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# ADAPTATION OF MAYA HOMEGARDENS BY "CONTAINER GARDENING" IN LIMESTONE BEDROCK CAVITIES

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ABSTRACT.—The northern Maya Lowlands of the Yucatán Peninsula are often characterized by outside observers as a challenging environment for agriculturalists. The limestone bedrock appears to have only a patchy cover of thin soil, yet the Maya inhabitants, both ancient and modern, have managed to successfully cultivate this landscape through a variety innovative techniques and micro-scale adaptations. Homegardens have a long history in the region, and continue today to provide most of the diversity in the Maya diet. Adaptation of Maya homegardeners to the thin soil of the northern peninsula may best be described as container gardening, in which natural cavities in the limestone bedrock serve as planters. The deep, vertical A-horizons of the bedrock cavities are not recognized in regional characterization of the soil, yet they may represent the primary soil resource for homegarden adaptation in portions of the northern Maya Lowlands.

Key words: Maya, agriculture, homegarden, Yucatán, soil.

RESUMEN.—El norte de las tierras bajas mayas de la Península de Yucatán ha sido caracterizado por observadores externos como un reto ambiental para los agricultores. La plataforma de roca caliza parece tener sólo una delgada y desigual cobertura de sedimento, aun así, los habitantes mayas, tanto antiguos como modernos, han logrado cultivar con éxito este paisaje a través de una variedad de técnicas innovadoras y adaptaciones a micro escala. Los jardines domésticos tienen una larga historia en la región, y continúan hoy en día proporcionando la mayor parte de la diversidad en la dieta Maya. La adaptación de los jardines domésticos a los delgados sedimentos de la zona septentrional de la península puede ser descrita de una mejor manera como maceteros, en donde las cavidades naturales de la roca caliza sirven como contenedores. Los profundos y verticales horizontes de las cavidades rocosas no son reconocidos en la caracterización regional de los suelos, sin embargo pueden representar el principal recurso para la adaptación doméstica en regiones del norte de las tierras bajas mayas.

RÉSUMÉ.—Les plaines Maya du nord de la Péninsule Yucatan sont souvent caractérisées par les observateurs extérieurs comme un environnement de défi pour les agriculteurs. La roche calcaire est inégalement couverte d'un sol peu épais, mais les habitants Mayas, anciens autant que modernes, ont réussi à cultiver ce paysage au moyen d'une variété de techniques innovantes et d'adaptation à petite échelle. Les méthodes d'agriculture intensives ont une longue histoire dans la région, et continuent aujourd'hui de fournir la plupart du régime alimentaire Maya. L'agriculture à conteneurs, dans laquelle les cavités naturelles des roches calcaires servent de pot, peut décrire le mieux la manière dont les Mayas se sont adaptés aux sols peu épais du nord de la péninsule. Les A horizons verticales et profondes des cavités rocheuses ne sont pas reconnues dans la caractérisation régionale des sols, mais ils peuvent représenter le premier sol de ressource pour l'adaptation de l'agriculture intensive dans certaines parties des plaines Maya du nord.

## INTRODUCTION

Many non-Maya observers have long noted the apparent lack of soil in the northern Yucatán Peninsula, beginning perhaps with Diego de Landa's commentary of 1566 that ''Yucatan is the country with least earth that I have seen, since all of it is one living rock and has wonderfully little earth … And among the stones and over them they sow and all their seeds spring up and all the trees grow and some so large and beautiful that they are marvelous to see.'' (Tozzer 1941:186).

To the casual observer of today, the landscape of northern Quintana Roo, in the northeast Yucatán Peninsula, looks particularly uninviting for the farmer or gardener. Where patches of forest or secondary growth have recently been cut and burned, the resulting landscape resembles more of a moonscape than a potential garden or agricultural field. Limestone bedrock dominates, with only patches of soil visible like islands in a sea of stone. The modern soil maps available for the region, generalized at a scale of 1:250,000, also characterize the region as lacking in soil resources. Yet within this regional landscape, a visit to a traditional Maya homegarden immediately presents the first-time visitor with an apparent contradiction. Lush, healthy fruit trees, medicinal herbs, tomatoes, chilies, and a great variety of other useful plants appear to be growing out of solid rock.

The current study explores the landscape described by de Landa over 400 years ago in an attempt to better understand the limestone geology, soil environment, and the ways in which the Maya have adapted to this challenging landscape for over three millennia. The adaptation of Maya gardeners in parts of the northern Maya Lowlands might best be described as ''container gardening,'' in which natural cavities in the limestone bedrock serve as planters. In recent years there has been an increasing interest in container gardening as a means to produce food in urban settings where land for cultivation is lacking (e.g., Cleveland and Soleri 1991:125–129; McGee and Stucky 2002; Saydee and Ujereh 2003), but a thorough overview of the subject from a cross-cultural anthropological or ethnobotanical perspective is lacking.

