and based on the farmer's perception and classification
- trees remaining after clearing were marked in the maps
- determination of how many, which and when different maize varieties were sown, and in which part of the field. Plant densities were determined by sampling an area of 5 x 5 metres with two repetitions in each soil type, seed selection was observed and samples of maize varieties were collected
- determination if mixed cropping was practised and with which species
- crop management practises such as application of mineral fertilisers and herbicides were noted
- grain yields of maize were estimated based on the farmers assessment and experience. Own assessments were carried out comparing ear characteristics of short-cycle maize varieties
- two soil samples were taken and analysed in the laboratory of the Institute of Crop Science/University of Kassel.

3.3 Definition of terms

A *maize race* typically contains numerous varieties of *Zea mays* L. that are grouped according to their similarities in morphological and phenological characteristics. A *variety of maize* refers to a maize population as it is recognized and named by farmers. *Modern* or *improved varieties* are varieties that have been developed by national plant breeding programs and are classed with numbers, such as V-527, V-536. They are genetically stable and well defined and may have been grown for many years by farmers. *Traditional varieties* are selected and developed by farmers and named in Mayan language. In this study traditional races and varieties have been identified by ear characteristics and growing period according to Hernandez X. (1959) and Wellhausen et al. (1987) (See Appendix B_1). *Seed selection* refers to the farmer's choice of seed for the next season's maize crop.

Milpa roza refers to a maize field in the first cropping cycle after a fallow period of several years. *Milpa caña* is a maize field in the second or subsequent years of cultivation after an extended fallow period.

Maya words and terms are written with uppercases. The ‘ marks a glottal stop. XNUC, meaning big and XMEJEN, meaning little are the Maya words to distinguish long-term and short-term variants of plants.

4 Results

4.1 Location 1: Yaxcaba

The community of Yaxcaba is located in the municipality with the same name in the central part of the state of Yucatan about 110 km from the capital Merida. It has an average annual rainfall of 1225 mm and a mean annual temperature of 26°C (CNA, 2000). The *ejido* of Yaxcaba has 2260 inhabitants (INEGI, 2000) and comprises an area of 11.021 ha where 456 *ejidatarios*[1] are cultivating milpa roza on 1.000 ha and milpa caña on 500 ha (Comisario ejidal, personal communication).

4.1.1 Case study 1: Don Esteban Cuxim Uc

The area of Don Esteban's cultivated milpa comprises 4 ha which are subdivided into six plots, of which one is covered by milpa roza (1.2 ha) and the rest by milpa caña (Figure 7).

Milpa roza

To set up a new milpa in the cropping cycle of the year 2000 Don Esteban cut down an area of 14 year old secondary vegetation in August/September 1999. The HUB'CHE around the milpa roza had a vegetation regrowth of about 5 years. Several tree species remained in the stony parts of the field (Table 2).

Table 2. Mayan and scientific names of tree species remaining in the milpa roza of Don Esteban, Yaxcaba

Mayan name	Scientific name	Botanic family
GUANO	*Sabal Yapa* C. Wright ex Beccari	Palmae
TSALAM	*Lysiloma latisiliquum* (L.) Benth.	Leguminosae
XU'UL	*Lonchocarpus yucatanensis* Pittier	"
PISI'IT	*Diospyros schippii* Standley	Ebenaceae
	D. verae-crucis Standley	
SILIIL	*Diospyros cuneata* Standley	"
KAKAL CHE'	*Diospyros anisandra* Blake	"
PE'ES KUUTS	*Croton reflexifolius* H.B. & K.	Euphorbiaceae
PUUTS'MUKUY	*Bumelia retusa* Swartz	Sapotaceae
K'AAN CHUNUUB	*Thouinia paucidentata* Radlk.	Sapindaceae
BOOB	*Coccoloba barbadensis* Jacq.	Polygonaceae

[1] *Ejidatarios* = community members of the ejido

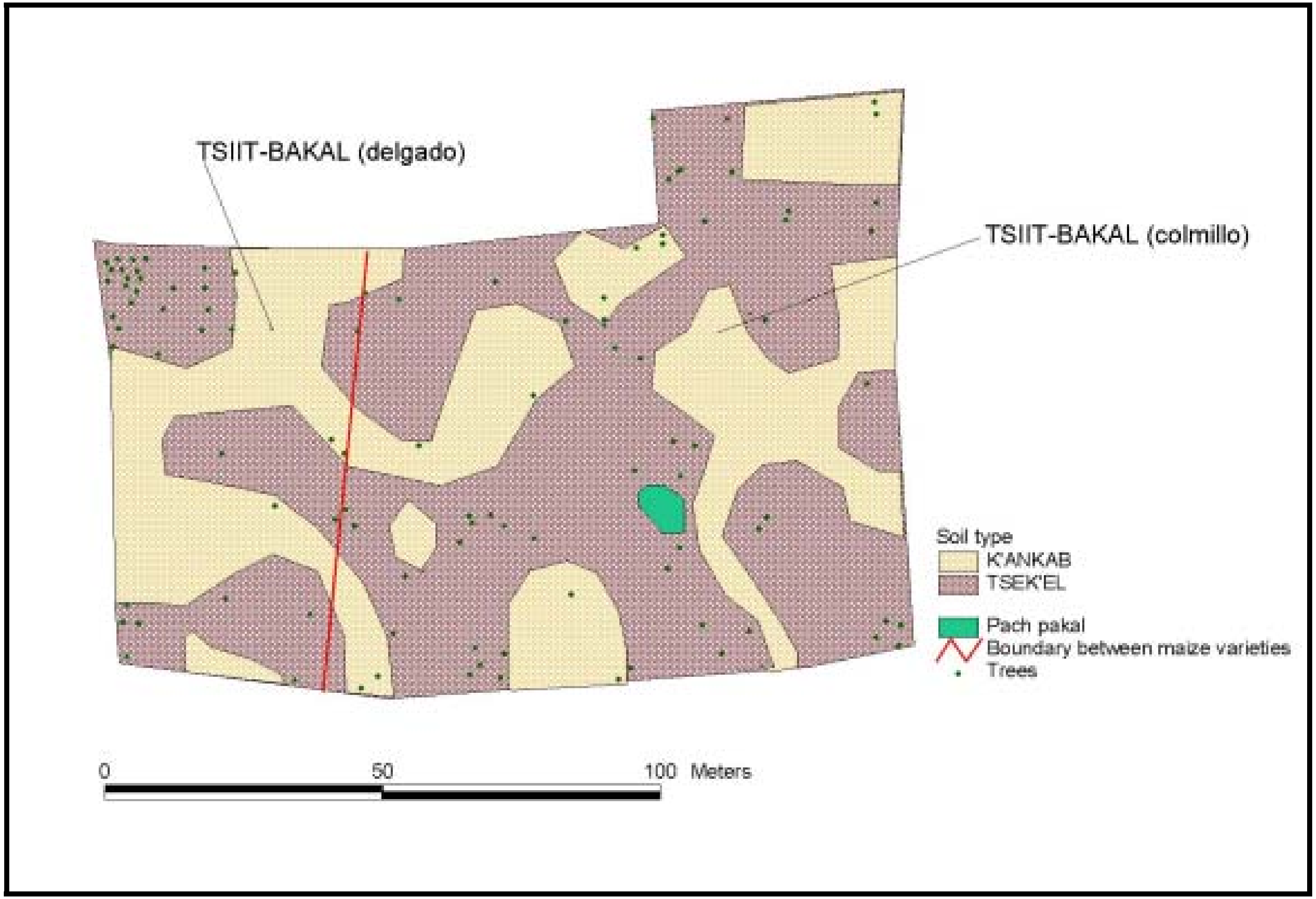

Figure 6. Milpa roza of Don Esteban, Yaxcaba

As need of firewood arises these trees may be cut and collected together with the unburned material left in the field. The fire that was carried out in late April was considered to be successful, as there were only small quantities of unburned material remaining. The soil presented the typical mosaic of red K'ANKAB and dark TSEK'EL (Figure 6).

As in previous years Don Esteban decided to sow two varieties of the race TSIIT-BAKAL (*Zea mais* L.) in the milpa roza. Both are medium to long-cycling varieties with a growing period of 105 days. On stony soils this maize may attain a height of 3-4 m, whereas plant height is smaller on K'ANKAB soils. One variety of TSIIT-BAKAL is characterised through its long, thin and flexible ears which do not contain more than eight rows of grain, whereas the other one, that he named as "colmillo", has 20 rows. According to his observations both varieties appeared to provide acceptable yields on stony soils.

"A bag full of TSIIT-BAKAL weighs more (32 kg) than a bag of V-527 (24 kg)."

(Don Esteban)

This means that TSIIT-BAKAL has a higher bulk density than V-527. Don Esteban grows TSIIT-BAKAL since 30 years.

Additionally he sowed beans (XCOLIBUUL, *Phaseolus vulgaris* L.) and squash (XNUC CUM and XMEJEN CUM, *Cucurbita moschata* Duch.), together and at the same time with maize in early June. The plant densities were estimated to be as follows (Table 3):

Table 3. Plant densities in milpa roza of Don Esteban, Yaxcaba

KANKAB	plot 1	plot 2	plot 3	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	97	85	49	77	30,800	8,800
Beans	12	8	6	8.7	3,467	
Squash	6	7	3	5.3	2,133	
TSEK`EL	**plot 1**	**plot 2**	**plot 3**	**average value plot^{-1}**	**average value ha^{-1}**	**Planting holes ha^{-1}**
Maize	65	72	51	63	25,067	6,800
Beans	2	5	1	4	1,600	
Squash	6	4	5	5	2,000	

Don Esteban added a PACH PAKAL in a distinct part of the milpa roza (Figure 6). He selected a patch of TSEK'EL where water concentrates between stones and can be used for irrigation of cucumber (*Cucumis sativus* L.).

"An elevation is better to grow cucumber, I like this patch of soil. Between the stones are pieces where the soil is soft." (Don Esteban)

Don Esteban did not apply herbicides and therefore practised hand-weeding. It may take him up to two weeks to weed this field. One weeding was considered to be sufficient and was carried out in late July/early August. Mineral fertiliser (type 18-46-00) was applied in the middle of July at the amount of 100 kg (two bags) for the whole field.

Milpa caña

Aside from the milpa roza Don Esteban is cultivating five other fields (Figure 7). These fields fall within the term of milpa caña but do not represent the continued cultivation of a milpa roza but rather a separated several years' cultivation of single plots with pure K'ANKAB soil. In the case of Don Esteban they contain a wide range of maize varieties. Two of them were selected for more detailed investigations.

I. This plot has been cultivated for five years. As Don Esteban was running late and the rainy season was imminent it was impossible to burn the old maize stalks. Therefore the farmer was forced to cultivate without burning. The field was sown with two improved maize varieties (V-533 and V-520) on each side and a PACH PAKAL in between. The sowing was carried out very late in early July, therefore he added a high quantity of squash (*Cucurbita moschata* Duch.) and beans (*Phaseolus vulgaris* L.) to the seedlings of maize (Table 4). The different flowering time of the maize varieties precluded intervarietal cross-pollination. In late August V-533 showed an advanced growth and was already flowering, whereas V-520 was less developed.

In the PACH PAKAL the following species were sown additionally to some young Guano palms (*Sabal Yapa* C. Wright ex Beccari): Chillies XKAT (*Capsicum annum* L.), Water-melon (*Citrullus lanatus* (Thunb.) Mats. & Nakai), MAKAL (*Xanthosoma yucatanense* Engler).

For maize and associated crops the following seed densities were determined (Table 4):

Table 4. Plant densities in milpa caña (I) of Don Esteban, Yaxcaba

	plot 1	plot 2	plot 3	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	78	62	36	58.7	23,467	7,867
Beans	10	12	10	10.7	4,267	
Squash	9	22	6	12.3	4,933	

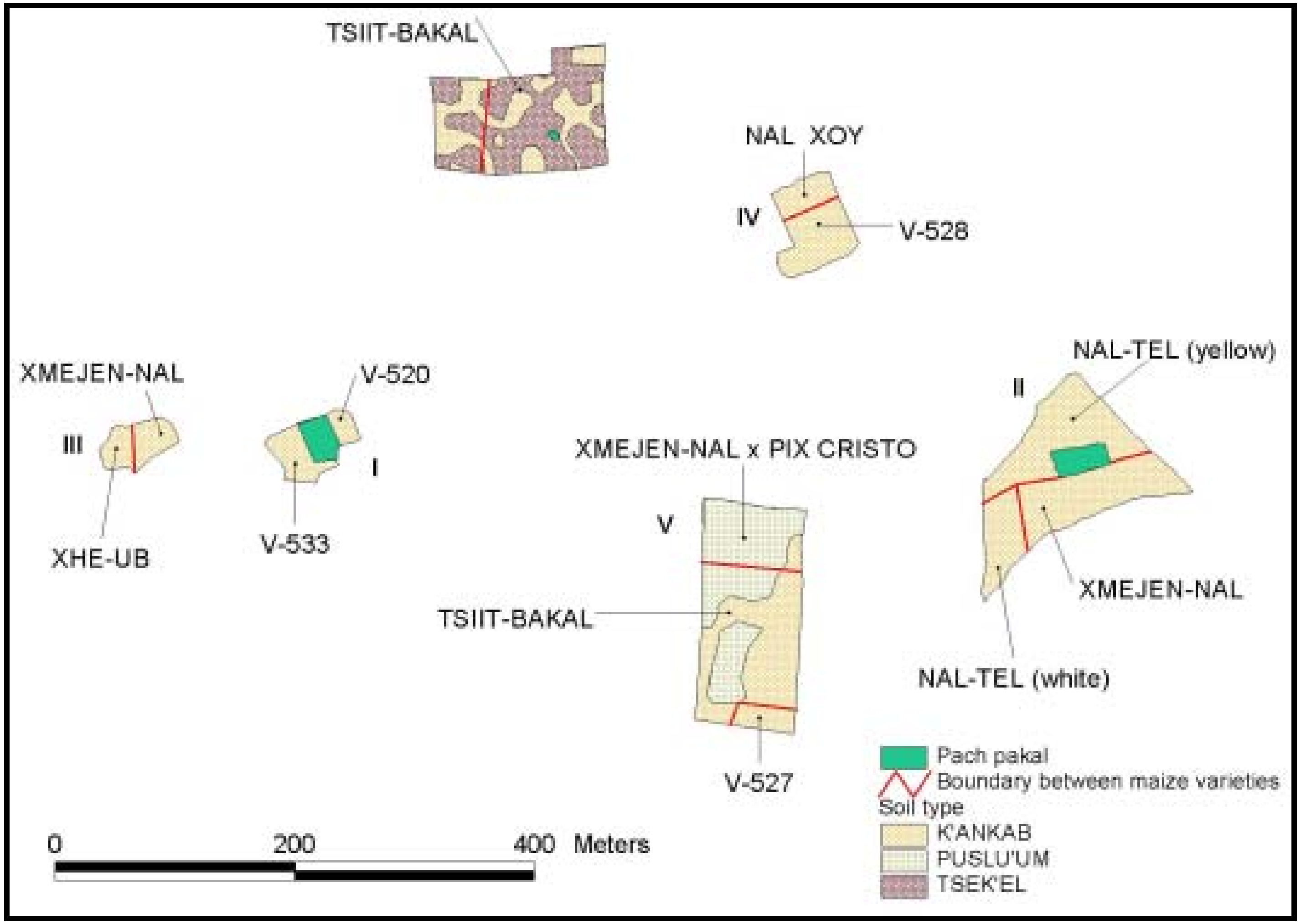

Figure 7. Fields of Don Esteban, Yaxcaba

II. This field has been cultivated for 14 years and presented with the deep stoneless K'ANKAB favourable soil conditions. It was dedicated to short-cycling varieties of NAL-TEL (50 days) and XMEJEN-NAL (75 days). Additionally white Lima bean (*Phaseolus lunatus* L.) and squash (*Cucurbita moschata* Duch.) were sown with the following densities (Table 5):

Table 5. Plant densities in milpa caña (II) of Don Esteban, Yaxcaba

	plot 1	plot 2	plot 3	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	58	94	82	78	31,200	8,800
Beans	3	5	9	5.7	2,267	
Squash	0	3	4	2.3	933	

In the middle of the field a PACH PAKAL with achiote (*Bixa orellana* L.) was located.

