24 PALEOENVIRONMENTAL RECORD, RECONSTRUCTION, FOREST SUCCESSION, AND WEEDS IN THE MAYA MILPA

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The paleoenvironmental reconstructions of the prehistoric Maya forest have emphasized that this culture's farming technology, their subsistence and household economy, impacted the environment negatively by ultimately replacing forest with savanna, and assuming that farming inhibits the regrowth of the forest. An examination of weeds typically found in traditional lowland Maya farmlands, or milpas, provides insights into this assumption showing that woody shrubs and trees are a major component of the maize dominated fields and that in fact once the maize cultivation ceases, these shrubs and trees will begin the succession process. While weeds are often characterized as annual herbs and grasses, their common characteristics can be identified in their competitive abilities and tolerance to the open field conditions created by agriculture. The negative value associated with weeds is inconsistent with the ethnobotanical and functional roles the listed weeds play in the Maya milpa. The habits and uses of the identified weeds in the open milpa have implications for understanding the home economy and conservation techniques of traditional Maya farmers that reach back to ancient Maya times and demonstrate that the milpa is an adaptive system in the Maya forest.

Introduction

The paleoenvironmental record for the Maya forest presents data that have been interpreted as demonstrating the forest conversion to grasslands over the course of ancient Maya land use and development. This interpretation, however, does not consider the nature of the agricultural landscape created by traditional Maya milpas and the role of weeds in these fields. Weeds, while typically considered undesirable in a plowed field, serve multiple purposes in a traditional milpa. This paper looks at the weeds of the milpa, their habits, uses, and pollination vector or syndrome (biotic or abiotic) to demonstrate that the predominant presence of wind-transported grass and herb pollens in lowland lake core sediments is indeed the product of an increasing anthropogenic landscape but not a deforested one. We will show that the weeds of the milpa become the foundation of the reforestation cycle that begins with the opening of the agricultural field.

Understanding the Maya Milpa-Forest Garden Cycle

To adequately interpret the signature of herbs and grasses in the pollen cores of the Maya forest it is necessary to understand the milpa-forest garden cycle in a mosaic across the landscape. In other words, at any one time, the landscape will have some proportion of milpa gaps, and other proportions of building succession, and other proportions of closed canopy trees along with the home gardens that would be the true forest garden. Traditional Maya agriculture features *the milpa*: a poly-cultivated plot of as many as 30 domesticated crops in a maize-dominated field (Ford and Nigh 2009).Milpa fields are found year round in a mosaic among reforested and mature forest cover. Each seasonal period is associated with a specific adaptive growing cycle. Maize is expected for the two rainy periods, with June planting providing the highest yields. Maize may be planted in a third dry period, but this will not produce a major crop. A variety of some 30 domesticated crops are selected from more than 70 crops to be intermixed in the open fields (Ford and Nigh 2009:216-218; Teran and Rasmussen 1994, 1998). This purposeful selection is apart from the pioneer weeds and stump sprouts that volunteer within the fields and make up the heritage of reforestation.

The landscape then is a mosaic of the open fields and the forest gardens intricately intertwined with the household economy providing subsistence, medicine, fiber, and foods that maintain the family system. The first stage of cultivation is the opening of the forest for the maize dominated field. Cultivation of maize is then followed by an initial stage of reforestation with selected economic trees and shrubs. Finally, reforestation is completed with the maturation of the closed canopy forest garden (Table 1). These stages match the natural cycle of forest dynamics with gaps, building phases, and maturation of the landscape (Kellman and Tackaberry 1997:146-157). The managed

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Milpa Cycle	Plants
Stage 1-2 open field *~ Favoring Sun* 1-3 yrs, 3-7 yrs	Open milpa: ~30 crops of ~ 70 spp; dominated by maize,squash, beans, tomato, chili, root crops, weeds Palms; Coppiced shrubs and trees; short lived perennials; seedling fruit trees for Stage 3-4
Stage 3-4 reforestation *~ Producing Shade* 7-15 yrs, 15-30 yrs	Long lived Perennials ~ Fruit trees and palms Seedling long lived perennial hardwoods interspersed with fruit trees for Stage 5
Stage 5 closed canopy *~ Favoring Shade* Harvest & ready for Stage 1	Closed Canopy well-managed forest ~ KänanK'aax Tall trees of hardwoods and fruit

Table 1. Representative Milpa –Forest Garden Cycle.

mosaic provides a dynamic of changing forest cover that is variably cycling through the landscape (Downey 2010).