Our study focuses on a modern homegarden in the traditional Maya village of Naranjal, northern Quintana Roo, Mexico. The size, variety of plants, and amount of bedrock exposure in the garden we selected for study is typical for the Yalahau region (Figure 1). Additional information on homegarden adaptation

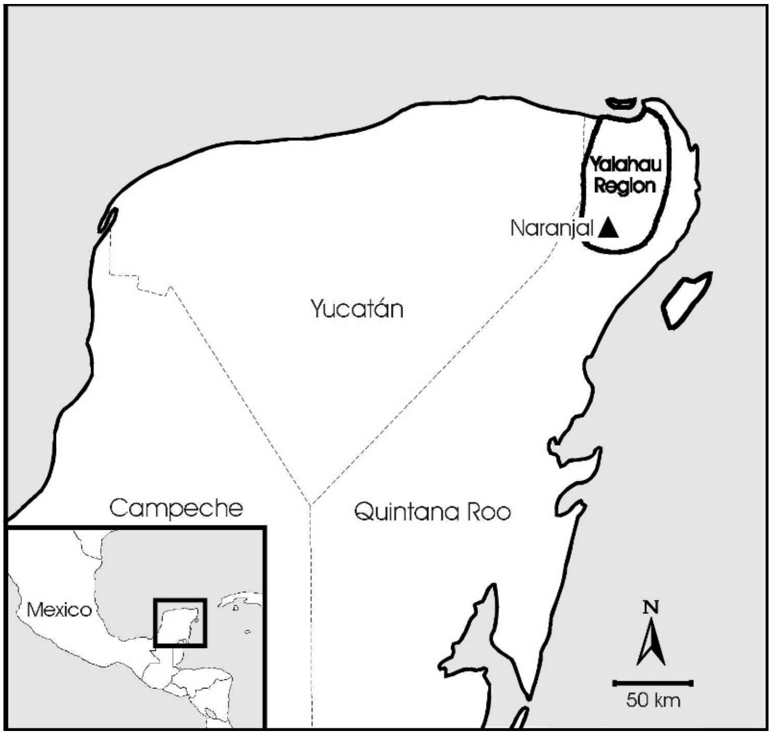


FIGURE 1.—Location of the study area.

was obtained from several other gardens in the region, as identified in our discussion. This study highlights the ways in which our standard scientific methods of resource quantification and land evaluation may misjudge the agricultural potential of the northern Maya Lowlands.

## VARIABILITY IN AGRICULTURAL ADAPTIVE REGIONS OF THE MAYA LOWLANDS

For many years, scholars perceived the Maya Lowlands as a relatively uniform environment of tropical forest growing from soil that was thin and of generally poor quality. Beginning in the 1970s, and continuing today, there is a growing recognition of environmental heterogeneity within the Maya Lowlands, and an appreciation for the ways in which Maya farmers, both ancient and modern, have adapted to this variable landscape (Bautista and Palacio 2005; Dunning et al. 1998; Fedick 1996a, 2003; Gomez-Pompa et al. 2003). While the recognition of regional environmental variability has improved our understanding of Maya agricultural adaptation, micro-environmental variability of land resources often is not apparent on the land surface, is obscured by generalization during mapping, or is too fine-scaled to be registered by standard quantification methods (Fedick 1996b). Such is the case with the unusual soil environment associated with the pocked-bedrock landscape of the Yalahau region.

*The Yalahau Region*.—The current study focuses on the Yalahau region in northern Quintana Roo (Figure 1). Geologically, the surface limestone deposits of the Yalahau region are of relatively recent origin, dating to the Miocene-Pliocene Epochs (Weidie 1985). The region is characterized by over 300 wetlands that are linked directly to the freshwater aquifer (Tulaczyk et al. 1993). Other common landscape features are a variety of karstic sinkholes and depressions that present microenvironments of soil and water resources ranging in diameters from 100 m to only a few centimeters. Because these features account for a relatively small percentage of the land surface, they are not included in available soil maps (1:250,000 scale), and are dramatically under-represented on available topographic maps (1:50,000 scale). Under conventions for generalization in mapping, it would require maps compiled at a very large scale of at least 1:10,000 to include even the largest of the karst sinkholes (Fedick 1996b:338–342).

The most common karstic feature of the northern Maya Lowlands are *cenotes*, naturally formed sinkholes in the limestone bedrock that often extend below the modern water table and sometimes link to extensive underground river systems. *Cenotes* began as caves formed by solution of limestone as rainwater percolating down through fissures and cracks in the bedrock. Eventually, the roofs of these caves collapsed, and as sea levels rose after the Pleistocene, the water table also rose to partially inundate the caves, resulting in the large, deep cavities with openings to the sky. Deeper *cenotes*, particularly those linked to underground river systems, are generally flushed of most sediments and remain water-filled cavities. Other forms of sinkholes, ranging from shallow, dry *rejolladas* to seasonally flooding *corchales*, are not linked to underground water flow, and therefore accumulate sediments and foster deeper soil formation (see also Houck 2006:62–65). Maya farmers, both ancient and modern, have made use of these ''dry *cenotes*'' as sunken gardens (Gomez-Pompa et al. 1990; Houck 2006:74–75; Kepecs and Boucher 1996).