100 kg ha^{-1} of fertiliser (18-46-00) were applied as well as the herbicide Gramoxone® [2]at the quantity of 1 l ha^{-1} in early July. Don Esteban mentioned decreasing yields in this plot and cultivation without the application of mineral fertiliser would be impossible. This maize was the first to be harvested in late August/early September.

III. In this field the maize varieties of XMEJEN-NAL (yellow, 75 days) and XHE-UB (dark violet, 120 days) were sown together with squash (*Cucurbita moschata* Duch.) and beans (*Phaseolus vulgaris* L.) in early June. The field had been burnt in the middle of May. This plot was the first of all to be sown. It was observed that maize varieties which were sown at the same time and which have nearly the same maturing time grew faster in this plot than in the milpa roza. In late August ears started to develop, whereas in the milpa roza this could not be observed.

IV. In this field Don Esteban has been cultivating for three years without burning plant residues and sowed the two modern varieties NAL XOY and V-528, together with squash and beans. Likewise caña I. they were sown late. Also here intervarietal cross-pollination was excluded as the variety V-528 is late and NAL XOY early maturing. Just previous to sowing some herbicide was applied. The amount of mineral fertiliser was 60 kg applied in the middle of July and the field was hand-weeded. This plot was under the program „procampo“ of the government which entitled Don Esteban to a subsidy of 520 Mex.$/ha. He will continue to practise this mode of operation in this plot.

[2] Gramoxone® is a non-selective herbicide containing paraquat as an active ingredient

V. This field presented a soil of the type PUSLU'UM and K'ANKAB. It was cultivated for three years and will be used one additional year. Here a variety of XMEJEN-NAL x PIX-CRISTO (yellow with red spots, 90 days) was sown together with yellow TSIIT-BAKAL (105 days). A small plot of three mecates was dedicated to the improved variety V-527 for multiplication purposes. Additionally red Lima bean (*Phaseolus lunatus* L.) and squash (*Cucurbita moschata* Duch.) were sown.

Yields

Given that there were twelve maize varieties (comprising modern and traditional cultivars) with different maturing periods maize could be harvested from late August (NAL-TEL, XMEJEN-NAL) until February/March (TSIIT-BACAL of milpa roza). The main harvest lasts from November to March. Squash could be harvested from December onwards and beans in January/February. As squash and beans play a minor role in the complex, Don Esteban was not able to give exact information on the yields of these crops.

For maize grain, yields may vary as follows (Table 6):

Table 6. Maize yields of Don Esteban, Yaxcaba

Variety	Yield kg ha^{-1} (grain)
TSIIT-BACAL colmillo	1,250-1,500
TSIIT-BACAL delgado	1,250
NAL TEL & XMEJEN-NAL	1,500-1,750
NAL XOY	1,250
V-528	1,750

Typically for seed selection the best ears will be set aside shortly after harvest and stored separately. Additionally Don Esteban practised seed exchange with other farmers.

Background

Don Esteban is very experienced in applying traditional as well as modern technologies and has acceptable yields. He is very enthusiastical about growing twelve different varieties of maize.

"I like these types of seeds and I like to see how they are developing over time"

(Don Esteban)

Additionally the diversity of varieties means a reduced risk of loosing the harvest. He and his family do not bother about the colour of maize for tortillas. Also to them the taste of the flour is the same for all genotypes. Still Don Esteban is very keen on preserving the genetic material of his traditional varieties. He sees a disadvantage in modern varieties which have thinner husks and poorer husk cover with the result of an early ear rot and insect damage during storage in the field or at home.

All varieties that were sown in milpa caña on K'ANKAB soil would not yield in a typical milpa roza as they depend on the better soil properties such as a higher content of organic matter. The purchase of fertiliser depends on the availability of cash and may change from year to year.

Don Esteban cultivated milpa for 40 years and has no reason to abandon his mode of operation. Daily he is accompanied by his 21 years old son and teaches him his cultivation practises.

4.1.2 Case study 2: Don Pablo Tut Cob

Don Pablo was cultivating milpa on five fields with a total size of 6 ha. Two of his fields were milpa roza, and one contained traditional milpa caña. On the other two fields he cultivated improved maize varieties of which he gets two harvests/year. This matter of fact was decisive to classify him as "modern".

Milpa caña

The "two-harvest-fields" were also designated as milpa caña. One of this fields that was investigated has a size of a little less than 1 ha and is the third year under cultivation (Figure 8). The soil is pure K'ANKAB which is essential to this mode of cultivation. The first step to prepare the field for the new cycle is to burn the old maize stalks. This was usually carried out in April.

The maize sown in this plot was an improved variety specified by the farmer as "hybrid"[3], although it is sown year after year. Don Pablo could not give information about the correct name of this maize which did not matter to him, as he was reproducing the best maize ears of this variety for 15 years to obtain new seed for the next cycle. The so called „hybrid" seemed to be highly cross-pollinated with other varieties as its seeds show a range of colours. This maize has a growing period of 75 days and it was sown in the middle of May. No other crops apart from maize were added, because Don Pablo stated that they would compete for nutrients.

> "*The maize doesn't like it and you can't harvest well"* (Don Pablo)

The plant density in this field was as follows (Table 7):

Table 7. Plant densities in milpa caña of Don Pablo, Yaxcaba

	plot 1	plot 2	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	49	51	50	20,000	9,000

To eliminate weeds, the herbicide Gramoxone® was applied in late July at the amount of 1 l ha^{-1}. Likewise fertiliser (18-46-00) was used at the amount of 50 kg ha^{-1}.

[3] The term "hybrid" circulates among the farmers and often refers to improved maize types, but no real hybrid varieties, of which seeds have to be bought anew each year.

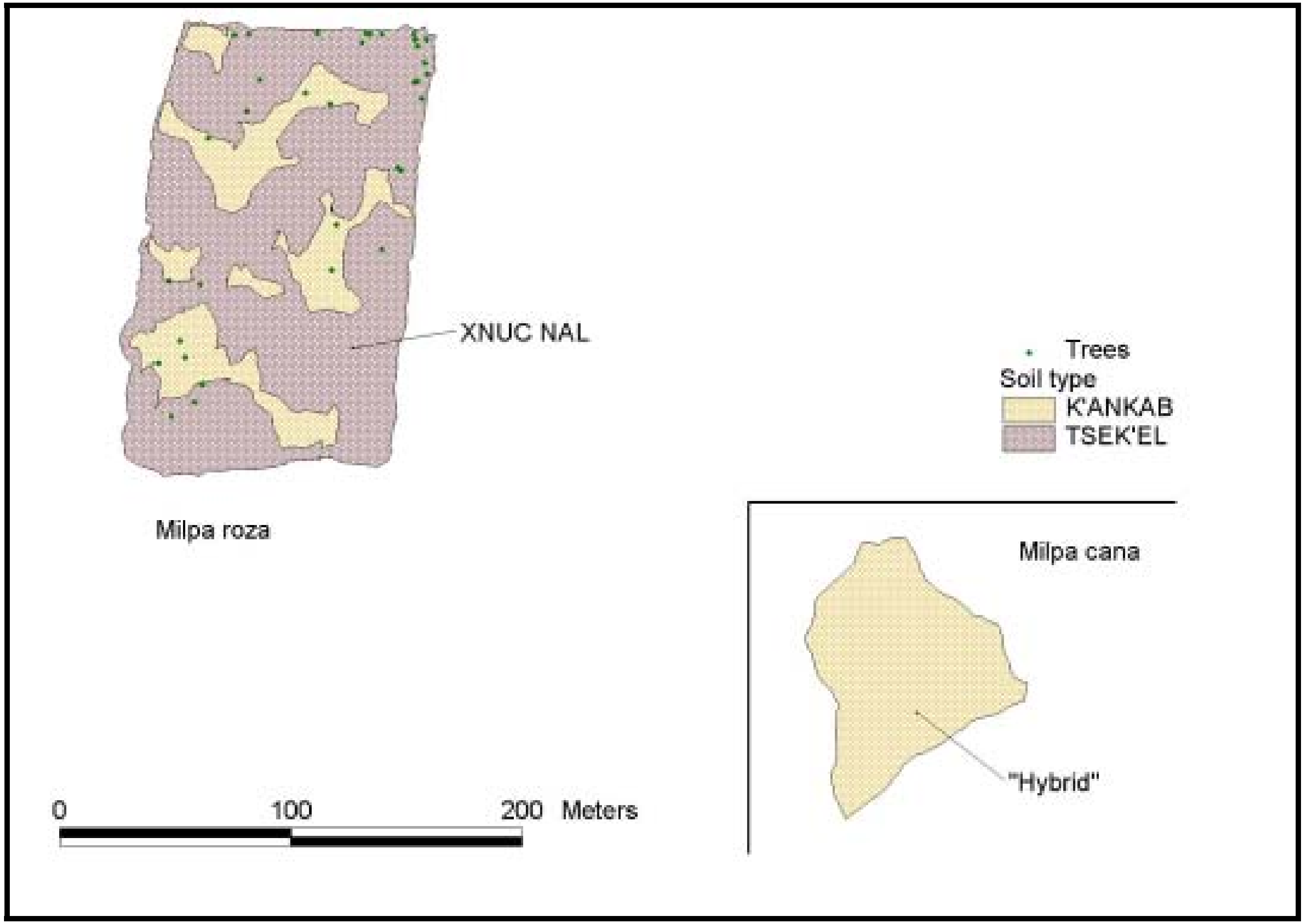

Figure 8. Fields of Don Pablo, Yaxcaba

The first maize harvest was carried out in the middle of August. The yields were around 1200 kg ha^{-1} according to Don Pablo's estimate. It is common among campesinos to quantify yields with the amount of bags that are harvested of one mecate. Therefore he mentioned to harvest three bags/mecate with the comment that 50 cobs fitted in one bag. All cops were harvested within a few days. The second sowing was done shortly after the harvest in late August, after slashing down the old stalks. Again herbicides and mineral fertiliser were applied at the same amount as previously. The second harvest may be carried out in the month of November. As this is the first maize to be harvested the family uses it to increase their food stock that may run low, but the main part is intended to be commercialised.

Milpa roza

The milpa roza that was investigated comprised an area of about three ha. The soils were TSEK'EL and K'ANKAB (Figure 8). According to Don Pablo's information the stony soil was more fertile and the maize had bigger ears, whereas in the K'ANKAB soil the maize grew faster. The fallow period was 5 years. The forest around the field was 20 years old and not allowed to be cut, but it was used to obtain construction material. The vegetation on the plot was cut in January and burned in late April 2000. Don Pablo considered the fire as successful, as there was a strong wind. Just one species of trees was left (CHUKUM, *Pithecellobium albicans* (Kunth) Benth., Leguminosae), which was to be used for firewood after the harvest. Maize was sown in the middle of June together with squash (*Cucurbita moschata* Duch) and beans (*Phaseolus lunatus* L. and *P. vulgaris* L.). The maize variety was the yellow type of XNUC-NAL with a growing period of 120 days. The following plant densities were estimated (Table 8):

Table 8. Plant densities in milpa roza of Don Pablo, Yaxcaba

TSEK'EL	plot 1	plot 2	plot 3	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	55	45	58	52.7	21,067	6,267
Beans	3	4	0	2.3	933	
Squash	10	1	3	4.7	1,867	
K'ANKAB						
Maize	52	46	35	44.3	17,733	5,867
Beans	1	0	0	0.3	133	
Squash	8	3	7	6.0	2,400	

With respect to seed selection Don Pablo preferred maize of the milpa roza in contrast to milpa caña as plants grew larger on average. He selected the largest ears and discarded the ends.

Herbicide (Esteron®[4]) was applied one month after sowing at the amount of 1 l ha^{-1}. It destroyed weeds but did not burn the maize. This work was carried out by his sons. When applying the herbicide they had to pay attention not to hit bean and squash. Regrowth of trunks had to be slashed by hand. In general less weeds existed on the slopes. Additionally partial hand weeding was necessary. To obtain a better harvest, fertiliser (18-46-00) was applied at the amount of 50 kg ha^{-1} on rains in late July.

The harvest was to be carried out from January to March 2001. A yield of 2 bags/Me was expected, resp 32 kg/Me which are 800 kg ha^{-1}. The harvest was intended for self-consumption.

Background

Don Pablo received help from his sons who seemed to be willing to continue the cultivation of milpa in the coming years. Some years ago he decided to cultivate additionally a modern short-duration variety (which would not yield in milpa roza) to overcome the scarcity of maize in summer and to get cash. It is usually sold soon after harvest to avoid storage problems given its thin husks. The maize was to be sold as PIBINAL[5] in several towns for 2$ (Mex. peso)/cob.

[4] Esteron® is a selective herbicide with 2,4 D as active ingredient
[5] PIBINAL is a traditional maize dish prepared in an underground oven.

4.2 Location 2: Progresito

The village of Progresito has 333 inhabitants (INEGI, 2000) and is located in the south-eastern part of the Yucatan state 20 km from the town of Peto in the municipality of the same name. The *ejido* of Progresito comprises an area of 3600 ha where 72 *ejidatarios* are cultivating milpa (Comisario ejidal, personal communication). Climatic records of Peto show an average annual rainfall of 1076 mm and a mean annual temperature of 26.3°C (CNA, 2000).

4.2.1 Case study 3: Jose Valerio Ake Cox

Altogether Don Valerio is cultivating one field of milpa roza on 2 ha and two fields of milpa caña on 1.2 ha each. One milpa caña is the continuation of the last year's milpa roza and adjacent to the new milpa, whereas the other one consists of a separated plot which has been under cultivation for six years. In the milpa roza and adjacent milpa caña predominantly TSEK'EL and additionally K'ANKAB can be found (Figure 9). The second milpa caña is located on pure K'ANKAB soil.

Milpa roza

The milpa was burned in mid May 2000. According to the farmer, the effect of the fire has not been completely satisfactory as there remained high quantities of unburned material, which made the sowing in some patches impossible. This arose from unfavourable weather conditions and the fact that it was too risky to await better conditions because of a possible onset of the rainy season. The preceeding slashing of the vegetation had been completed in January 2000. Trees have been felled at a height of 50-80 cm. Remaining tree species are listed in Table 9.