The field cutting, which initiates the milpa cycle, is accomplished with one hot burn occurring at the end of the dry season in May, in preparation for the rains. Coincident with the first rains, the maize is planted in the field. This is the main maize crop of the year with yields from 855 kg/ha (Cowgill 1962) to 1144 kg/ha (Redfield and Villa Rojas 1962) and up to 2800 kg/ha (Nations and Nigh 1980:13). Yields of beans, squash, and squash seeds, as well as many other crops, are reaped from the same fields. A second planting takes place in November and is dependent on the lower precipitation characteristic of the cool northern rains typical for this time of the year. There may be a third dry season crop as well, adding to the annual household economy. A traditional lowland milpa is typically used for maize cultivation for approximately four years. This period of intensive maize cultivation is followed by reforestation stages lasting from 12-20 years. The fields opened for maize cultivation invite the growth of weedy plants, but our questions are: *Do these weeds contribute to overall field management and the household economy and how may this be reflected in the pollen observed in lake-core sediments?*

Managing and maintaining fields that build economic value stresses the importance of the labor investments in all aspects of the milpa-to-forest garden cycle. Weedy volunteers themselves may be immediately useful for food, spice, dye, and medicine. They may also provide ecological functions such as land cover for moisture conservation, animal and insect attraction for pollination, plant competition for improved yields, and the acceleration of reforestation for the next stages of the cycle (Lambert and Arnason 1989). These values build into the subsequent reforestation stage with trees for fruit and construction, typical of the forest garden (Ford 2008). This orchestration of species selection, planting, and management has created one of the most diverse domesticated plant systems in the world (Campbell 2007), and it has been facilitated by the fundamental tool of the open maize field, or milpa. We will show that the diversity of the weed communities that flourish in the disturbed agricultural field habitat of the traditional Maya milpa function is an essential platform for the progression to the forest garden. Thus, it is evident that the crop and weed components of the open milpa field contribute to the pollen recorded in the lake cores that form the paleoecological record.

Identifying Milpa Weeds

The data we use come from two areas representing Maya adaptation: the northern Yucatan of Mexico and the western Cayo district of Belize (Figure 1). The northern Yucatan, with

1000 mm of rain per year, is drier than Western Belize, with c. 2000 mm per year. For both areas, the milpa cycle proceeds in a similar manner based on the distribution of the rain over the year. Both areas are associated with archeological sites (ChichénItzá in the case of Yucatan and El Pilar in the case of Belize).

To address the nature of weeds, we explore the defined lists of weeds derived from farmers' fields in Piste, Yucatan and in Cayo, Belize (Steggerda 1941; Kellman and Adams 1970). While each researcher had different strategies of data collection, both efforts itemized plants that were not cultivated as crops; these volunteer and pioneer species were considered weeds in the observed active maize milpa fields.

To gain a perspective on the weeds of the researched fields, we created a spreadsheet of the plant inventories with our research on habit, uses, life cycle, and pollination. Our catalog of the weeds reveals considerable diversity of plant habits, an amazing variety of recorded plant uses, the presence of both annuals and perennials, and all types of pollination syndromes. These are anthropogenic plants that withstood, and even required, cutting and burning to thrive (e.g., the corozo/cohune palm: Steinberg 1998; see Anderson et al. 1991). These fields are multifaceted with useful crops and weeds that, together, are an essential indicator of the human-environment relationship.