While *cenotes* are fairly common throughout the northern lowlands in varying concentrations, the Yalahau region is characterized by an unusually high occurrence of smaller solution features. Cavities extending down from the surface of the bedrock range from a few centimeters to several meters in diameter, with depths of similar scale (Figures 2 and 3). These cavities often tend to grow wider with depth, forming bell-shaped chambers similar to the larger *cenotes*. Also like *cenotes*, the smaller cavities are sometimes free of soil, with sediments apparently washing deep down into fissures and possibly being flushed out to sea through linkages with underground streams. Other cavities contain deep deposits of soil.

The formation of this pock-marked landscape is most likely influenced by the local hydrogeology. Rainfall patterns in the region are highly variable, both seasonally and over long-term cycles. With the dry season water table only a few meters below the surface, fluctuations in the water table vary greatly, resulting in a constant and rapid cycle of saturation and drying of the near-surface bedrock, likely resulting in the development of a fine-scale pattern of surface solution features. As the surface capstone is harder than the underlying soft bedrock or unconsolidated limestone (referred to locally as *sascab*), the solution features tend to be restricted at the surface, forming larger chambers below the caliche

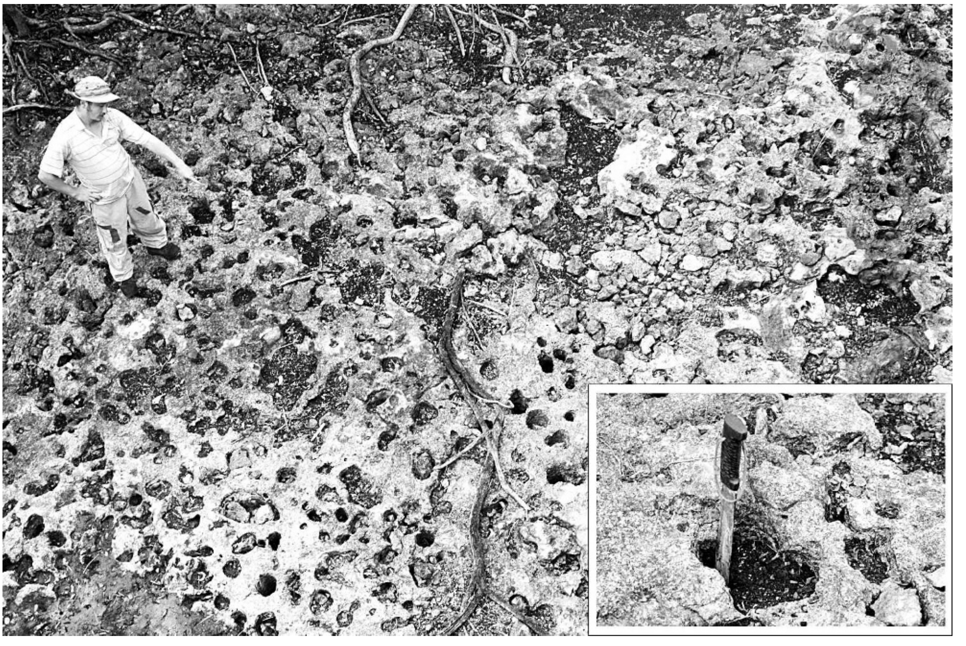

FIGURE 2.—Cavities in the limestone bedrock near the wetland at the El Edén Ecological Reserve. Inset shows a machete pushed 50 cm into a soil-filled cavity.

capstone. The formation of surface cavities is most pronounced along the margins of the seasonally inundated wetlands of the Yalahau region, while still finding strong expression in upland areas well-away from the flood zone wherever the water table is within a few meters of the surface during the dry season.

At a macroscale characterization (1:250,000), soil of the Yalahau region is classified as a lithosol, which is characteristically less than 10 cm in depth over bedrock (Bautista et. al 2005b). As noted above, local variability in land resources if often masked at macro scales, and the characteristics most favorable for agriculture may be recognizable only at microscale levels of observation and analysis. We suggest that the small, soil-filled cavities of the region hold a significant percentage of the soil resources, and are the focus of traditional Maya homegardens in the Yalahau region.

## THE STUDY SITE

The homegarden described in this study is in the village of Naranjal, located in the southern portion of the Yalahau region. The village is the population center of a communal landholding unit, or *ejido*, that is home to about 14 families. The modern community is situated within the ruins of a large ancient Maya site that has been the subject of archaeological studies since 1993 (Fedick and Mathews 2005). The village is situated near the southern end of a freshwater wetland that covers an area of about 500 ha, and lies within a north-south linear depression surrounded by gently undulating terrain. The wetland is perennial, with the