Table 9. Mayan and scientific names of tree species remaining in the milpa roza of Don Valerio, Progresito

Mayan name	Scientific name	Botanic family
GUANO	*Sabal Yapa* C. Wright ex Beccari	Palmae
SILIIL	*Diospyros cuneata* Standley	Ebenaceae
YA'AX EEK'	*Pithecellobium latifolium* (L.) Benth., *P. leucospermum* Brandegee	Leguminosae
JA'ABIN	*Piscidia piscipula* (L.) Sarg	"
TSALAM	*Lysiloma latisiliquum* (L.) Benth.	"
TAMAY	*Zuelania guidonia* (Swartz) Britt. & Millsp.	Flacourtiaceae
K'AAN CHUNUUB	*Thouinia paucidentata* Radlk.	Sapindaceae

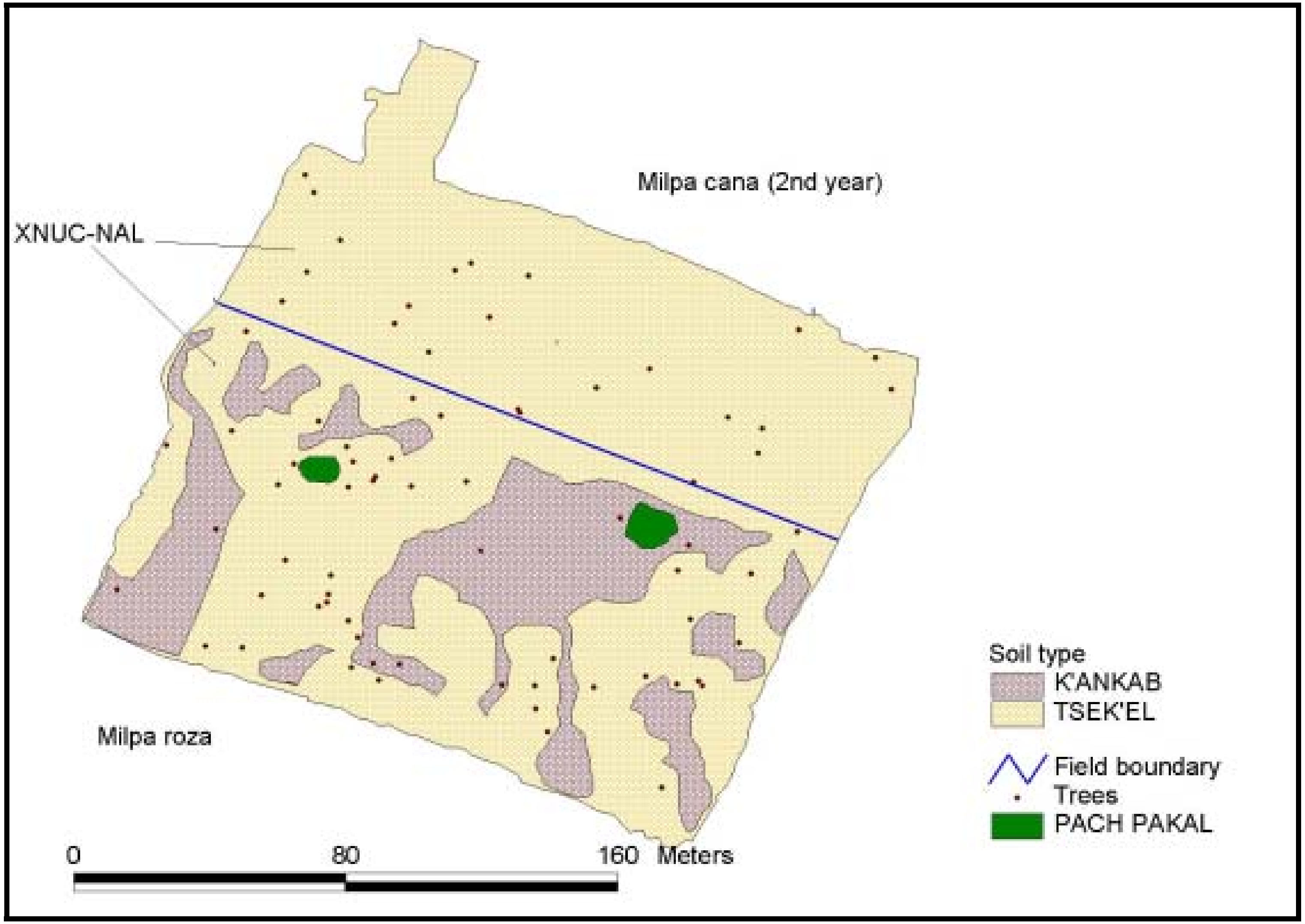

Figure 9. Fields of Don Valerio, Progresito

The field was sown with the yellow type of XNUC-NAL, which is a long duration maize variety (120 days). Due to a scarcity of rain which was insufficient for germination, the sowing was carried out very late in early June and it took two weeks to complete it for the whole field. Don Valerio stated to have put 2-3 seeds in each hole in TSEK'EL soil, but 4-5 in K'ANKAB. For seeds he selected the biggest ears of the previous harvest. He took care not to select only seeds of a single colour as according to him this may cause a degeneration of the genetic material. Additionally to maize he sowed beans (XCOLIBUUL, *Phaseolus vulgaris* L.) and a short- and long cycle type of squash in each part of the field (XMEJEN CUM and XNUC CUM, both *Cucurbita moschata* Duch). For the different crops the following plant densities were estimated (Table 10):

Table 10. Plant densities in milpa roza of Don Valerio, Progresito

TSEK`EL	plot 1	plot 2	plot 3	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	68	67	51	62	24,800	6,267
Beans	2	1	1	1.3	533	
Squash	6	1	2	3	1,200	
K'ANKAB						
Maize	53	70	44	55.7	22,267	5,867
Beans	1	3	1	1.7	667	
Squash	5	1	2	2.7	1,067	

A second sowing was required in some patches as seeds were eaten by animals.

Additionally Don Valerio planted two PACH PAKAL in the milpa roza. One was sown with pure short-cycle squash (XMEJEN CUM, *Cucurbita moschata* Duch) on K'ANKAB soil, the other one with tomatoe (*Lycopersicum esculentum* L.) and cucumber (*Cucumis sativus* L.) in TSEK'EL.

Compared with other milpas the field of Don Valerio showed a lower incidence of weeds which may be due to the relatively long fallow period of 20 years. But it was obvious that the weed density in K'ANKAB soil was higher than in TSEK'EL which he explained with the water-induced removal of weed seeds from elevations of TSEK'EL and their accumulation in K'ANKAB. He neither applied herbicides nor mineral fertiliser as he considered his milpa as traditional-organic.[6]

[6] Don Valerio completed a course on organic agriculture which heavily influenced his cultivation practises.

Milpa caña

Additionally to the long-cycle variety of XNUC-NAL Don Valerio planted three other varieties of maize in a separated field that he cultivated for six years:

NAL XOY is a cross-breed of NAL-TEL and an improved variety whose breeding took place in a village near Peto with the name of Xoy. It typically takes 75 to 90 days to mature. He cultivated this variety for two years and observed how it grew as he had no previous experience with it. He was not yet sure to grow this variety in the milpa roza as it seemed to be better suited for pure K'ANKAB soil. For four years Don Valerio cultivated a short-cycle variety (75 days) from the state of Oaxaca that he got from his brother-in-law and which he defined as „Oaxaqueño". Another variety was distributed by the government five years ago as the result of a hurricane that had devastated parts of the maize harvest in Yucatan. Due to its white coloured, long and thin ears and medium growth duration it resembled the variety of TSIIT-BAKAL, but Don Valerio could not give an exact answer to its varietal classification.

Each of these three varieties were sown on 0.4 ha. They were mainly cultivated for multiplication purposes and because of Don Valerio's interest to experiment with different varieties to find the best suited types of maize for his milpa. He was careful to sow each variety with a certain distance in order to prevent cross-pollination.

Yields

The maize was bent in October but the harvest should have lasted until February/March 2001. The cobs will be preferably stored in a small shed near to the field because of lower mice incidence in the field than at home.

The following yields were expected (Table 11):

Table 11. Maize yields of Don Valerio, Progresito

Variety	Field	Yield kg ha^{-1} (grain)
XNUC-NAL	milpa roza	800 -1,000
XNUC-NAL	milpa caña	500 - 600
NAL XOY	milpa caña	1,500 -1,700

4.2.2 Case study 4: Don Jeronimo

The area of Don Jeronimo's milpa comprised 6 ha, of which 3.5 ha were milpa roza divided into two fields and 2.5 ha milpa cana divided into three fields. Additionally he was cultivating a PACH PAKAL of 0.4 ha with water-melon (*Citrullus lanatus* (Thunb.) Mats. & Nakai).

The soils within the milpa roza presented the typical succession of K'ANKAB and TSEK'EL (Figure 10). In-between also patches of PUSLU'UM existed which were characterised by an abundance of small stones. Behind and in front of the milpa roza two fields of milpa caña were located on pure K'ANKAB soil in the third year of cultivation (Figure 10).

> *"Only on the plains you can sow several times. On the elevations the maize will not grow. In the K`ANKAB the maize grows faster"* (Don Jeronimo)

There was a 10 year fallow period. The field was slashed in October 1999 and trees were felled at a height of 80-100 cm. The field was burned in late April 2000. The fire was considered to be successful as there was dry weather and a strong solar radiation. But not all material was burned which hampered sowing in some patches. The milpa caña has been slashed and burned in late March/early April. Tree species remaining in the milpa are listed in Table 12.

Table 12. Mayan and scientific names of tree species remaining in the milpa roza of Don Jeronimo, Progresito

Mayan name	Scientific name	Botanic family
BOOB	*Coccoloba barbadensis* Jacq.	Polygonaceae
GUANO	*Sabal Yapa* C. Wright ex Beccari	Palmae
TAMAY	*Zuelania guidonia* (Swartz) Britt. & Millsp.	Flacourtiaceae
SILIIL	*Diospyros cuneata* Standley	Ebenaceae
CHUKUM	*Pithecellobium albicans* (Kunth.) Benth.	Leguminosae
YA'AX EEK'	*Pithecellobium latifolium* (L.) Benth., *P. leucospermum* Brandegee"	"
TSALAM	*Lysiloma latisiliquum* (L.) Benth.	"
JA'ABIN	*Piscidia piscipula* (L.) Sarg.	"
SIW CHE'	*Parkinsonia aculeata* L.	"
SAK KAATSIM	*Mimosa bahamensis* Benth.	"
PE'ES KUUTS	*Croton reflexifolius* H.B. & K.	Euphorbiaceae

Don Jeronimo cultivated just one variety of maize which was the long-cycle XNUC-NAL (120 days), but he distinguished between white and yellow maize. The investigated field of milpa roza was sown with yellow XNUC-NAL as was the adjacent milpa caña. His family did not bother about the colour of the maize, but merchants prefer white maize. Don Jeronimo considered the two types of maize planted as equal, but he mentioned that with the application of mineral fertiliser the white maize would rot sooner. For both varieties sowing was carried out in late May, however the milpa caña needed to be sown first, because of a stronger regrowth of weeds. The sowing took place quite early as he was short in time due to the large size of the fields under cultivation and the fact that he was alone for most of the field work. He sowed this variety as long he is cultivating milpa. For seed selection in the weeks before sowing he only took ears of the milpa roza as they grew larger. Don Jeronimo did not practise mixed cropping as he applied herbicide. For the different crops the following plant densities were estimated (Table 13):

Table 13. Plant densities in milpa roza and milpa caña of Don Jeronimo, Progresito

Milpa roza TSEK`EL	plot 1	plot 2	plot 3	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	48	55	62	55	22,000	7,333
Beans	-	-	-	-	-	
Squash	-	-	-	-	-	
Milpa roza K'ANKAB	**plot 1**	**plot 2**	**plot 3**	**average density plot^{-1}**	**average density ha^{-1}**	**Planting holes ha^{-1}**
Maize	53	66	66	61.7	24,667	9,066
Beans	-	-	-	-	-	
Squash	-	-	-	-	-	
Milpa caña, K'ANKAB	**plot 1**	**plot 2**	**plot 3**	**average density plot^{-1}**	**average density ha^{-1}**	**Planting holes ha^{-1}**
Maize	57	45	56	52.7	21,067	7,333
Beans	-	-	-	-	-	
Squash	-	-	-	-	-	

In the K'ANKAB soil the distance of one seed hole to the next ranged between 1.0-1.5 metres and could be characterised as regular, whereas in TSEK'EL seeds were placed into a seed hole with sufficient soil cover.

Don Jeronimo applied herbicide (Esteron®) to all of his fields at the amount of 1 l ha^{-1}. The time of herbicide application was in late June for the milpa caña, resp. early in July for the milpa roza. Additionally he would apply mineral N and P fertiliser (18-46-00) had he the necessary cash to purchase it. He mentioned that ears grew larger on average with fertiliser but that they would also rot faster. For this reason he saw little advantage in applying fertiliser. The milpa caña needed to be treated with mineral fertiliser every two years at the amount of 150 kg ha^{-1}

" With fertiliser they are developing ears faster." (Don Jeronimo)

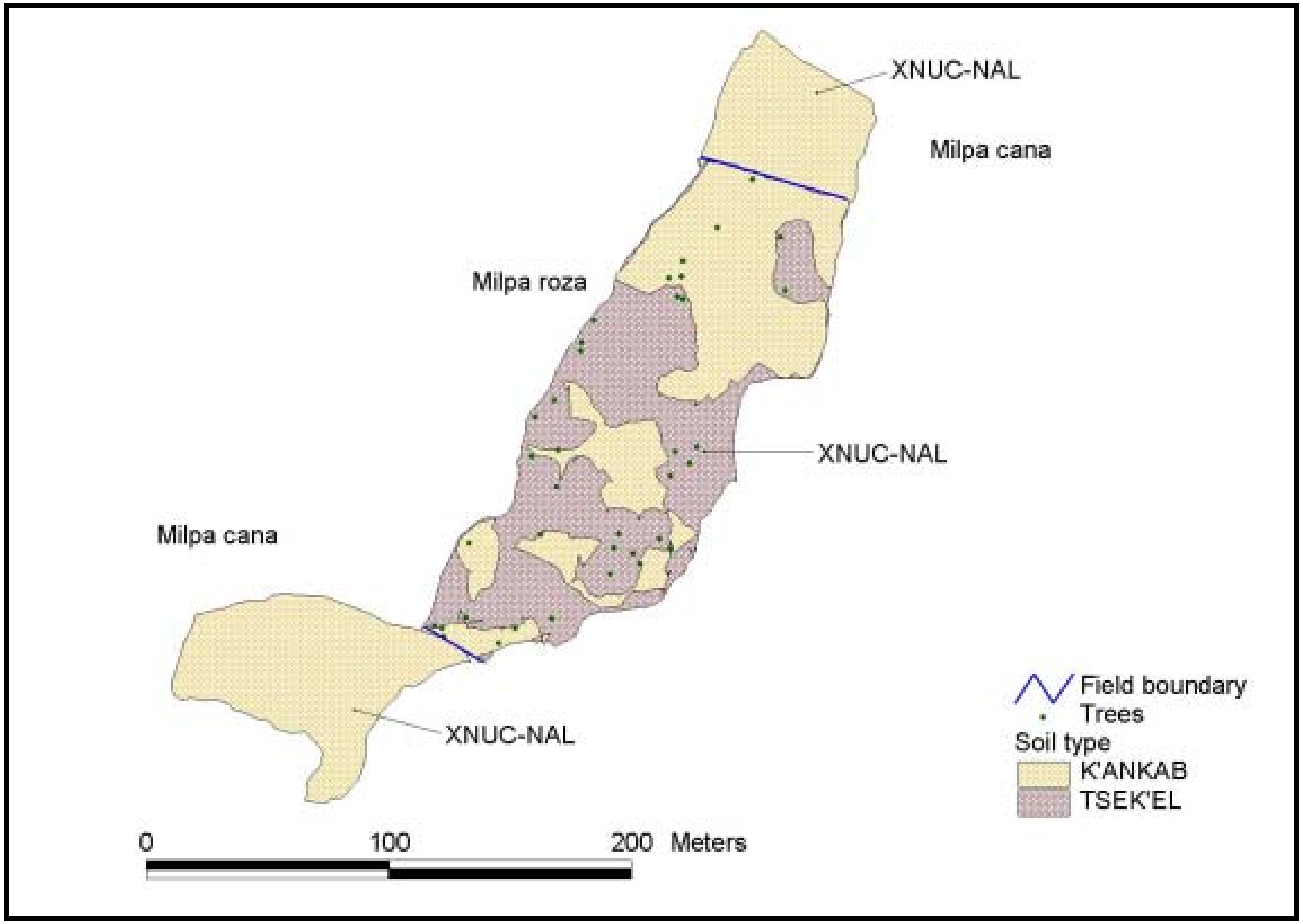

Figure 10. Fields of Don Jeronimo, Progresito

Yields

The maize of Don Jeronimo matured in late September but was left in the field until December to March. The yields were expected to be around 150 to 200 kg ha^{-1}. He considered 500 kg ha^{-1} to be a good harvest and mentioned that in K'ANKAB soil maize yields were higher.