The Yucatan example dates to the 1930's before WWII and the introduction of commercial fertilizers, pesticides, and hybrids (Steggerda 1941). The ethnographic context for Steggerda's research was under the auspices of the Carnegie Institute of Washington, a major interdisciplinary Maya research program of the time. Steggerda's study examined Maya family size and make-up, health and work habits, and metric measurements of physique. Part of his consideration of health and work included Maya subsistence practices. Rigorously recording all he could, Steggerda documented agricultural field size, planted crops, and crop yields from the fields of his Maya informants. These fields were the source of his itemization of weeds. The data come from a series of 4 sq. meters in the center of five fields and included additional plants noted beyond the sample inventory (Steggerda 1941:100-107). Every weed—any plant that was not a crop—was counted along with the number of times it was represented in the field (Steggerda 1941:99). A total of 49 different plants were recorded by Mayan and scientific names in his sample, with an additional 29 weeds noted outside the sample and itemized across the same fields for a total of 78 plants.

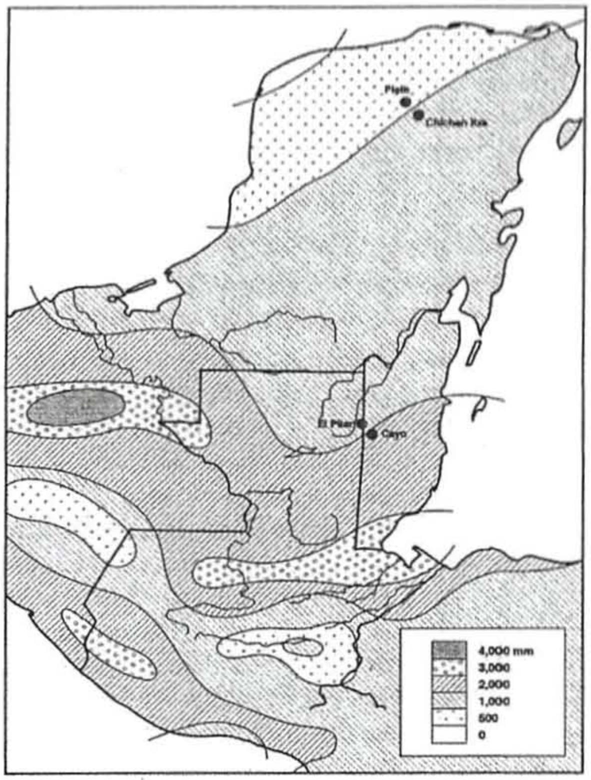

Figure 1. Map of Rain Gradients with Chichén Itza and Cayo locations indicated.

The Belize example incorporates data collected in the late 1960's (Kellman and Adams 1970), well after WWI and within the era when petrochemicals and plant hybrids began to be available. There is no indication that any supplements were used in these fields. Using scientific names and frequency, Kellman and Adams present a methodical itemization of the classified weeds and their distribution (1970:330-333). They identify weed genera and species from 31 fields totaling 196 species.

The weed lists were tabulated and examined separately for habit, economic use, duration, and pollination syndrome to create a new database on weeds of the milpa. Habit was determined using several sources, most prominently the Unites States Department of Agriculture web site (USDA 2011). Habits were then charted to compare the percentage of herbs, shrubs, trees, vines and grass. The two main sources used for determining economic values were Roys (1976 [1931]), *The Ethno-botany of the Maya*, and Balick et al. (2000), *Checklist of the Vascular Plants of Belize*. Each listed plant was assessed in terms of origin, pollen syndrome, and habit and the uses inventoried and tabulated in our new database. The economic plants are charted based on the type of use including medicine, production, food, and construction, to name a few examples.

The pollination syndrome is important in the interpretation of the herb and grass components in the lake core sediments. We used over 40 authoritative sources to research the difficult question of pollination syndromes (sources available upon request). An effort was made to determine the syndrome at the levels of genus and species whenever possible; where data were unavailable, we resorted to the family level for comparison. Pollination syndromes are evaluated by category: wind, insect, mammal, or self-pollination, as is the case for ferns and some grasses. It is commonly understood that it is the wind pollen that is broadly represented in the lake cores (Kellman and Tackberry 1997).