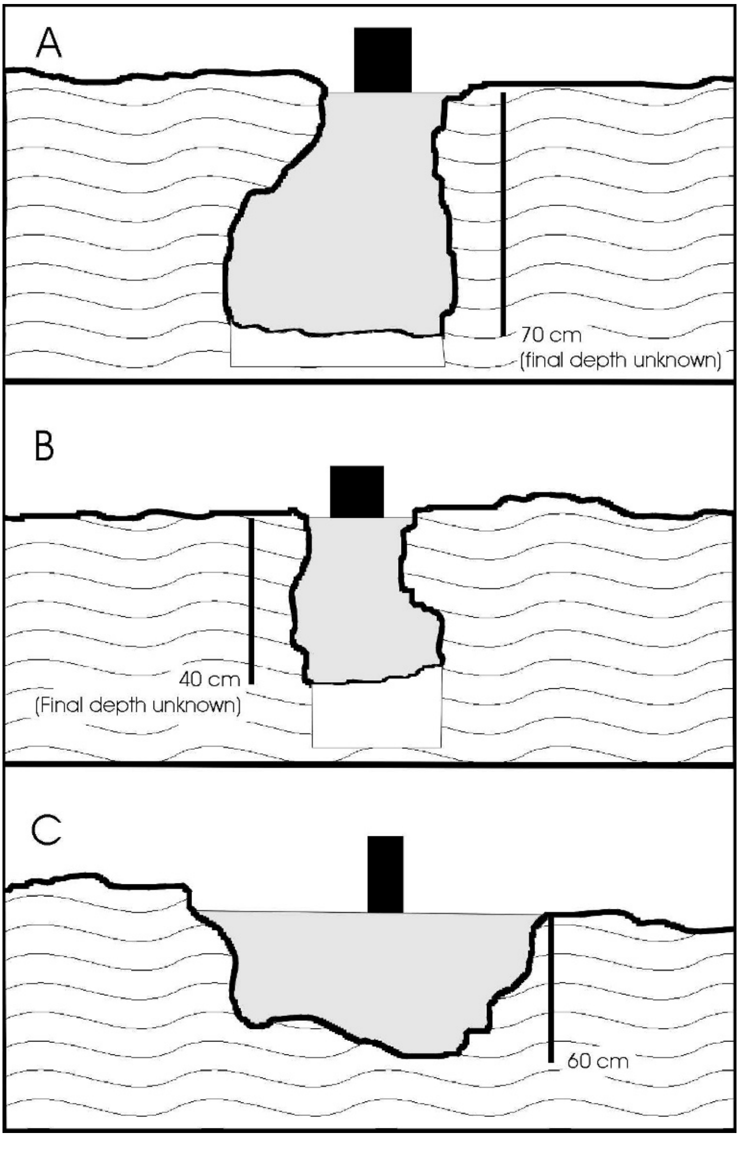


FIGURE 3.—Cross-section drawings of bedrock cavities in the Naranjal homegarden. A) avocado (*Persea americana* Mill.) tree height = 300 cm; B) cherimoya (*Annona cherimola* L.) tree height = 200 cm; C) chaya (*Cnidoscolus chayamansa* McVaugh) shrub height = 200 cm.

water level rising and lowering significantly during alternating wet and dry seasons. It is dominated by thick stands of cattail (*Typha dominguensis* Pers.) and sawgrass (*Cladium jamaicense* Crantz). The wetland is not used as a source for drinking water, which instead comes from numerous wells scattered throughout the village, where the water table generally lies within 2 or 3 m of the surface.

The family parcel or *solar*, that includes the homegarden under study measures roughly 50 m × 50 m, for an area of 0.25 ha. The family also makes use of 4 ha of land for milpa cultivation using traditional slash-and-burn cultivation of maize, beans, squash, etc. The location of the current homegarden was originally cleared and used as a milpa. When the family decided to settle the parcel in 1991, the garden was established, including the planting of numerous trees. A rapid visual inspection and soil-probing of the *solar* estimates that about 40% of the parcel is exposed bedrock, 40% contains soil cover up to 10 cm deep, with the remaining 20% containing depressions and cavities in the bedrock.

## OBSERVATIONS ON CULTIVATION METHODS

A visitor's first impression of the Naranjal homegarden is typical for the region; the lush garden seems to be growing out of solid rock. It is only on closer examination that the adaptive method of the gardeners is evident. Nearly all of the plantings are situated within the natural cavities that are common in the bedrock.

The gardeners at Naranjal report that soil from the upland forest, as well as cow manure, was sometimes added to the limestone cavities to increase soil depth and quality. We also noted that a significant amount of household organic trash was deposited within the larger cavities. Larger depressions and cavities located near the rear of the *solar* were also used as latrine areas. In other areas of the Yalahau region where homegardens were in the process of being established, gardeners reported that they would often plug deep cavities lacking soil by partially filling them in with large rocks and gravel, then adding soil from the surrounding forest. At Naranjal, as well as elsewhere throughout the region, the homegardens were sometimes watered by pot irrigation with water originating from nearby wells.

The surface openings of the cultivated cavities range in diameter from only a few centimeters to about 150 cm. A soil probe was used to estimate the minimum depth of several cavities that were under cultivation. Many of the cavities with relatively small surface openings were found to expand with depth, and to extend down at least three to four times the width of the surface opening (Figure 3). In many cases, the base of a large, healthy tree would nearly fill the surface opening of the cavity. Depending on the size of the opening, an individual cavity may contain a single tree, or several smaller herbaceous plants (Figure 4). One larger depression in the bedrock measures 10 m × 8 m, and contains a variety of trees and smaller cultivated plants. Table 1 provides a listing of most, but not all, of the edible plants cultivated in the Naranjal garden. These food plants add a great deal of variety to the daily meals of the family, and include spices, flavorings, and ingredients for beverages. A large number of other plants are cultivated in the garden for family medicinal use, while decorative species are grown both for the enjoyment of the family and for sale in local road-side nurseries. The small number of plants intended for sale are cultivated in a variety of portable plastic or metal containers rather than in bedrock cavities.