Background

Don Jeronimo's maize cultivation system could be described as a degraded traditional milpa. As a result of his very low yields he was forced to slash each year a new area of 4 ha which is very much given that he is working alone. The excessive workload made him to neglect his fields. Don Jeronimo did not use modern varieties as he knew of the disadvantage of an early ear rot and insect damage. He remembered cultivating short-cycle varieties 20 years ago but was not interested in diversifying his seed stock again.

The water-melon field served to obtain cash but the price was bad as there was little market for it during the common harvest time. In case of need he would also sell some bags of maize.

4.3 Location 3: Becanchen

Becanchen is a village of 1160 inhabitants (INEGI, 2000) and is situated in the southern fringe of the municipality of Tekax in the extreme south of the state of Yucatan. It has an average annual rainfall of 1036 mm and a mean annual temperature of 26°C (Dzib, 1987). In addition to the typical stony surface of Yucatan's soils extensive areas of deep stoneless ground can be found in the area of Becanchen. On these soils the Mexican government intended to modernise the agriculture with development programs in the late 70's/early 80's through mechanisation and a permanent form of land use (Cortina, 1994). Today modern as well as traditional maize cultivation is practised by the local campesinos.

4.3.1 Case study 5: Don Ignacio Bautista May

Don Ignacio cultivated a field of 6 ha where milpa caña (2nd year) and roza were adjacent (Figure 11). The field of milpa roza comprised an area of 2.5 ha. The soil of the milpa caña was a mosaic of TSEK'EL and K'ANKAB which continued into the milpa roza. The soil pattern of the milpa roza was characterised according to Don Ignacio's observations (Figure 11). He described the K'ANKAB soil as EK'LU'UM K'ANKAB which refers to a higher content of organic matter and a darker colour than the typical red K'ANKAB. This soil passed over to the humic K'AKAB (not to be confounded with K'ANKAB) that he described as CH'OCH'OL K'AKAB, which indicates the abundance of small stones that were spread on the soil surface. Soil of the type TSEK'EL was also abundant.

The milpa roza was burned in late April and the milpa caña in May. The fallow period was 50 years due to the fact that the milpa was located in an area where few campesinos slashed and burned as they were concentrating cultivation in parts of the ejido with favourable soils that are closer to the village. Following tree species were selected to remain in the field (Table 14):

Table 14. Mayan and scientific names of tree species remaining in the milpa roza of Don Ignacio, Becanchen

Mayan name	Scientific name	Botanic family
TSALAM	*Lysiloma latisiliquum* (L.) Benth.	Leguminosae
JA'ABIN	*Piscidia piscipula* (L.) Sarg	"
YA'AX EEK'	*Pithecellobium latifolium* (L.) Benth. , *P. leucospermum* Brandegee	"
LU'UM CHE'	*Karwinskia calderoni* Standley, *K. humboldtiana* (Roem. & Schult.) Zucc.	Rhamnaceae

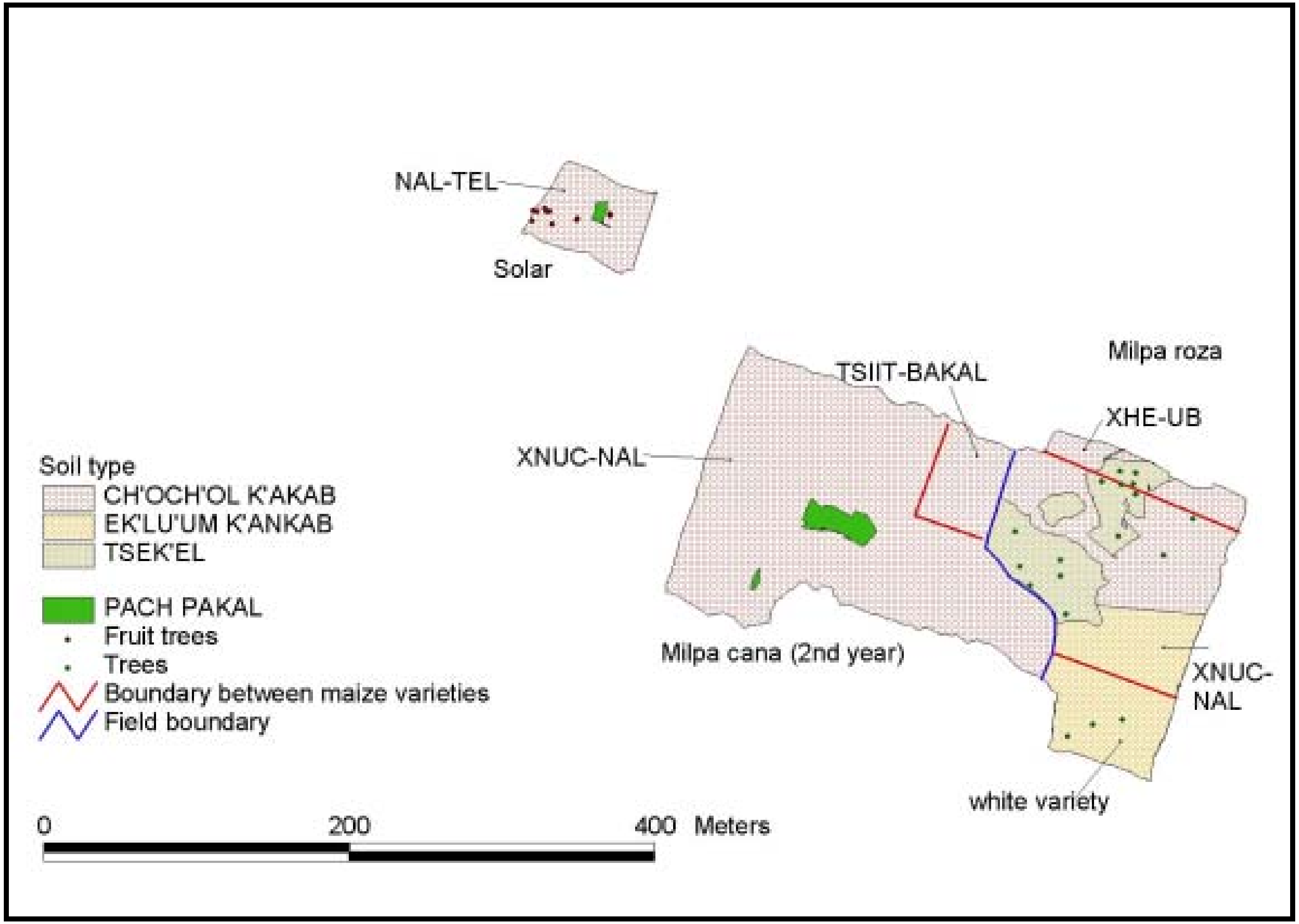

Figure 11. Fields of Don Ignacio, Becanchen

The milpa of Don Ignacio was sown in late May. He mentioned to have placed 3-5 seeds of maize in each hole. In the milpa roza he cultivated three varieties of maize. One was a white variety of 90 days cultivated on 1.1 ha, which was exchanged with another farmer and sown for the first time. The other one was a yellow variety with a growing period of 105 days sown on 1.1 ha which might be related to the variety of XNUC-NAL. The last one was the dark violet variety of XHE'UB (105 days) on 0.3 ha. No measures were taken to exclude intervarietal cross-pollination and some violet cobs seemed to be genetically related to the yellow variety. Don Ignacio did not practise intense seed selection, but some days before sowing he choose the ears for sowing from his seed stock. Likewise the milpa caña was sown with the yellow variety and a small patch of 0.25 ha was dedicated to the variety of TSIIT-BAKAL. Don Ignacio mentioned that TSIIT-BAKAL had the purest ears. Additionally he sowed beans (XCOLIBUUL, *Phaseolus vulgaris* L.) and squash (XNUC CUM, *Cucurbita moschata* Duch.). The following plant densities were estimated for the milpa roza (Table 15):

Table 15. Plant densities in milpa roza of Don Ignacio, Becanchen

	plot 1	plot 2	plot 3	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	66	73	57	65.3	26,133	7,200
Beans	7	9	7	7.7	3,067	
Squash	1	5	8	4.7	1,867	

Additionally a PACH PAKAL with banana (*Musa paradisiaca* L.), water-melon (*Citrullus lanatus* (Thunb.) Mats. & Nakai) and Jicama (*Pachyrrhizus erosus* (L.) Urban) was found in the milpa caña as well as a small patch dedicated to manioc (*Manihot esculenta* Crantz) (Figure 11).

Don Ignacio neither applied herbicides nor fertiliser because he did not have the cash to purchase it. In addition a lack of water normally prevents him from applying herbicides as his milpa is far away and the path impassable to take along water.

Solar

Additionally to his milpa Don Ignacio was cultivating a *solar* [7] near to his home. He slashed the area two years ago and considered the solar as an investment for the future to be used for an unlimited time period. The soil was related to the type of K`AKAB (Figure 11). In this field he sowed the short-cycle variety NAL-TEL (50 days) together with squash (XMEJEN CUM) and beans (XCOLIBUUL) in late May with the following seed densities (Table 16):

[7] A *Solar* is a divers homegarden, which is set up around a home or near the village. It constitutes a permanent form of land use. When campesinos consider to sow maize in the solar they usually prefer short cycle varieties.

Table 16. Plant densities in the solar of Don Ignacio, Becanchen

	plot 1	plot 2	plot 3	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	109	91	105	102	40,667	29,600
Beans	6	7	7	6	2,667	
Squash	2	4	3	3	1,200	

Additionally the following crops were cultivated: water-melon (*Citrullus lanatus* (Thunb.) Mats. & Nakai), cucumber (*Cucumis sativus* L.), white Lima bean (*Phaseolus lunatus* L.), banana (*Musa paradisiaca* L.), papaya (*Carica Papaya* L.) and sweet potato (*Ipomoea batatas* (L.) Poir).

Yields

The harvest of Don Ignacio started in September with the short-cycle varieties of the solar and were to cease with the long-cycle varieties of the milpa until February/March 2001. The following yields were expected (Table 17):

Table 17. Maize yields of Don Ignacio, Becanchen

Variety of maize	Grain yield (kg ha^{-1})
white variety	875
yellow variety	1250
XHE'UB	1375-1425
TSIIT-BAKAL	1500
NAL-TEL	1375

Don Ignacio had a strong preference to bend the maize with the full moon to prevent it from rotting. *"When there is little moon insects are quick entering into the maize."*

(Don Ignacio)

Very early in late August he started slashing a new field for the next year's cropping cycle.

Background

Don Ignacio had a large traditional knowledge on milpa cultivation that was passed on from generation to generation. He grew up in the forest and moved to Becanchen at the age of 20. He was illiterate and never went to school. He started slashing the forest at the age of ten years. Additionally he had a profound knowledge about traditional medicine and medicinal herbs as his uncle was a traditional medical practitioner.

To his sons the milpa cultivation did not seem profitable. They prefered jobs that allowed them to earn money. They were not interested on the traditional knowledge of their father thus the experience of Don Ignacio which he obtained during years of working in the milpa is likely to get lost in the near future.

Don Ignacio considered the mechanised milpa as inferior. He stated that under this type of agriculture soil would be tilled every year, which was not the case under shifting-cultivation. He considered his milpa as better adapted to the environment. He mentioned that he was the last campesino of Becanchen cultivating the variety of XHE'UB. Just four other campesinos cultivated NAL-TEL with whom he practised seed exchange.

4.3.2 Case study 6: Don Apolonio Cohuo Ku

Don Apolonio practised two systems of milpa cultivation simoultaneously. He cultivated 4 ha under traditional management and 5 ha were mechanised.

Milpa roza

This field comprised an area of 2.4 ha and was located on an elevation of 12 m height behind a mechanised maize field (Figure 12). The soil was dark and very stony. It was related to the soil types of PUSLU'UM and TSEK'EL. Don Apolonio characterised the soil as not very fertil. The lenght of the previous fallow period had been 8 years. The vegetation was slashed in November 1999 and burned in late April 2000. No tree species remained in the field.

Don Apolonio defined the sown maize variety as SAC NAL, which can be put in the same category as the long-cycle white variety of XNUC-NAL (120 days) (Teran et al., 1998). The maize was sown in mid June. Don Apolonio mentioned to have placed 5 seeds in each hole. Before sowing he selected the biggest ears of the previous milpa roza harvest. Additionally he sowed white Lima bean (*Phaseolus lunatus* L.) and squash (*Cucurbita moschata* Duch.). The following plant densities were estimated (Table 18):

Table 18. Plant densities in milpa roza of Don Apolonio, Becanchen

	plot 1	plot 2	plot 3	average density plot^{-1}	average density ha^{-1}	Planting holes ha^{-1}
Maize	57	87	82	75.3	30,133	7,467
Beans	0	0	3	1	400	
Squash	5	2	5	4	1,600	

He did not apply mineral fertilisers. According to his observations the maize would grow faster with the application of mineral fertilisers but would not develop ears that well. Herbicide (Herbipol®) was applied at the amount of 1 l ha^{-1}.