The results of our research are illuminating. While crop production was the primary function of the field, many other products are derived from the milpa (Steggerda 1941:117-124; Teran and Rasmussen 1994, 1998). Indeed, weed species increase the potential of the milpa to support the home economy, providing significant value during cultivation and contributing value thereafter in the reforestation stages (Ford and Nigh 2010). These are the "good farmers" that Wilken (1987) discusses where the open milpa is only one stage of the land use cycle and the plot evolves into the mature woody plants favored for food and construction (Ford 2008).

Results

Our research began with the habits and economic uses of the weeds of the milpa.Remarkably, all plant habits, including trees and shrubs, are found in the list of weeds (Figure 2) and thus the fields are not simply crops with annual volunteer herbs and grasses, as routinely assumed when considering agricultural field clearings. Interestingly, the majority of the plants have uses that are referenced in economic botanical sources. Clearly, there is more to the fields than solely domesticated crops.

The weeds in the open milpa field have many identifiable uses. Beyond the immediate values and uses recorded in ethnobotanical studies, stumps of the trees and shrubs that were once cut and burned, re-sprout during the period of time in which the maize is the dominant crop. These resources aid in the next phases of reforestation and provide the source of organic matter and ultimately shade that hastens succession and inhibits herbs and grasses (see Figure 2).

Diversity in plant habits is the theme of the milpa fields. The trend in habit in Steggerda's plant list dates to the 1930s (Figure 2). Trees and shrubs represent 49% of the inventory, plant habits of vines and herbs each represent a quarter of the inventory at 25% and 25% respectively, and even though the fields are open to encourage grasses, they represent only the small fraction of 1% of the Yucatecan fields. The data of Kellman and Adams' from the 1960s share many common themes but different trends. Trees and shrubs represent more than a quarter of the inventory at 26% (Figure 2). Combined, herbs and vines are similar to those of the 1930s example, but in different proportions, herbs with 38% and vines with 12%. Grasses on the other hand represent nearly one fifth of the inventory, at 20%. Annuals are not a large component of the weeds in the milpas of either context: perennials make up 88% of Steggerda's and 76% of Kellman and Adams' weeds (Figure 3).

This diversity of weed presents a number of options for household adaptation and succeeding stages of the cycle. In an environment where there is a distinct dry period where evapotranspiration is high and the limestone bedrock is porous, there are advantages to having plant cover to maintain moisture in the system (Torres 2006). Furthermore, weed association may be beneficial in that the crops will compete to supersede the