## SOIL OF THE HOMEGARDEN

*Methods*.—Soil of the Naranjal homegarden was studied along a transect that began outside of the large depression mentioned above, and extended 2,200 cm

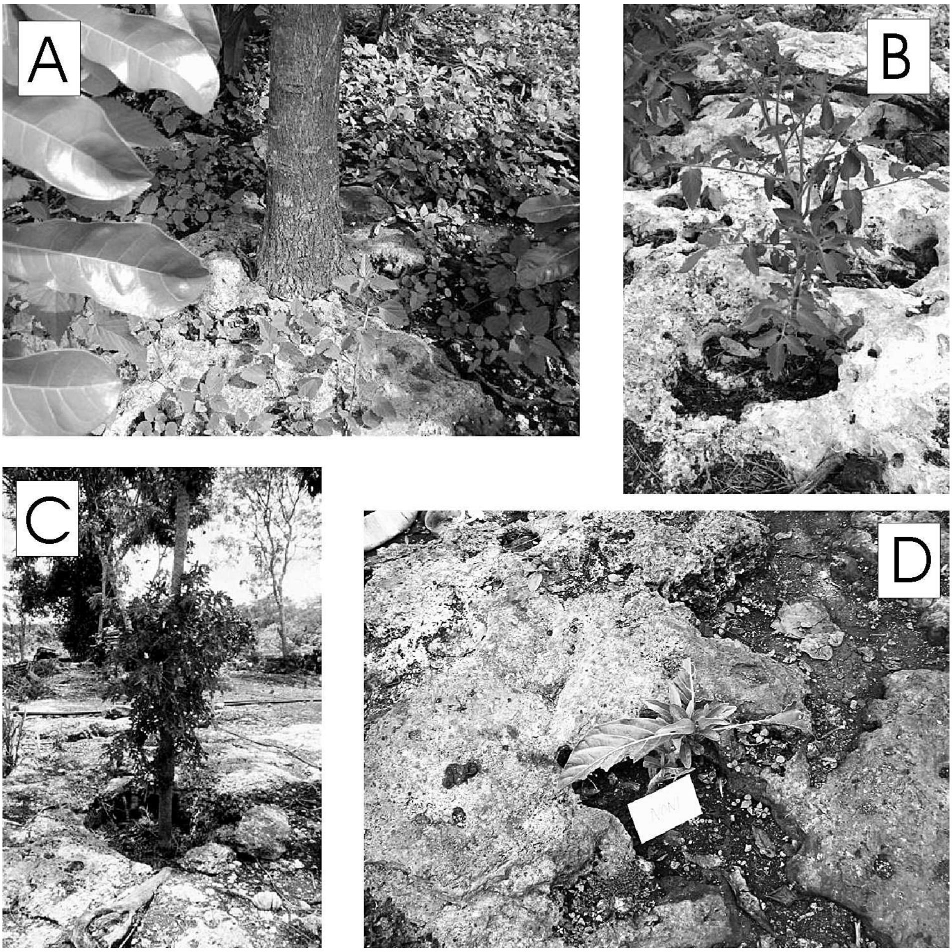


FIGURE 4.—Examples of plants growing in bedrock cavities. A) calabash (*Crescentia cujete* L.); B) tomato (*Lycopersicon esculentum* Mill.); C) papaya (*Carica papaya* L.); D) noni seedling (*Morinda citrifolia* L.). Photographs A and D by Lucia Gudiel.

to the south. Along this transect, six soil-sampling units were spaced at 300 cm intervals (beginning 300 cm from the depression edge), with samples collected from the surface and, where depth allowed, at vertical intervals of 10 cm. Soil depth measurements were taken at 30 cm intervals along the transect. In addition to the sampling transect, a soil unit was excavated within the large depression, providing samples and a profile extending to a depth of 80 cm.

A battery of chemical and physical tests was conducted on the soil. These analyses include bulk density determined by the core method, particle density by pycnometer, water content by gravimetric method, saturated hydraulic conductivity, particle size distribution by the pipette method, total porosity as calculated from particle and bulk density (all described in Klute 1986), macro- and microporosity (Ahuja et al. 1984), as well as color as measured with a Chroma Meter (Minolta Model CR-310). Chemical soil parameters such as pH, exchangeable

TABLE 1.—Edible plants cultivated in the Naranjal homegarden.