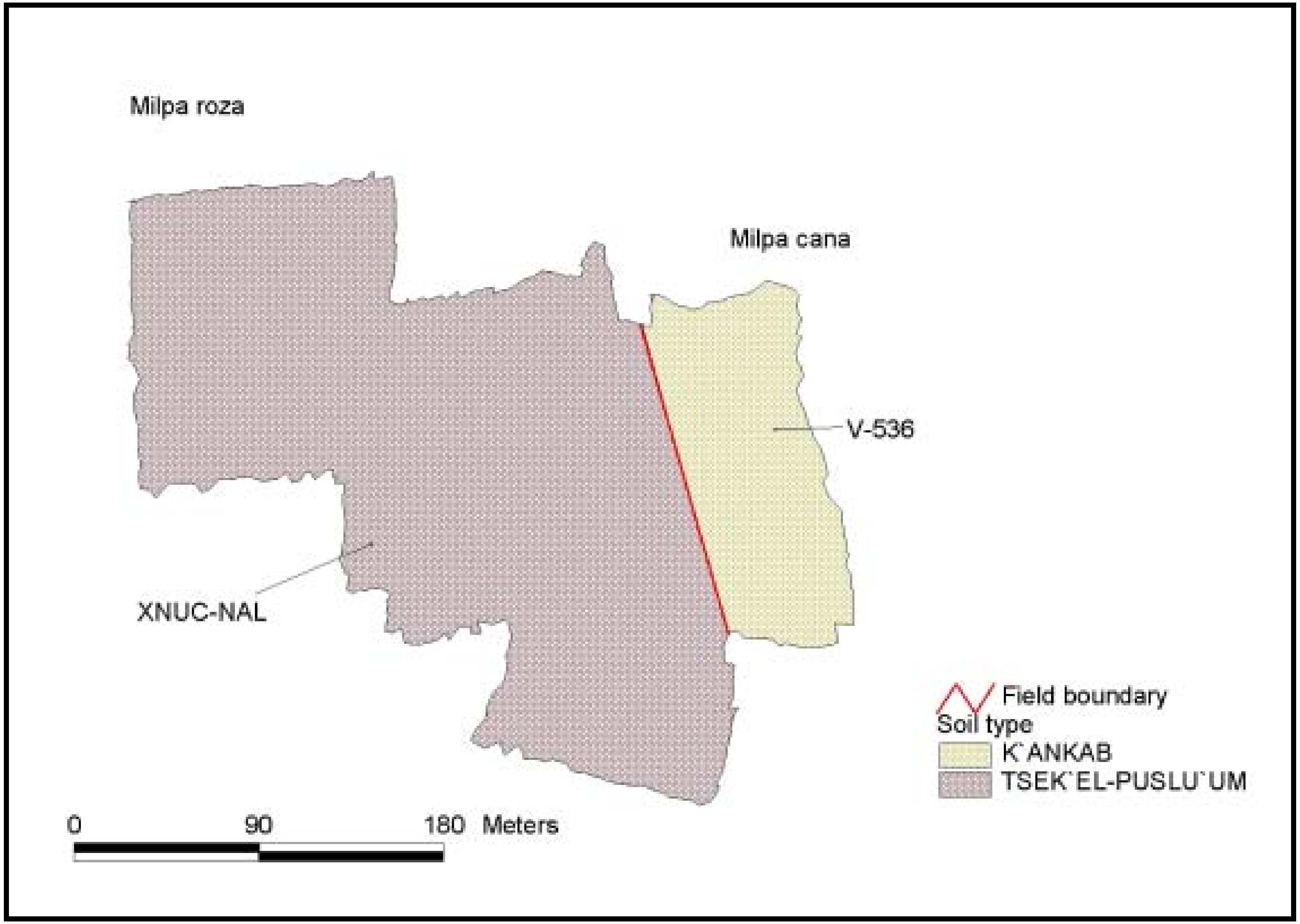

Figure 12. Fields of Don Apolonio, Becanchen

Mechanised milpa

This field of one ha was located in front of the milpa roza and had totally different and spatially rather homogeneous soil properties (Figure 12). The soil type was red stoneless K'ANKAB on a flat surface. The field allowed mechanisation and was for three years under cultivation after a previous fallow period of ten years. In April old maize stalks were slashed and two weeks later burned. Before sowing the field was tilled with a tractor-drawn harrow. In early June the white hybrid variety V-536 (75 days) was sown at the density of 38.400 plants ha^{-1} with a drilling machine. Maize seeds had to be purchased every year in Tekax which is the nearest town.

Don Apolonio did not practise mixed cropping, but sowed a special variety of *Phaseolus vulgaris* L. (TSAMA') into the rows of the bended maize in the middle of September. The maize was harvested and sold from December onwards.

Herbicides (Herbipol® 2 l ha^{-1} and Altanizan® 1 l ha^{-1}) were applied one week after sowing as well as mineral fertiliser (18-40-00) at the amount of 100 kg ha^{-1} three weeks after sowing.

Yields

The hybrid maize of the mechanised milpa matured in early September and was than bended down. The harvest was carried out from November onwards. As the maize of the milpa roza was of a long cycle, its harvest was carried out from December 2000 until February 2001. The yield of the mechanised milpa was around 1800 kg ha^{-1} and obviously higher than in the traditional milpa where grain yields of 1000 kg ha^{-1} may have been harvested[8]. All maize of the milpa roza as well as a certain part of the mechanised milpa were used for autoconsumption, but when cash is needed the hybrid will be sold to a merchant at Becanchen for 1 Mexican peso/kg.

In the case of Don Apolonio the term „mechanised“ just refers to soil tillage and sowing operations. The application of herbicides and mineral fertilisers as well as the bending of the ripe maize and the harvest were carried out by hand.

Don Apolonio was not sure to convert the milpa roza in milpa caña the following cycle as the field was strongly infested by weeds. But he wanted to continue slashing a new field for the next cropping period.

[8] despite of the fact that the hybrid develops just one ear/plant whereas the traditional varieties may form two.

Background

Don Apolonio was cultivating the milpa together with four sons who run the machinery. All of them seemed to be optimistic and consider their mode of operation as progressive and likely to have a future. To them the co-existence of traditional and mechanised milpa means a reduction of risk:

„If there is no harvest in one field the other one will yield“ (Son of Don Apolonio)

This cropping-cycle the family of Don Apolonio lost three ha of mechanised milpa as the *canícula* in late July/early August coincided with the flowering period of the early-maturing hybrid. They were conscious about having a degraded traditional milpa. The variety of XNUC-NAL was preferred for tortilla production.

5 Comparison and discussion of the results

5.1 Ecological limitations

Lazos (1994) stated three ecological factors limiting maize production in Yucatan:

- annual precipitation
- age of the secondary vegetation
- soil development

Precipitation is typically highly variable during the critical flowering phase of maize, which is in the month of July and August (Table 19, Figure 13). The variation of the amount of rainfall reaches 40 to 60% (Lazos, 1994).

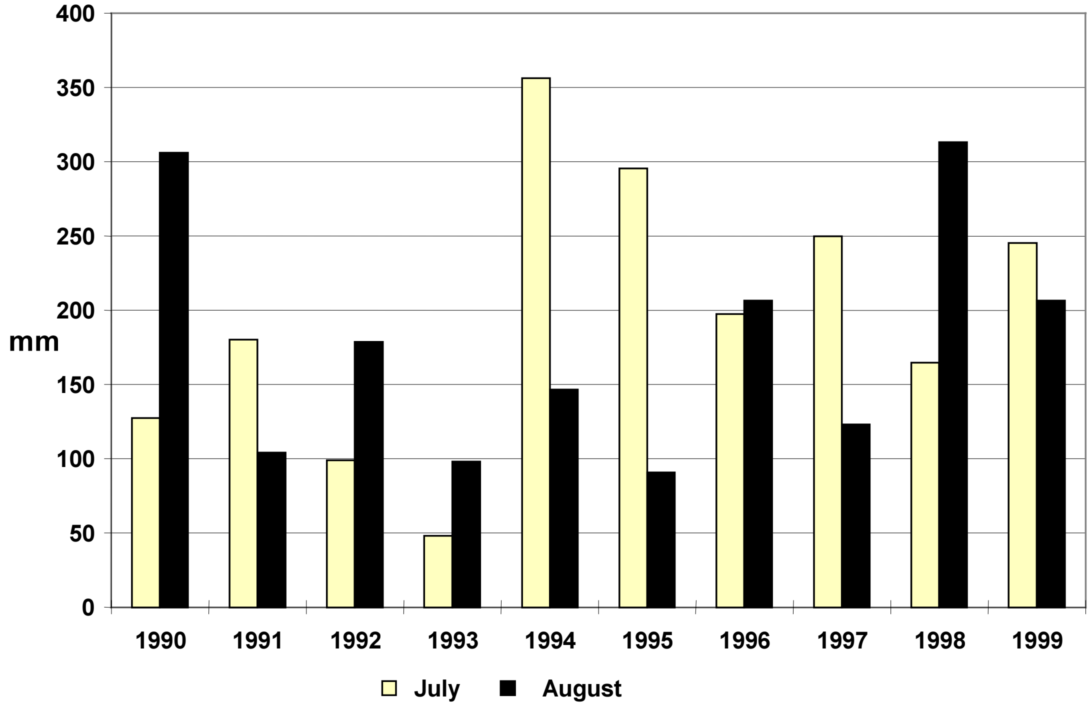

Figure 13. Variation of rainfall in July and August, Sotuta, Yucatan, 1990-1999
Source: Comision Nacional del Agua (2000)

Table 19. Monthly variation of the precipitation in Sotuta, Yucatan, 1961 to 1999

Month	Min-Max (mm)	Variation (mm)
January	0- 98	98
February	0-164	164
March	2-118	116
April	0-213	213
May	11-220	209
June	49-347	298
July	7-356	349
August	66-377	311
September	57-584	527
October	20-290	270
November	4-175	171
December	0-187	187

Source: Comision Nacional del Agua (2000)

Lazos (1994) also mentioned following factors influencing the impact of rainfall for the yield of milpas:

- age of the vegetation surrounding the fields
- topography
- soil type
- time of sowing

Less affected by drought are those milpas which are surrounded with high vegetation and elevations. Stony soils of the type TSEK'EL (Rendzinas, Lithosols) show a better retention of humidity and maize crops may resist a drought of three to four weeks, whereas the deeper soils of K'ANKAB loose their moisture earlier and the maize may wilt after two weeks. According to Lazos (1994) maize grows better on stony TSEK'EL soil when rain is scarce during the cropping cycle, but with abundant rain the maize will develop and yield better on the profound K'ANKAB soil. This is reflected in the statements of the campesinos of the case studies, who mentioned the K'ANKAB soil to be more fertile, but at the same time did not consider the TSEK'EL soil type as inferior and in some cases even stated that it produced bigger ears. The typical traditional milpa roza contained a mosaic of both soil types which may provide a certain risk reduction. Duch (1994) stated that the TSEK'EL-K'ANKAB soils have the highest yields in years with irregular rainfall.

5.2 Differences in soil quality

Soil types found in milpa rozas consisted of a mosaic of dark, stony TSEK'EL and red stoneless K'ANKAB, and to a lesser extent transitions of PUSLU'UM which were hardly to mark in the GPS-based maps presented. One exception was the milpa roza of Don Apolonio at Becanchen where there was no K'ANKAB soil.

Table 20. Percental distribution of soil types in milpa roza

Farmer	TSEK'EL %	K'AKAB %	K'ANKAB %
Yaxcaba			
Don Esteban	58	-	42
Don Pablo	77	-	23
Progresito			
Don Valerio	68	-	32
Don Jeronimo	67	-	33
Becanchen			
Don Ignacio	20	48	32
Don Apolonio	100	-	-

Except of Don Ignacio TSEK'EL was the predominating soil type in all cases (Table 20). According to investigations of Pool (1986) yields in K'ANKAB soil are higher despite of soil analyses which showed higher amounts of organic matter, total nitrogen and plant available phosphorous at a depth of 0-15 cm in TSEK'EL soil (Table 21).

Table 21. Range of soil chemical properties among two main soil types (depth 0-15 cm), Yaxcaba, Yucatan

Constituents	TSEK'EL	K'ANKAB
Organic matter (%)	20.8-36.9	6.7-11.5
Total nitrogen (%)	0.8- 1.4	0.3- 0.6
Plant available phosphorous (ppm)	8.3-17.6	1.8- 3.4

Source: Pool and Hernandez X. (1994), p. 117, modified

Soil samples taken from a recently burned milpa roza in Progresito with a vegetation regrowth of 20 years showed similar properties (Table 22).

Table 22. Chemical parameters of two milpa soils (depth of 0-15 cm) at Progresito

Constituents	TSEK'EL	K'ANKAB
pH (in 0,02 CaCl2)	7.5	6.9
P_2O_5 (CAL, mg/100g soil) available for plants	47.4	10.1
P_2O_5 (mg/100g soil) complete	177.5	67.0
K (CAL, mg/100g soil) available for plants	107.8	69.5
K (mg/100g soil) complete	532.1	439.7
N (mg/ 100g soil)	1,430	351

It has to be considered that the very high amounts of nutrients in these soils are due to the effects of recent forest burning. Higher yields of maize in K'ANKAB soil may be explained by higher seeding densities and a stronger competition for soil nutrients between the associated crops in TSEK'EL soil (Pool, 1986).

5.3 Forest management

Mayan campesinos have a detailed knowledge of the regeneration process which they use in their management of trees and forests. One strategy consists in the protection of particular trees in the milpas during the slash and burn operation. This technique is still widespread among campesinos. All but one farmer in the case studies (Don Apolonio of Becanchen) left a range of tree species scattered throughout their milpas, of which many were nitrogen-fixing species such as *Mimosa* spp., *Piscidia* spp. or *Lysiloma* spp. They may provide a certain part of the nitrogen required to maintain soil fertility (Gomez-Pompa et al., 1993). Flores (1987) pointed out that the abundance of these species may reflect centuries of human selection and protection. It has to be stressed that the campesinos involved in this study protected trees mainly on the stony elevations (TSEK'EL). This may be explained by the stronger fire intensity on K'ANKAB soil due to the high amount of gramineous species which tree species can not resist as well as the farmer's attempt to take fully advantage of K'ANKAB patches for sowing (Arias, personal comment).

Another fact to be stressed is the manner in which trees are cut. All informants cut trees at a height of 0.5 to 1.0 meters, which is of paramount importance for the succession process. Illsley (1984) mentioned an improved survival rate of trees if regrowth is allowed to begin from a high trunk (coppicing). Rico-Gray et al. (1988) found out that although only about 10 percent of the trees of a tropical dry forest in Yucatan may be regrowing from coppices, these may account for more than 50 percent of the biomass during the recovery phase.

5.4 Fallow period and management practises

There appeared to be a correlation between the years of fallow before slashing a new area for the cropping cycle 2000 and the total area under a farmer's cultivation. Shorter fallow periods seemed to go along with larger areas under cultivation (Table 23). The campesinos slashed one to two fields of milpa roza with an average size of 1.8 ha. The number of milpa cañas per farmer was higher, but these plots tended to be smaller (in average 1.2 ha).