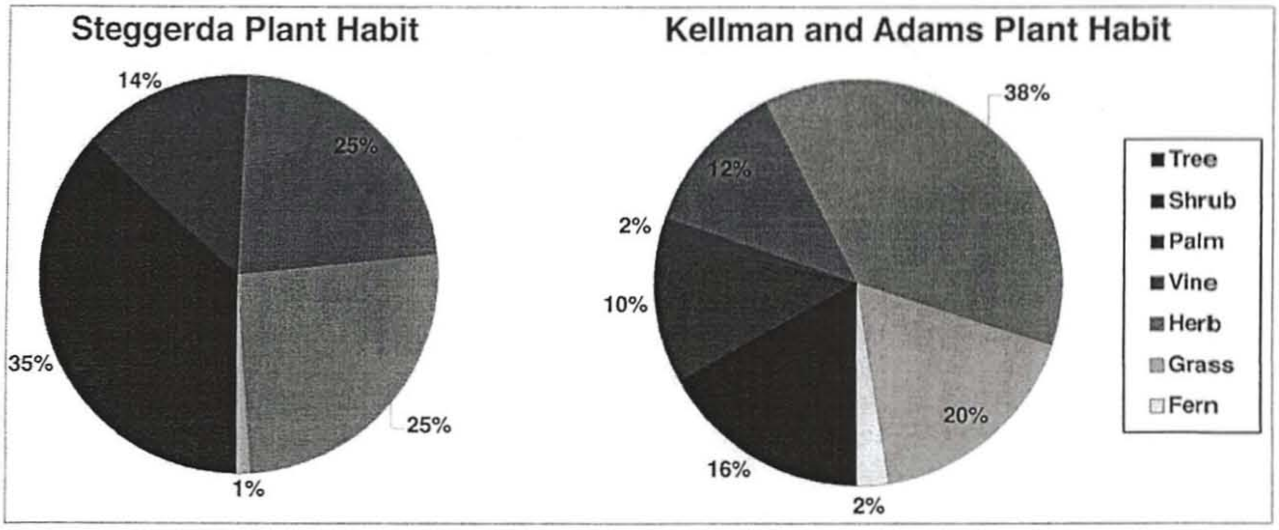

Figure 2. Habits of the Milpa Weeds.

milpa cycle where woody plants promote shade and mulch for ensuing reforestation (see Table 1).

Turning to the ethnobotany of the weed inventories, there is another factor favoring the presence of the weeds. The majority of the inventoried weeds have listed uses in Roys (1976) and Balick (2000): 86% for Steggerda's list and 66% of Kellman and Adams list. These economic uses provide everything from medicine and spice to food and construction (Figure 4). Most plants indicate multiple uses: 69% for Steggerda's and 49% for Kellman and Adam's list.

Considering the weeds with uses, both Steggerda's and Kellman and Adam's lists indicate that the majority of uses fall into the realm of medicines (see Stepp 2004; also Figure 4). Medicinal herbs are routinely related to the areas of disturbance created by human activity and abound near homes and in fields where the sun will favor the sprouting of these pioneering herbs because of exposure. Food and production are the next most important uses of milpa weeds by the lowland Maya. Steggerda's list reveals that 31% were used for food and 22% for production, while Kellman and Adam's list reveals 31% each for food and 33% for production. Other uses for plant lists for the Yucatan and Belize include construction, poison, beverage, dye, fuel, spice, and fiber (see Figure 4).

The potential immediate, as well as future, values among the weeds are numerous. The intimate relationship between the Maya farmers and their landscape is indicative of these utilities. The skill and knowledge that is represented in these known uses reflects a remarkable integration of the Maya forest landscape (Atran 1993) and the farmers' land use.

Another noteworthy variable considered in our catalogue was pollen. It has been assumed by the paleoecologists that annual herbs and grasses dominate the open maize fields favoring a move to savanna as opposed to reforestation, but this is not the case. In addition, it is assumed that the presence of disturbance taxa is indicative of deforestation. The data we have compiled on the weeds from the traditional milpa context demonstrate that this is not the case. The wind pollinated weeds represent less than one third of the weeds, 28% of the total. These are the disturbance taxa reported in the lake core pollen and include these families: Amaranthaceae, Asteraceae, Cyperaceae, Euphorbiaceae, and Poaceae. Interestingly, there are 2 families represented among the herbs that are generally classed as forest taxa, Burseraceae and Moraceae, suggesting that even these generalizations about the Maya forest and disturbance taxa must be considered carefully with respect to land use.

Discussion

To understand the weeds of the Maya milpa it is important to appreciate that, like the butterfly, the milpa cycle has multiple stages. We are visually attracted to the maize field and understand it as an investment in cropland. Just as the first *conquistadors* named the milpa, they propagated the use of the word *milpa* to define the Mesoamerican maize field. The maize field, however, is just one of the stages of a recurring cycle (see Table 1) which begins with the initially cleared maize-dominated plot, is succeeded by the building of the useful woody perennials, and culminates with maturation as a closed canopy forest garden. The long-standing use of this cycle by farmers of the Maya region is, in fact, suggested through an etymological study of the word *milpa.* Traced back to its Nahuatl origin, the word milpa is a combination of the words *millipan, milli* meaning to cultivate and *pan* meaning place (Bierhorst 1985: 213, 259). The open field is crowded with plants, representing every plant habit from grasses and herbs to shrubs and trees; it is not merely maize. The milpa harbors a diversity of plants of all habits that are critical to the process of the development of the milpa cycle (Ford and Nigh 2009:217).