| Family | Genus | Species | Mayan name | Spanish/English name |
|---|---|---|---|---|
| Aizoaceae | *Trianthema* | *portulacastrum* L. | shanamocui | verdolaga bronca/desert horsepurslane |
| Annonacae | *Annona* | *cherimola* L. | ek'mul, op, pox | cherimoya |
| Annonacae | *Annona* | *muricata* L. | tak'ob | guanabana/soursop |
| Annonacae | *Annona* | *squamosa* L. | ts'almuy | saramuyo/sweetsop |
| Annonacae | *Annona* | *purpurea* Moc. & Sessé ex Dundal | chak oop, poox, pool boox | soncoya/woodpecker's or horse anona, wild anona, cowsap |
| Amaranthaceae | *Amaranthus* | *hybridus* L. | tes, tesquish | amaranto/amaranth |
| Arecaceae | *Cocos* | *nucifera* L. | | coco/coconut |
| Bixaceae | *Bixa* | *orellana* L. | k'uxub | annato, achiote |
| Cactaceae | *Nopalea* | sp. | pak'am | nopal |
| Cactaceae | *Hylocereus* | *undatus* (Haw.) Britton & Rose | wob | pitahaya, pitaya/dragon fruit, strawberry pear |
| Caricaceae | *Carica* | *papaya* L. | puut, put | papaya |
| Convolvulaceae | *Ipomoea* | *batatas* (L.) Lam | lis, is | camote/sweet potato |
| Cucurbitaceae | *Cucurbita* | *moschata* Duchesne | k'uum, k'u'um, sikil | calabaza de pepita menuda/squash |
| Cucurbitaceae | *Cucurbita* | *pepo* L. | ka', ts'ol, ts'ool, to'op', top, xtop' | calabaza/squash |
| Cucurbitaceae | *Momordica* | *charantia* L. | ah caliz chuu, tulu | sandia/watermelon |
| Dioscoreaceae | *Dioscorea* | *alata* L. | aak'il makal | makal de raiz |
| Dioscoreaceae | *Dioscorea* | *bulbifera* L. | xboolador makal | papa voladora |
| Euphorbiaceae | *Cnidoscolus* | *chayamansa* McVaugh | chay, chaay | chaya |
| Euphorbiaceae | *Manihot* | *esculenta* Crantz | ts'iin | yucca, manioc, cassava |
| Fabaceae | *Phaseolus* | *vulgaris* L. | bu'ul | frijol/bean |
| Lauraceae | *Persea* | *americana* Mill. | oom, on, oon | avacado |
| Musaceae | *Musa* | *X paradisiaca* L. | | platano/banana |
| Nyctaginaceae | *Boerhavia* | *erecta* L. | shiu | |
| Piperaceae | *Piper* | *auritum* Kunth | mak'olam | hoja santa/Mexican pepperleaf, bullhoof, cowfoot |
| Poaceae | *Saccharum* | *officinarum* L. | | cana de azucar/sugarcane |
| Rutaceae | *Citrus* | *aurantifolia* (Christm.) Swingle | | lime |
| Rutaceae | *Citrus* | *aurantium* L. | | sour orange |
| Rutaceae | *Citrus* | *reticulata* Blanco | | mandarin orange |
| Rutaceae | *Citrus* | *sinensis* (L.) Osbeck | | sweet orange |
| Sapotaceae | *Calocarpum* | *mammosum* (L.) Pierre | chakalja'as | mamey |
| Solanaceae | *Lycopersicon* | *esculentum* Mill. | p'aak, p'ak | tomato |
| Sterculiaceae | *Guazuma* | *ulmifolia* Lam. | pixoy | guasima |
| Verbenaceae | *Lippia* | *graveolens* Kunth | ak'ilche', xak'ilche', xaak'che' | orégano/Mexican oregano |

cations ($Na^+$, $K^+$, $Ca^{++}$, $Mg^{++}$), soil organic matter, total nitrogen, retention of phosphorous and Fe oxides, were evaluated using standard USDA methods. Together, these standard analyses provide a characterization of soil fertility, workability, and drainage that are significant for gardening, while also providing information on the sustainability of the gardening system after more than ten years of use.

*Results*.—The results of the physical and chemical analyses are briefly summarized here, and will be presented at length in a separate technical presentation. The results presented here focus on the variance of soil depth, which we will argue is the primary variable to which the homegarden cultivation system is finely adapted.

*Physical and Chemical Analyses*.—The soil of the Naranjal homegarden is classified as a Rendzic Leptosol (FAO 1998). The physical soil characteristics from both the transect and the profile show that the soil is clay textured and has a very dark gray color (dry soil), high values of hydraulic conductivity and relatively high contents of water at sampling time. The soil presents a low bulk density, which has a beneficial effect for root growth and in the yield of cultigens. In the soil profile it was clearly observed that the reflectance values increase as the soil depth increases, a consequence of the decrease of organic matter content. Also in the soil profile, the hydraulic conductivity values increase with soil depth, which may be due to the presence of biopores and channels. The soil has a good capacity to transport water and oxygen. The chemical analyses indicated that the pH values in all samples varied from 7.1 to 8.0, with an average of value of 7.5 (n = 18). In the soil profile, pH values decreased toward neutral with decreasing depth.

The organic matter contents among the Naranjal samples are high to extremely high. Organic matter content is a parameter directly related to overall soil quality due to the multiple benefits that this fraction provides the soil, such as the elevated concentration of total nitrogen observed in the samples. High levels of organic matter were present in the surface level of the soil (0–30 cm), ranging along the transect from 5.97% to 20.23%, and averaging 11.11% (n = 10). Organic matter in the lower profile of the transect tended to decrease with increasing depth, with the 30–80 cm levels averaging 3.11% (n = 5). The C/N ratios of the samples range from 4 to 11, again indicating good soil quality since rates of organic matter mineralization is high.