It is obvious that soil fertility in a shifting cultivation system cannot be maintained with a decreasing length of the fallow period which provokes a high pressure of weeds as pointed out by several authors (Ruthenberg, 1980, Hernandez X. et al., 1994, Illsley, 1994), associated with a reduction of crop species and increasing operating time in handweeding or external inputs such as mineral fertilisers and herbicides.

Table 23. Fallow period related to area under cultivation (cropping cycle 2000)

Farmer	Fallow period of milpa roza (years)	Total area under cultivation (ha)	Milpa roza		Milpa caña	
			No. of fields	area (ha)	No. of fields	area (ha)
Traditional						
Don Esteban	14	4	1	1.2	5	2.8
Don Valerio	20	6	2	3.4	3	2.6
Don Ignacio	50	4.4	1	2	2	2.4
Modern						
Don Pablo	5	6	2	3.5	2	2.5
Don Jeronimo	10	6	1	2.5	2	3.5
Don Apolonio	8	9	2	4	4	5

The farmers of the case studies who were classified as modern maintained fallow periods shorter than ten years, whereas the fallow period of traditional farmers was much longer (Table 24). With respect to the number of crop species and the number of maize varieties it is obvious that the traditional farmers maintained a higher diversity, which was due to their habit to dedicate a special part of their field (PACH PAKAL) to crops other than maize-bean-squash and to have a seed stock with more varieties than simply the long-cycle XNUC-NAL well suited to soil properties in milpa roza (TSIIT-BAKAL, XHE-UB). None of the traditional farmers applied herbicides, whereas all of the modern did. This may not only be explained by the correlation fallow period/growth of weeds but also by personal preferences of the farmer. Except for one case (Don Jeronimo of Progresito) the application of herbicides did not hamper the mixed cropping with beans and squash, which seemed to be still a common practise among milpa cultivators. Compared with the use of herbicides the application of mineral fertilisers seemed to be less wide-spread in milpas of the first year. Ku Naal (1992) mentioned herbicides to be the first innovation of modern agriculture which was adopted and integrated to the milpa.

Table 24. Fallow period, number of crop species, varieties of maize and use of external inputs in milpa roza fields of Yucatan, 2000

Farmer	Fallow period (years)	Number of crop species	Number of maize varieties	Use of mineral fertilisers	Use of Herbicides
Traditional					
Don Esteban	14	4	2	yes	no
Don Valerio	20	5	1	no	no
Don Ignacio	50	3	3	no	no
Modern					
Don Pablo	5	3	1	yes	yes
Don Jeronimo	10	1	1	no	yes
Don Apolonio	8	3	1	no	yes

5.5 Diversity of crop species and maize varieties

All milpa rozas were planted with a landrace of maize, which was mainly XNUC-NAL, as improved varieties did not seem to be adapted to continued cultivation. Improved varieties were found in distinct milpa cañas with adequate soil type. Apart from one case the number of cultivated crop species and maize varieties were higher in the milpa cañas than in milpa rozas (Table 25). These additional fields provided an important security for the farmers.

Table 25. Number of crop species and maize varieties cultivated in milpa roza and caña

Farmer	Milpa roza		Milpa caña	
	Number of crop species	Number of maize varieties (total/improved)	Number of crop species	Number of maize varieties (total/improved)
Traditional				
Don Esteban	4	2 / -	9	11 / 5
Don Valerio	5	1 / -	3	3 / 1
Don Ignacio	3	3 / -	11	4 / -
Modern				
Don Pablo	3	1 / -	3	2 / 1
Don Jeronimo	1	1 / -	2	2 / -
Don Apolonio	3	1 / -	2	1 / 1

5.6 Farmer's choice of maize varieties

It was common among the campesinos to use maize varieties that were well adapted to specific soil properties. It was evident that farmers differentiated well between more heterogeneous soils sown to medium to long-cycle varieties such as XNUC-NAL, XHE-UB and TSIIT-BAKAL, and on the other side fields with pure K'ANKAB soil sown to local short to medium-cycle (NAL-TEL, XMEJEN-NAL) and improved varieties.

Bellon and Taylor (1993) mentioned the following traits to be important for the farmers in their choice of the most suitable maize variety:

- response to ecological conditions which may be drought avoidance and length of the growth cycle
- suitability to soil type
- performance with intercropping

- input responsiveness
- resistance to lodging as strong winds may knock down plants
- yield level

As the rainy season in Yucatan is characterised by a dry spell of uncertain length (canícula), which may have devastating impact on crop yields, the flowering time of short-cycle maize (NAL-TEL, XMEJEN-NAL and improved varieties) likely falls in this period. With respect to intercropping all but the improved varieties seemed to be suitable. With respect to lodging improved varieties are superior to other varieties due to their shorter stature and stronger stalk.

Table 26. Classification of maize varieties related in farmers fields

Farmer	Milpa roza	Milpa caña 2nd year	Milpa caña on K'ANKAB soil	Solar cultivated with maize
Don Esteban	TSIIT-BAKAL	-	NAL-TEL XMEJEN-NAL XHE-UB NAL XOY V-520 V-527 V-528 V-533	-
Don Valerio	XNUC-NAL	XNUC-NAL	NAL-XOY "Oaxaqueño" TSIIT-BAKAL	-
Don Ignacio	XNUC-NAL White variety XHE-UB	XNUC-NAL TSIIT-BAKAL	-	NAL-TEL
Don Pablo	XNUC-NAL	XNUC-NAL	"Hybrid"	-
Don Jeronimo	XNUC-NAL	XNUC-NAL	-	-
Don Apolonio	XNUC-NAL	-	V-536	-

It has to be pointed out that long-cycle local maize varieties such as XNUC-NAL were favoured over improved varieties in milpa roza and that both improved and short-cycle to intermediate varieties such as NAL-TEL and XMEJEN-NAL were favoured on higher-quality land of milpa caña (Table 26), where they are likely to have an absolute advantage over long-cycle local varieties. On these soils improved varieties were superior to traditional varieties with respect to yield, but only if purchased inputs such as mineral fertilisers were applied. Even those farmers who were classified as "modern" milpa-cultivators by planting extended areas with improved varieties tended to sow the same traditional landrace in the milpa roza. Pereales et al. (1998) stated that a campesino's choice to grow more than one variety simultaneously reflects his need to address numerous needs, which no single variety is likely to satisfy.

All farmers considered improved varieties to be inferior to landraces for domestic use because of their small husks and relatively soft kernels and a subsequently higher insect damage, a fact reported previously by other authors (Bellon and Brush, 1994, Rice et al., 1997). For this reason farmers who planted improved varieties tried to sell them shortly after the harvest. As maize tortillas are an important staple food one may assume that campesino families prefer a certain variety of maize according to taste or nixtamal texture[9], but such differences were not often mentioned by the informants of this study. This may be explained by the statement of Bellon and Brush (1994) that the common use of mechanical mills veils differences between maize varieties as far as grinding or textural properties.

5.7 Gene flow

The concept of "intra-varietal diversity" defined as the amount of genetic diversity found within a given population takes into consideration the possibility that variation occurs within a given crop population or particular variety (Meng et al., 1998). For open pollinated crops such as maize spatial isolation would be required to maintain pure varieties. As in Yucatan land fragmentation is a common feature gene flow among farmers may be less widespread. It certainly depends upon a farmer's awareness to avoid cross-pollination when cultivating different varieties with equal flowering periods. Campesinos were found to isolate their maize varieties in two ways: (1) when planting one field, varieties with different flowering time were selected, (2) varieties with equal flowering time were spatial separated. Nevertheless growing cycles may still overlap because different planting dates may cause flowering to coincide. Bellon and Brush (1994) stated that modern varieties may be transformed from uniform populations into highly heterogeneous ones by a farmer's management practices. This was likely the case with Don Pablo (Yaxcaba), whose improved maize variety was transformed from a purchased uniform population to a heterogeneous one as a consequence of hybridisation with local maize varieties.

[9] Nixtamal is the mixture of maize grain and lime that is made to prepare the maize grain for grinding

5.8 Seed selection

All farmers of these case studies showed similar seed selection practises. The most wide-spread use of maize was for home consumption, therefore an important criterion for the selection of a variety was the storability of the maize ears. This property may be determined by how well the husk covers the ear and by the hardness of the kernels. At seed selection, the selecting person also observed the husk cover of the single ears as it is common to store ears in the husks.

The farmers used to select their seed at home once the ears had been harvested, but not in the field. Bellon and Brush (1994) stated that this habit does not allow farmers to directly take into consideration plant morphological traits, such as stalk strength, but they added that farmers' knowledge associated plant morphology with seed type. Farmers who harvested the same varieties in both milpa roza and milpa caña prefered those of the milpa roza as they produced larger ears. Generally it can be said that the largest well covered ears were opened and then only those selected that had the largest expression of the desired character, based on kernel size, density and shape, cob length and number of seed rows. The selected ears were shelled and it was common to take only the grain from the central part of the ear as seed. Kernels at the bottom and the tip were not used. No preservation of seeds by fumigation was observed except for the purchased improved variety V-536 used for the mechanised field in Becanchen which was treated by the distributor or the seed company.

5.9 Plant densities

The two factors that determine overall stand density are mature plants per planting hole and the spacing of planting holes. The analysis of plant densities did not demonstrate obvious differences for soil type or maize variety.

Table 27. Plant densities of maize-bean-squash mixed cropping

Crop	Average density (plant ha^{-1})	Variation (minimum-maximum)
Maize	25,000	20,000-30,000
Beans	1,800	400-4,270
Squash	1,900	930-4,900

The estimated densities of maize (Table 27) are comparable with those reported from Neugebauer (1987) and Arias (1994). The average number of planting holes ha^{-1} was 7.100 which means an amount 3.5 maize plants $hole^{-1}$. The campesinos stated to put three to five maize seeds in each hole, thus the plant densities were only slightly lower than the original seed densities. The assessments showed an average ratio between maize and beans of 14:1 and between maize and squash of 13:1 or one crop of bean in every fourth and one crop of squash in every 3.7^{th} planting hole. In reality the distribution of the associated crops may vary strongly over space. Campesinos express their manner of planting the secondary crops as follows: *"Seeds of beans and squash fall where they fall."*

The observation of Lazos (1994) that within one field seed densities in K'ANKAB soil are higher than in TSEK'EL could not be confirmed in this study. TSEK'EL soil nevertheless tended to have a lower number of planting holes with a higher average number of maize plants/hole (3.5) than K'ANKAB soil (3.2). An exception with very high densities of 38.400 plants ha^{-1} was found in the mechanised field with pure maize and in the *solar* with 40.500 plants ha^{-1}. The SARH (1990) recommended seed densities of 40.000 for mechanised fields in Yucatan. The solar presented very favourable soil properties with a high content of organic matter (K'AKAB). Teran and Rasmussen (1992) reported a seed quantity of 10 to 12 kg ha^{-1} for maize in Yucatecan milpas, and that 0.5 kg of squash and bean seeds were typically added to 4 kg of maize seed.

5.10 Mixed cropping

The practise of maize-bean-squash mixed cropping still seems to be widespread among milpa farmers in Yucatan as this practise was observed in all but one of the case studies for the milpa roza. Likewise all milpa caña fields apart from two exceptions were mixed cropped. Those were the mechanised field of Don Apolonio of Becanchen with dense stands of pure maize and the fields of Don Pablo in Yaxcaba with two harvest per cropping cycle. Both examples were sown with improved maize varieties with the explicit goal to obtain a high production just of maize. Those farmers who applied herbicides (Gramoxone® or Esteron®) in multiple cropped fields paid attention not to hit squash and beans, as the herbicide application eliminated all crops apart from the gramineae. This was practicable as the associated crops were planted in the same planting hole with maize and were at an early stage of growth. For this reason, the assumption that the use of herbicides displaces mixed cropping (Caamal et al., 1998) does not seem to be always true. The most common varieties of squash and beans associated with maize were XMEJEN-CUM (*Cucurbita moschata* Duch.) and XCOLIBU'UL (*Phaseolus vulgaris* L.). The statement of Brush (1975) that "mixed cropping in the same field and at the same time is common wherever traditional farmers need to maximize total output per unit of area" is transferable to the strategy of milpa farming found in Yucatan: the fact that tall maize, medium stature climbing beans and ground-hugging squash may share the same horizontal space but occupy different vertical levels where they find sufficient room to develop is part of the success of this system. Yields of individual crops may not be as good as if they were planted separately and mixed cropping may also be more laborious (Brush, 1975), but it has to be considered that multiple cropped fields are reported to be less subject to infestation by above-ground pathogens and pests and create desirable, sheltered microenvironments that replicate the structure and diversity of natural stands (Ruthenberg, 1980) thus providing reduced risk to farmers compared to pure stands.

5.11 Maize yields

The three traditional farmers had higher yields in the milpa roza than the modern farmers, which may have several reasons such as more intense seed selection over a long period or a longer fallow period. Another fact is that in all case studies higher yields were found in the milpa caña than in the milpa roza (Table 28).

Table 28. Comparison of maize yields in milpa roza and milpa caña

Farmer	Milpa roza		Milpa caña	
	Yield (kg ha^{-1})	Variety	Yield (kg ha^{-1})	Variety
Traditional				
Don Esteban	1,250-1,500*	TSIIT-BAKAL	1,500-1,750* 1,250* 1,750*	NAL-TEL & XMEJEN-NAL NAL XOY V528
Don Valerio	800-1,000	XNUC-NAL	1,500-1,750	NAL XOY
Don Ignacio	1,250 875 1,375-1,425	XNUC-NAL white maize XHE-UB	1,500 1,375	TSIIT-BAKAL NAL-TEL
Modern				
Don Pablo	800*	XNUC-NAL	1,200*	„Hybrid“
Don Jeronimo	200	XNUC-NAL	200	XNUC-NAL
Don Apolonio	1,000	XNUC-NAL	1,800*	V536

* application of mineral fertiliser

With respect to the range of the yields for the different maize varieties, irrespective of the type of farmer, improved varieties tended to have higher grain yields than traditional ones. Improved varieties are followed by the short-cycle landraces of NAL-TEL and XMEJEN-NAL. The most common variety XNUC-NAL showed the widest range in yields (Table 29). The assumption that longer periods of crop growth are correlated with higher yields could not be observed in this study, but it has to be taken into consideration that the higher-yielding short-cycle varieties were cultivated under conditions superior to those of the milpa roza. These were homogenous K'ANKAB sites where mineral fertilisers and herbicides were applied, or in the case of Don Ignacio of Becanchen a solar with a high content of organic matter. Also one may bear in mind that yields may vary strongly from year to year, depending on rainfall patterns especially during flowering.

Table 29. Variation of yields within maize varieties

Variety	Yield (kg ha^{-1}) max-min
V536	1,800
V528	1,750
NAL XOY	1,250-1,750
XMEJEN-NAL	1,500-1,750
NAL-TEL	1,375-1,750
TSIIT-BAKAL	1,250-1,500
XHE-UB	1,375-1,475
XNUC-NAL	200-1,250

It has to be stressed that yield levels of maize are not dependent upon a single factor but rather upon a complex of several ecological and socio-economical conditions, which may be soil type, length of the fallow period, variety of maize, seed density and the application of herbicides and mineral fertilisers (Lazos, 1994). The assumption emphasized by Pereales et al. (1998) that "modern varieties are always superior to traditional varieties in yield and economic profitability" may be applied to such cases where soil quality corresponds to the demands of improved varieties and where the maize production is clearly geared towards the external market which requires precisely defined qualities of a homogeneous product. But in the Yucatan context with its heterogeneous soils, unpredictable weather conditions and the fact that the major part of the campesinos are subsistence farmers and highly dependent upon their own harvest, for subsistence farmers landraces may still be competitive and superior in growing habits and yield. Furthermore storage losses of modern varieties may outweigh their apparent yield advantage over traditional ones.