The weeds of the maize milpa play a significant role in the short-term management of resources of the open field stage of the cycle (Linares and Bey 2010). As the foundation of the Maya land use system, the milpa is biologically diverse and in sharp contrast with what has become known as "conventional agriculture" founded on the principle of mono-cropping. Not simply made up of the triad of maize-beans-squash, other crops as well as the weeds of the milpa play important roles both biologically and culturally. Immediate uses that make up the weeds are just the beginning—uses that include gum, incense, latex, oil, fiber, spice, ritual, fuel, ornamental, tannin, dye, beverage, poison, construction, food, production, and medicine. Over 90% of the useful plants are classed as medicinal. These are obviously important, but it does not end there.

The multiple economic uses cataloged among these weeds speak to the subtle qualities of the greater groups of plants in the milpa. These weeds set the stage for the long-term land

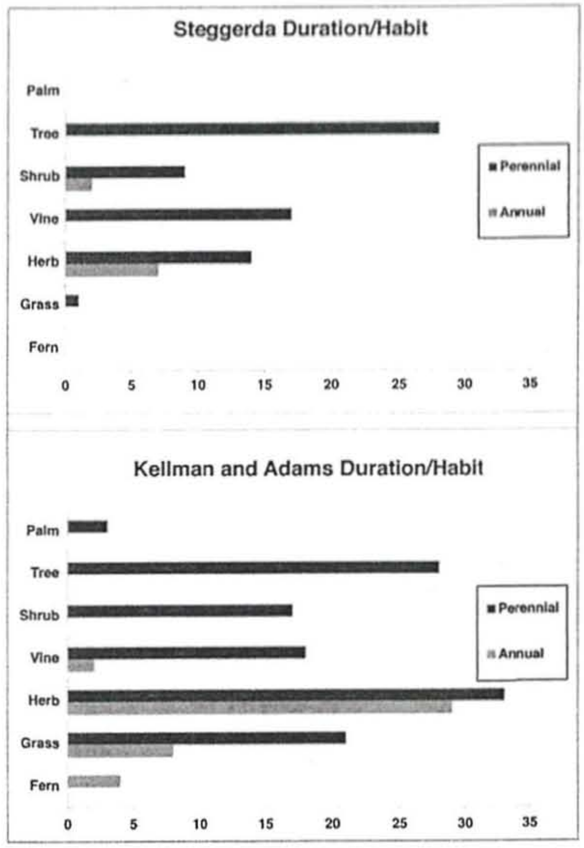

Figure 3. Plant habits and duration of the Milpa Weeds.

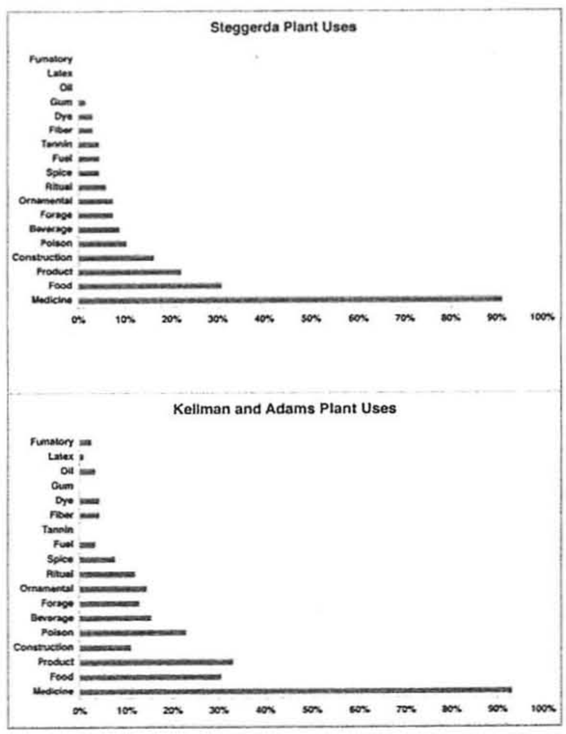

Figure 4. Economic Uses for the Weeds of the Milpa.