The most limiting nutrient factor of the Naranjal homegarden soil is the low values for available Phosphorus. The soil had available P values ranging from 0–19 kg/ha, along with high percentages of P retention (22–83%), without having reached its maximum retention capacity.

*Soil Depth Variability*.—Soil depth was found to be the most variable soil attribute of the Naranjal homegarden, with a Coefficient of Variation (CV) of 72% (Mulla and McBratney 2002). Other physical and chemical properties analyzed for the transect exhibited variability that ranged between 3.37% for pH and 65.74% for hydraulic conductivity, although it should be pointed out that there is a difference in sample sizes; for soil depth n = 74 and for other properties n = 6.

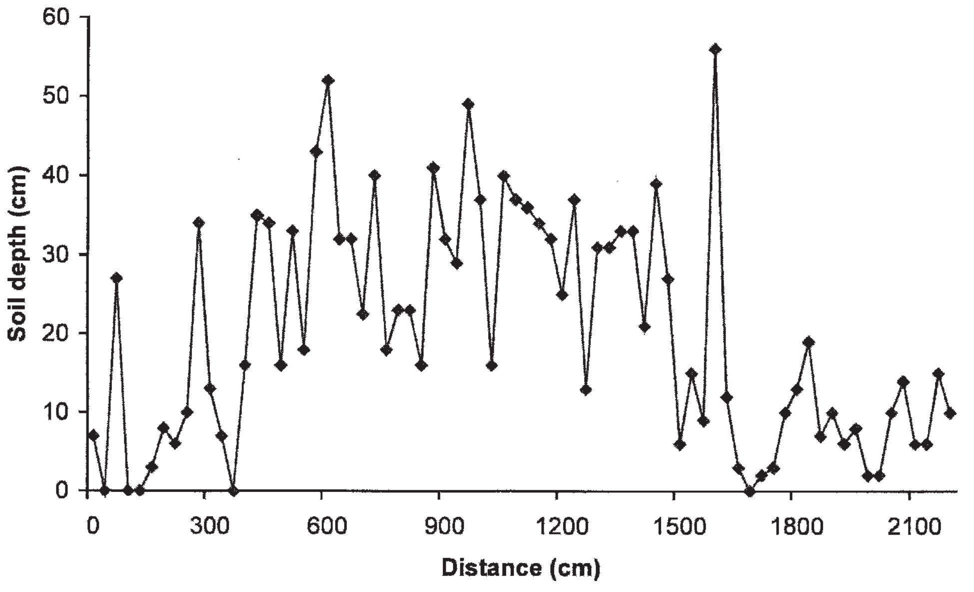


FIGURE 5.—Distribution of soil depth along the 2,200 cm transect in the Naranjal homegarden. The sampling interval is 30 cm.

The variability of soil depth along the transect is shown in Figure 5. Descriptive statistics for soil depth are: mean, 20.07; median, 16; standard deviation, 14.52; minimum, 0.0; maximum, 56; skewness, 1.42; and kurtosis, −1.50.

Spatial variation in bedrock exposure as well as soil depth within the homegarden is suggested by the informal visual inspection and soil probing mentioned above. We used conventional geostatistical methods (Webster and Oliver 2001) to determine if variation in soil depth is structured, rather than random, and to measure spatial correlation of soil depth along the transect. The resulting experimental semivariogram and the adjusted semivariogram model for soil depth are given in Figure 6. The spatial behavior of this soil parameter could be described using a spherical model with a nugget effect. The spherical

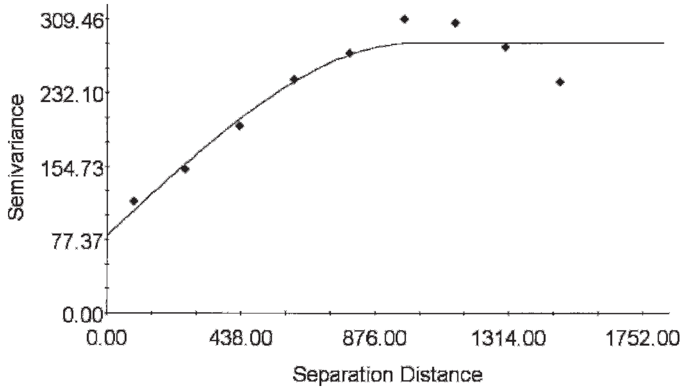


FIGURE 6.—Experimental semivariogram of soil depth in the Naranjal homegarden.

function represents transition features that have a common extent and which appear as patches, some of them with large values and others with small ones. The average diameter of the patches is represented by the range of the model (Webster and Oliver 2001). The spherical model suggests that soil depth is spatially patterned and that the semivariance ($\gamma$) first rises and then levels off at the sill ($C_0 + C = 284.20$ cm), indicating the distance beyond which observations are independent. Other features of this model are range ($A_0 = 1{,}004$ cm) and nugget ($C_0 = 81.30$ cm); the former indicates the range over which observations show spatial dependence and the latter is the variance that exists at scales finer than the field measurements (30 cm). The range of spatial dependence is 1,004 cm, which indicates that the transect spacing was adequate for the characterization of the spatial variability of this property. The semivariogram shows the increase in variance up to the separation distance of 1,000 cm which then essentially stops, with only a very small decrease in variance taking place at larger distances.