6 Conclusions

The persistence of the labour intensive mixed-cropping slash and burn "milpa" system in the maize growing area of Yucatan can be attributed to its adaptation to the edaphic, climatical and economic limitations of the ecosystem in this marginal area. Especially on heterogeneous soils of the milpa roza campesinos continue to plant local varieties of maize. Apparantly so far improved varieties did not displace local varieties as their performance seemed to require more homogeneous and profound soils. On the predominantly stony soils with large spatial variation in productivity landraces remain competitive with improved maize cultivars. "Intraspecific crop diversity" is still a central part of farmers' adaptive strategy to cope with environmental conditions. Diversity of crops and varieties within one farmer's fields is given by the cultivation of smaller plots outside the typical shifting system which presents soil conditions (K'ANKAB) especially suited to individual crop species and maize varieties. Particular varieties are still cultivated by traditional farmers on small areas with the purpose to make use of their special characteristics such as early maturity. The more market-orientated farmers decided to use "milpa caña" fields for the cultivation of cash crops which would not yield in the TSEK'EL soil. In this context the term "milpa caña", originally referring to fields of the second or following cropping cycles, may get another meaning as in several cases these fields carried a modernised type of the farmer's milpa system. It was evident throughout the survey that farmers maintained their plant genetic resources while at the same time adopting modern agricultural technology such as mineral fertilisers, herbicides and improved maize varieties.

Shifting cultivation is generally regarded as an unsustainable mode of agricultural production. But consciously and rationally realised by small farmers it is not more than a temporary and reversible transformation of nature. Each year milpa farmers clear a new area with the help of fire, but equally every year an area similar in size is abandoned and left for prolonged fallow. Milpa destroys forest and at the same time remains intrinsingly part of it. With an adequate length of fallow, milpa agriculture was and still is the most adapted agricultural system to the ecosystem of the Yucatan peninsula.

Duch et al. (1998) did not note decreasing maize yields for the period of 1930-1990 in the traditional maize producing area of Yucatan, rather a stagnation of yields at 700 to 900 kg ha^{-1}. But overall maize production did not increase with increasing population over time. As the scarce K'ANKAB is the only soil type were maize production can be intensified, such overall increases are hard to expect

While partial adoption of modern technologies took place within the traditional milpa system its conversion into a “high input high output system” would likely result in its destruction as a multi-dimensional strategy of adaptation to environmental and social constraints. A decrease in labour availability and the access to government subsidies and loans have led to an increased use of agrochemicals. But the use of external inputs may vary from year to year, as it is dependent on the campesinos’ cash availability.

7 Summary

Six case studies have been conducted to investigate the Status quo of the traditional shifting cultivation system "milpa" in the south-eastern Mexican state of Yucatan. Until today milpa agriculture is heavily based on ancient knowledge of land husbandry but also influenced by the technologies of modern agriculture. For more than three millennia this mode of cultivation has been the basis of food production for the Mayan population and was characterised through a productive and self-sustaining system with long fallow periods and the management of a high degree of plant diversity. But due to an increase in population the milpa is not anymore capable to produce sufficient food. This resulted in shortened fallow periods, decreasing soil fertility and an increasing pressure of weeds. Farmers counteract these problems with the application of mineral fertilisers and herbicides.

The case studies were carried out in the villages of Yaxcaba, Becanchen and Progresito, located in the traditional maize growing area of Yucatan. Two farmers per village were selected to analyse their cultivation strategy on the basis of soil, plant and management parameters. Efforts were made to categorise the farmers into "modern" and "traditional" with the purpose to document two extreme production strategies.

The first part of this study is devoted to a detailed description of the environmental conditions which are limiting agriculture in Yucatan, as well as to an introduction into the land use system of the milpa. The results of the case studies are illustrated and discussed with respect to farmer's decisions on which production strategy to choose according to ecological limitations and the availability of genetic resources.

For both, modern and traditional farmers, the use of local landraces and maize-bean-squash mixed cropping was found to be common on the very heterogeneous soils which presented in general a mosaic of Lithosols and Luvisols. Modern farmers tended to intensify only the more profound and homogeneous soils through the use of improved varieties and the application of mineral fertilisers and herbicides. Traditional farmers, in contrast, continued the cultivation of a range of local maize varieties and additional food crops satisfying different household needs and the farmers' interest in preserving genetic material.

The study also revealed that there still existed a wealth of traditional knowledge among milpa farmers which was combined to different degrees with modern inputs. It depended upon the socio-economic condition of the family unit whether a farmer tended to use more modern technologies or relied upon his traditional knowledge about milpa cultivation. But under the given circumstances of this location-specific production system, partial adoptions of external inputs are not able to displace the adapted tradtitional cultivation strategies at the large scale.

Resumen

El objetivo de este trabajo fue documentar y discutir las condiciónes actuales que afectan la agricultura tradicional en el sistema de roza-tumba-quema de la Peninsula de Yucatán en el Sureste de México. Desde hace tres milenios la milpa fue la fuente fundamental de alimentos básicos en la cultura Maya y está caracterizada por una gran diversidad en cultivos y un ciclo largo de barbecho. Hoy este sistema está enfrentado a un incremento en la población acompañado de un decremento en la productividad de la tierra. Los efectos más evidentes de la profunda crisis de la milpa yucateca son un acelerado deterioro del suelo, de la vegetación secundaria y de la diversidad genética. Muchos productores se sirven de tecnologías modernas como son el uso de fertlizantes y herbicidas para mantener el nivel de producción.

Las investigaciónes fueron realizadas en las comunidades de Yaxcabá, Becanchén y Progresito, que se encuentran en la zona maicera del Estado de Yucatán. Con el fin de analizar las estratégias agrícolas por medio de parámetros del suelo y de cultivos, en cada localidad un productor "tradicional" fue comparado con un productor "moderno" para obtener un gradiente entre casos extremos.

La primera parte de esta tesis se dedica a la descripción del medio ambiente que caracteriza la peninsula de Yucatán y de una introducción general de la agricultura milpera. Después los resultados están presentados y analizados mediante explícitos parámetros que determinan las estratégias del productor enfrentarse al ecosistema.

Los resultados demuestran una adaptación de los cultivos de la milpa a las condiciones edáficas muy pedregosas y heterogéneas a través de variedades locales de maíz y el policultivo con calabaza y frijol. En parcelas adicionales con suelos más profundos y de mejor calidad se observa en el caso de los productores tradicionales una tendencia a diversificar. En cambio los productores modernos tienden a intensificar la producción en esas parcelas. La intensificación se realiza tanto por variedades mejoradas de maíz como por el uso de fertilizantes y agrochemicos. Milperos tradicionales siembran más variedades de maíz del ciclo corto y otras especias de plantas alimentarias para el autoconsumo.

El estudio confirme que la agricultura milpera tradicional es muy adaptada a las condiciones ambientales de la Peninsula aun en las condiciónes economicas de estos dias. Es común entre los productores de combinar sus conocimientos tradicionales con inovaciones tecnológicas. El grado en que el campesino va a adaptar inovaciones modernas o continuar sus practicas tradicionales depende del ambiente socio-económico. Pero remedios externos no están capaz de sustituir tecnológicas tradicionales en gran escala en este sistema.

Zusammenfassung

In dieser Arbeit wird anhand von sechs Fallstudien der Status quo des traditionellen Brandrodungsfeldbaues der Maya in Yucatan/Südost Mexiko dokumentiert und diskutiert. Im Hintergrund steht die Frage nach dem heutigen Entwicklungsstand der "Milpa"-Landwirtschaft. Seit mehr als drei Jahrtausenden stellte es als ein hoch diverses Anbausystem die Grundlage für die Nahrungsmittelproduktion dar, und zeichnete sich durch einen in sich geschlossenen Kreislauf mit langen Bracheperioden aus. Aber auch dieses landwirtschaftliche System blieb in den letzten Jahrzehnten nicht unberührt von modernen Einflüssen.

Das Hauptproblem der kleinbäuerlichen yucatekischen Landwirtschaft liegt in einem starken Bevölkerungswachstum, welchem die Produktion an Grundnahrungsmitteln nicht mehr gerecht werden kann. Durch verkürzte Bracheperioden sind die Sekundärwälder nicht mehr in der Lage, die Bodenfruchtbarkeit aufrechtzuerhalten und der jüngere Sukkzessionsstand der Sekundärvegetation ruft einen erhöhten Unkrautdruck hervor. Viele Campesinos reagieren hierauf mit dem Einsatz von Herbiziden und mineralischen Düngemitteln.

Die Fallstudien wurden in den drei Dörfern Yaxcaba, Becanchen und Progresito durchgeführt, welche im traditionellem Maisanbaugebiet von Yucatan liegen. Es wurden bei jeweils zwei Bauern pro Ort eine Vielzahl von Boden-, Management- und Pflanzenparametern erhoben. Je ein Bauer wurde als "traditionell" bzw. "modern" eingestuft, um zwei Extreme betreffend der Anbaustrategie miteinander vergleichen zu können.

Der erste Teil dieser Arbeit widmet sich der Beschreibung des Naturraumes als Einflussfaktor auf die Landnutzung in Yucatan, sowie einer Einführung in das Anbausystem "Milpa". Anschließend werden die Fallstudien dargestellt und die Ergebnisse anhand von Parameter gegenübergestellt und diskutiert welche die Produktionsstrategien der Bauern beeinflussen.

Die Ergebnisse zeigen, dass die sehr heterogenen Böden, welche in der Regel aus einem Mosaik von Lithosolen und Luvisolen bestehen, mit lokalen Landsorten von Mais und generell in Mischkultur mit Bohnen und Kürbissen bestellt werden, unabhängig von der weitern Anbaupraxis des Bauern. Jedoch werden zusätzliche Flächen mit homogeneren Bodenverhältnisse intensiver und mit anderen Maissorten kultiviert. Hier konnte eine stärkere Differenzierung zwischen moderner Anbaupraxis in Zusammenhang mit verbesserten Sorten, dem Einsatz von externen Hilfsmitteln und einer stärker marktorientierten Produktion getroffen werden. Auf der anderen Seite wurde eine Vielfalt von verschiedenen Maissorten und weiteren Nahrungspflanzen zum Zweck der Selbstversorgung gefunden, einhergehend mit der Erhaltung von lokalem genetischen Material und einer starken Identifizierung der Bauern mit ihrem landwirtschaftlichen System.

Wohl aufgrund der starken Anpassung an die marginalen Standortbedingungen Yucatans ist noch ein großes traditionellem Wissen über die Milpa vorhanden. Dieses Wissen wird von Bauern angewendet und mit modernen Hilfsmitteln kombiniert. Diese Beobachtungen legen nahe, daß es vom sozio-ökonomischen Umfeld des Bauern und seiner Familie abhängt, in welchem Umfang Innovationen angenommen und mit traditionellem Wissen kombiniert werden. Unter den gegebenen Umständen dieses sehr standortspezifischen Produktionssystem sind moderne Technologien jedoch nicht in der Lage, traditionelle Anbaustrategien in großem Umfang zu ersetzen.

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Appendices

Appendix A: Glossary of Mayan terms

Appendix B:

Appendix B_1: Pictures of maize varieties

Appendix B_2: Classification of traditional maize varieties

Appendix B_3: Ear characteristics of short-cycle maize varieties

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Appendix A

Glossary of Mayan terms used in the study

CH'OCH'OL	abundance of small stones
DZONOT	limestone caverns
EK'LUUM	black soil with high content in organic matter
HALTUN'OB	small limestone hollows
HUB'CHE	secondary forest with a vegetation regrowth of 2-3 years
K'AKAB	dark soil high in organic matter
K'ANKAB	red soil, Luvisols / Cambisols
MACAL	tubercle crop
NAL	maize
PACH PAKAL	small patch in the milpa dedicated to special crops
PUSLU'UM	dark shallow soil with abundant small stones
TSAMA'	special variety of beans (*Phaseolus vulgaris* L.)
TSEK'EL	dark, shallow and stony soil, Lithosols / Rendzinas
XCAT	variety of chillies (*Capsicum annum* L.)
XCOLIBU'UL	bean (*Phaseolus vulgaris* L.)
XMEJEN CUM	short cycle variety of squash (*Cucurbita moschata* Duch.)
XNUC CUM	long cycle variety of squash (*Cucurbita moschata* Duch.)

Appendix B_1

Pictures of maize varieties

Plate 1. NAL-TEL (50 days), 8.5 - 12 cm

Plate 2. XMEJEN-NAL (75 days), 12 - 14 cm

Plate 3. XMEJEN-NAL x PIX CRISTO (90 days), 13 cm

Plate 4. TSIIT-BAKAL (105 days), 11 - 17.5 cm

Plate 5. XNUC-NAL (120-150 days), 14 - 16 cm

Plate 6. XHE-UB (120 days), 10.5 - 14 cm

Plate 7. NAL XOY (75-90 days), 15 - 18 cm

Plate 8. V-527 (105 days), 13 - 15 cm

Plate 9. V-536 (75 days), 16 cm

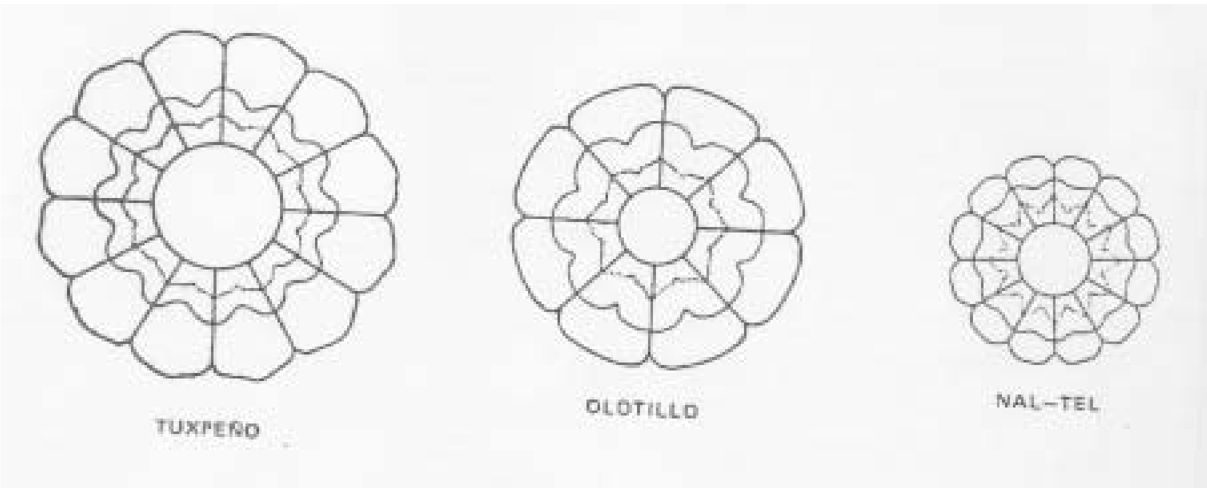
Plate 10. Improved variety cross-pollinated with local landrace (75 days), 15 cm

Appendix B_2

Classification of traditional maize varieties

Race	Variety	Colour	Growing cycle (days)
Tuxpeño	XNUC-NAL	white/yellow	120-150
	XHE-UB	purple	120-150
	PIX-CRISTO	red	120-150
TSIIT-BAKAL	TSIIT-BAKAL	white/yellow	105
	XMEJEN-NAL	white/yellow	60-90
NAL-TEL	NAL-TEL	white/yellow	50

NAL-TEL is an ancient indigenous race which originated from a primitive maize in Mexico. It is well adapted to areas with low altitude and mainly found in the Peninsula of Yucatan. Pure populations of NAL-TEL are rare, but its genetic influence on other varieties is remarkable. It typically produces a number of intermediate varieties and created a new race known as TSIIT-BAKAL. The intermediate varieties of TSIIT-BAKAL and XMEJEN-NAL are both influenced of NAL-TEL and XNUC-NAL. The long-cycle variety of XNUC-NAL belongs to the race "tuxpeño" which is widespread in Mexico and often used in plant breeding programs.