The statistical analysis of soil depth in the Naranjal homegarden recognizes high variability at all distances, starting at the sampling interval of 30 cm, indicating that patches with uniform soil depth are smaller than 30 cm. Soil depth is autocorrelated over distances of 1,004 cm, indicating spatial structure in the attribute of depth, and implying that samples collected at close distances could not be considered as independent. The lack of soil-depth uniformity emphasizes the need for thorough sampling for all soil properties, since spatially dependent behavior can lead to misinterpretation of the results obtained by standard sampling schemes that generally assume a relatively uniform soil depth across a soil mapping unit.

## DISCUSSION

Diego de Landa’s wonderment in 1566 over the lushness of cultivated trees and other crops that appeared to be growing from living rock with little apparent soil may not be as extraordinary as it seemed. A substantial amount of soil is hidden from casual view within the numerous bedrock cavities that typify many areas in the northern Yucatán Peninsula. The quality of the soil we examined in the Naranjal homegarden is quite high, and it does not differ much (e.g., in humus content, pH, etc.) from soil of the high-stand forests of the region. This means that soil of the garden does not show major signs of physical and chemical degradation despite prolonged and intensive land use, a situation rather rare for agricultural soil in the tropics, which typically suffers from rapid degeneration. This points to a relative sustainability of soil management within the studied ‘‘container gardening’’ agrosystem.

After conducting the formal spatial modeling of soil depth, it is helpful to step back from the statistical analysis and look at how the Naranjal family has adapted gardening practice to the specific soil environment. The larger patches of relatively deep soil (>10 cm) within the *solar* are used for shallow rooting herbs and decorative flowers. The few larger bedrock depressions, such as the 8 m by 10 m depression noted earlier, are used for the cultivation of a variety of trees and other plants, including, notably, the only root crops found in the garden.

Much, if not most, of cultivation takes place in the bedrock cavities of smaller surface diameter and greater soil depth; those cavities that would be registered as ''nuggets'' of variance at scales finer than the 30 cm sampling interval in the statistical analysis. For example, in our soil transect, only one deep cavity with a small surface opening (<30 cm) was encountered along the 2,200 cm transect, at 1,590 cm (Figure 5). Probing at that point on the transect encountered soil that was 56 cm deep (the deepest encountered on the transect), bounded by three readings on either side with depths averaging less than 10 cm.

The Maya gardeners in Naranjal do not adapt to the average soil depth of their *solar*; they seek out the cavities in the bedrock, which might account for less than 10 percent of the actual surface area of the parcel, and plant within those holes. The result is in effect a container garden, with the sunken containers (cavities) acting as catchments for soil and rainwater within the surrounding bedrock. These containers hold deep, rich soil that might be characterized as a vertical *A* horizon surrounded by bedrock.

The occurrence and quantity of small bedrock cavities outside of the Yalahau region is not currently known. At the ancient Maya site of Chunchucmil, in the western area of Yucatán State, Dahlin and his colleagues (Dahlin et al. 2005) report the existence of bedrock cavities (referred to as ''natural drain holes'') that are large enough to have been used as ''tree planters'' (their term). They say, however, that these cavities are not numerous enough at the site to have provided for a significant amount of tree cultivation (Dahlin et al. 2005:238). Future research into the potential productivity of container gardening in bedrock cavities should seek to quantify the number and soil-volume capacity of cavities per unit of land surface, perhaps through the use of ground penetrating radar.

At Chunchucmil, as well as throughout the Yalahau region, another cultivation method used by the ancient Maya to compensate for thin soil is the construction of gravel-mulch piles, referred to locally as *chich* mounds. These *chich* mounds were probably used to support the root systems of trees and to help conserve moisture (see also Fedick and Morrison 2004; Kepecs and Boucher 1996).

It is interesting to note that the pocked landscape of the study region seems pre-adapted to fixed plot cultivation of trees and other perennials. Milpa cultivation in this region of thin topsoil is precarious and not very productive. While the thin soil is generally fertile and of high quality, it is highly susceptible to drought. When left exposed, or cultivated for too many consecutive years, they rapidly erode, with much of the surface soil apparently being lost into the cracks, crevices and cavities in the bedrock. Fruit trees and other perennials generally need more spacing between individuals than do annuals, and are also deeper rooting. As many of the bedrock cavities and crevices undoubtedly extend down to the water table, deep-rooting trees would be able to tap a permanent water supply. Perennial cultivation within the deep soil-filled cavities represents a natural agricultural adaptation to the local landscape.

In the Maya Lowlands, perhaps particularly in the northern lowlands, land resource heterogeneity is often patterned at the micro-scale. In characterizing land resources by standard scientific methods, we often overlook this micro-patterning as we go about mapping at our usual scales of resolution. Yet it is this micro-patterning that the Maya gardeners in our study area have adapted to. As scientists, we need to learn to adapt our quantitative field methods to better capture the subtle ways in which Maya gardeners have successfully managed to turn what outsiders perceive as a hostile environment into a lush garden.

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