Source: Wellhausen et al. 1987. Razas de maíz en Mexico, su origen, características y distribución. *In* Hernandez X. Xolocotzia Volume II. Revista de Geografía Agrícola, Universidad Autonoma Chapingo.

Appendix B_3

Ear characteristics of short-cycle maize varieties

Variety: NAL-TEL Farmer: Don Esteban, Yaxcaba

	Sample										
Characteristics	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Means**
Number of rows	14	10	12	14	14	14	18	18	16	14	**14.4**
Ear length (cm)	11.5	13.8	16.3	15	14.2	14.5	16.6	14.6	12.7	11.5	**14.1**
Ear diameter (cm)	14	13.8	12.5	13	13.1	13.3	12.5	13.4	13	12.3	**13.1**
Number of kernels	276	270	402	424	518	428	425	417	350	348	**386**
Kernel weight (g)	56.5	48	69	58.5	60	52	42.5	50	45.5	38	**52**

Variety: NAL-TEL Farmer: Don Ignacio, Becanchen

	Sample				
Characteristics	**1**	**2**	**3**	**4**	**Means**
Number of rows	14	18	14	16	**15.5**
Ear length (cm)	12.7	16	16.4	15.7	**15.2**
Ear diameter (cm)	13	14.4	11.9	13.1	**13.1**
Number of kernels	397	511	430	378	**429**
Kernel weight (g)	63.5	89.5	58	77.5	**72**

Variety: XMEJEN-NAL Farmer: Don Esteban, Yaxcaba

	Sample					
Characteristics	**1**	**2**	**3**	**4**	**5**	**Means**
Number of rows	16	18	14	18	16	**16.4**
Ear length (cm)	15.5	18.2	14	14.8	15	**15.5**
Ear diameter (cm)	15.7	14.5	14.3	13.8	14.5	**14.6**
Number of kernels	495	656	368	474	496	**498**
Kernel weight (g)	87.5	83	68	54.5	64.5	**71.5**

Variety: "Hybrid" **Farmer: Don Pablo, Yaxcaba**

	Sample							
Characteristics	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Means**
Number of rows	16	18	14	14	14	16	14	**15.1**
Ear length (cm)	17.8	15.2	17.8	24	17.2	18.9	17.8	**18.4**
Ear diameter (cm)	16.5	16.7	16.2	16.5	14.5	15.5	14.2	**15.7**
Number of kernels	438	408	454	413	318	425	422	**411**
Kernel weight (g)	142.2	146	168	157	135	159.5	126.5	**147.7**

Variety: V-536 **Farmer: Don Apolonio, Becanchen**

	Sample				
Characteristics	**1**	**2**	**3**	**4**	**Means**
Number of rows	16	16	16	18	**16.5**
Ear length (cm)	18.8	19	19.5	15.4	**18.2**
Ear diameter (cm)	14.7	17	15.5	15.7	**15.7**
Number of kernels	485	525	475	535	**505**
Kernel weight (g)	162.5	199.5	171	144.5	**169**

Appendix C :

Profile description of three Yucatan soil types

1. Rendzina

Location	Chunhuhub irrigation settlement area, Yucatan
Altitude	About 1 masl
Parent material	Mainly coral limestone

Profile description

A	**0-18 cm**	Brownish black gravelly clay; friable moist, rather soft dry but with slightly hardened peds; slightly sticky and very plastic when wet; strongly developed fine angular blocky structure with some coarse granules; roots abundant; boundary highly irregular but quite sharp.
C	**18+**	Strongly fragmented limestone and limestone gravel with stained surface; some limestone fragments show a pinkish colour when broken; soil continues on downward fissures in limestone and has more brownish colour than the topsoil.

2. Chromic Cambisol

Location	3 km S of town of Uman on the road to Uxmal
Altitude	About 45 masl
Parent material	Probably mainly marine coastal mud with some volcanic ash drifted on to reef and uplifted *in situ*

Profile description

Ah	**0-15 cm**	Dark reddish brown clay; friable when moist, loose when dry; moderately sticky and very strongly plastic when wet; very strong (cast) granular structure, breaking to very fine granules and crumbs; no clayskins; many roots; boundary indistinct.
Bw	**15-27 cm**	Dark reddish brown clay; almost massive structure in place and very porous, breaking easily in the hand to moderatly developed coarse subangular blocky structure, and breaking further to weakly developed fine and very fine angular blocks, coarse and fine granules and crumbs; no clayskins; consistency slightly firm when moist, slightly hard when dry; slightly sticky and very strongly plastic when wet; slightly compact and fairly hard to dig at all moisture contents; roots common; boundary abrupt; very hard white limestone with a "washed" surface.

3. Chromic Luvisol

Location	Chichen Itza, Yucatan
Altitude	About 70 masl
Parent material	Probably volcanic tuff impurities in limestone and volcanic marine mud in place on coral when platform uplifted

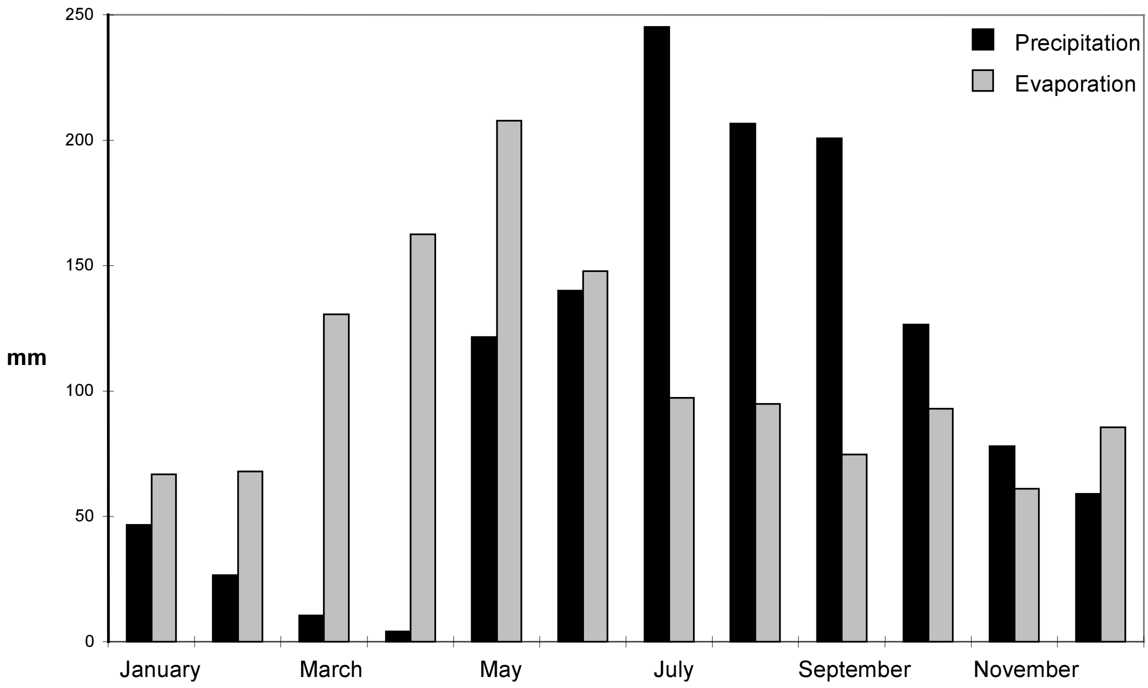
Profile description

Ah	**0-8 cm**	Dark brown, reddish brown clay; firm when moist, slightly hard when dry; slightly sticky and very plastic when wet; moderately developed medium and coarse subangular blocky structure, breaking to very fine subangular and angular blocks and coarse (cast) granules; abundant roots; boundary gradual.
AB	**8-18 cm**	Dark reddish brown clay; firm moist, slightly hard dry; slightly to moderately sticky and moderately to strongly plastic when wet; almost massive structure in place, breaking abruptly under pressure to weakly developed composite structure of very fine (cast) granules and fine to very fine subangular blocks; roots common; boundary indistinct.
Bt	**16-60 cm**	Reddish brown and red clay; patches firm and firm to friable when moist, very slightly hard when dry; slightly sticky and moderately to strongly plastic when wet; more or less massive in place but shows very weakly developed coarse angular and subangular blocky structure when drying out and these blocks break suddenly under light pressure to very fine rounded granules and powder; few roots; boundary irregular but abrupt.
R	**60+**	Very hard crystalline limestone of pinkish white colour; some large blocks, some smaller fragments, soil continuing down the fissures in the soil.

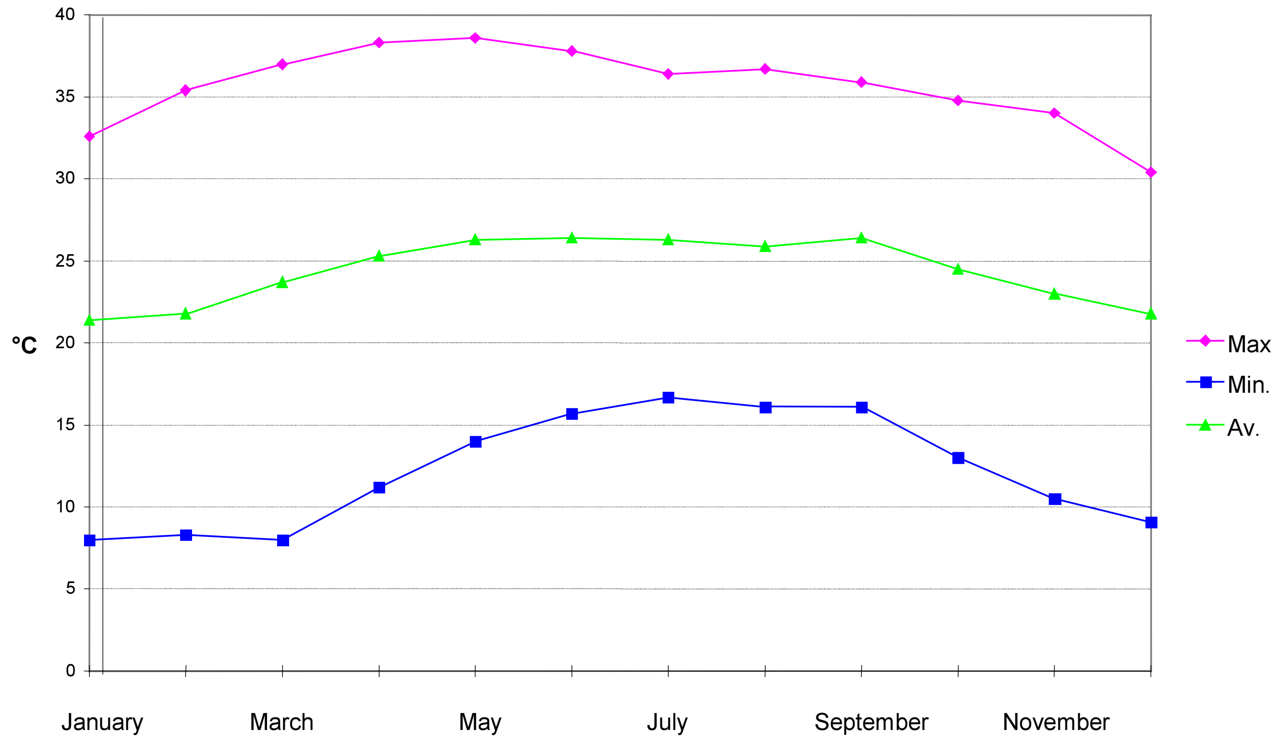
Source: FAO. 1975. Soil map of the world. Volume III. Mexico and Central America. FAO-UNESCO, Paris, France.

Appendix D

Climatic data of the case study villages



Monthly precipitation and evaporation of Sotuta (Yaxcaba), 1999



Monthly maximum, minimum and average temperature of San Diego Buenavista (Becanchen), means of the 1992-1999 period
Source: Comision Nacional del Agua (2000)

Appendix E

Guide of questions used in the interviews

Soil preparation and clearing method

- how long was the fallow period before slashing the vegetation?
- in which month the field was cleared?
- date of burning?
- was the fire considered to be successful?
- which tree species were selected to remain in the field, do they have a special use?
- how old is the vegetation around the field?

Soil quality

- how are the soil types classified according to the Mayan terminology?
- how is the soil fertility to be considered?
- how is the water retention of the soil?
- on which soil type does the maize perform better when there is scarce rain?

Crops

- how much maize varieties are sown?
- are they improved or traditional varieties?
- what are their names and how long is their growing period?
- when is the time of flowering?
- which steps are undertaken to prevent maize varieties from cross-pollination?
- are special varieties sown to a distinct soil type?
- does the variety have a special characteristic which is considered to be important?
- since how long the variety is cultivated?
- is seed exchange practised with other farmers?
- is mixed cropping performed? With which species?
- is a distinct part of the field dedicated to a PACH PAKAL?
- how much seeds of maize/squash/beans are placed in each seed hole?
- in which month the maize will be bended and between which month the harvest will be carried out?
- which grain yields for maize are to be expected, how were yields in previous years?
- how will the maize be stored ?

Seed selection of maize

- will ears dedicated for next seasons seed be stored separately?
- when does seed selection take place, shortly after harvest or just previous to sowing?
- do seeds come from a distinct soil type or special field (Milpa roza/caña)?
- which ear characteristics are decisive for selection?

Management practises

- is handweeding practised?
- are herbicides applicated (which type of herbicide and at which amount)?
- are mineral fertilisers used (type and amount)?
- do weed pressure and soil fertility allow continued cultivation in the field?

Socio-economic background

- has maize to be purchased as the own harvest does not cover the demands of the household?
- will maize be sold? Which variety will be sold preferably?
- how was milpa cultivation in previous years?
- does there exist the intention to change the cultivation mode in future years?
- how is the family involved/interested in milpa cultivation?