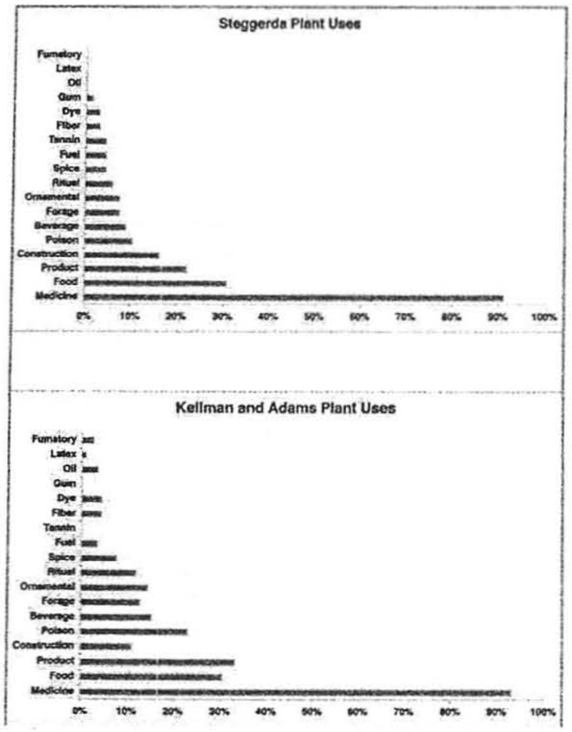

Figure 4.Economic Uses for the Weeds of the Milpa.

use, soil conservation, and reforestation of the open maize plot. Within the immediate uses of the plot are the biological controls. Domesticated crops are susceptible to a variety of pest and plant competitions, and specific weedy plants are known to have interactions that support crops and advantage yields.Allelopathic components can eliminate undesirable crop pests, attract insects and mold that otherwise would attack crops, and inhibit soil borne diseases to act as a natural biological control for the domesticated crops (Gliessman 1981:182, 1983, 2004:66). Soil improvement and natural chemical protection; insect, fungi, bacteria, and nematode pest control, and pollinator attraction, are just some of the ways weeds act to benefit crops. At the same time, plants are encouraged for other services: fast growing shade, production of leaf litter, and attraction of birds. The weeds described by Steggerda, as well as those identified by Kellman and Adams, serve conservation roles in the field. Alfonso Tzul, a retired agricultural extension officer in Belize, states that he has never seen a traditional milpa subject to erosion and has never seen a plowed field without erosion (Tzul 2011). Weeds, in fact, facilitate the resourceful and resilient management design of the milpa.

The picture that emerges is of an eclectic combination of plants in both the crop and weed components of the milpa. While most crops are annuals, most of the weeds are perennials that are largely biotically pollinated: 88% of the Yucatan milpa weeds and 75% of the Belize milpa weeds. We discovered that, like the crops that are predominantly biotically pollinated, only 6% of the Yucatan weeds, and 28% of the Belize weeds were wind pollinated. This demonstrates that the wind pollination component that would contribute to the pollen of the lake cores represents only a quarter of all the weeds, commonly found in the Maya milpa. In essence, there are no means by which direct data can identify the variety of plants of the milpa or the forest (Ford 2008). The lake core sediments are dominated by wind pollinated plants, all of the families of wind pollinated plants are found in the milpas and are found in the lake cores.

The milpa cycle is a creative development of the landscape that improves the quality of the biomass towards economical utility at every stage of the cycle. Beyond the immediate uses of plants, woody species recorded in the milpa fields, mainly in the form of stump-sprouts, play a significant role in the reforestation phase of the fields. These stump sprouts grow vigorously and quickly and shade the soil surface during the reforestation stage (Kellman 2011), inhibiting the expansion of grasses and representing a major advantage for water conservation in this area of porous limestone bedrock. The high proportion of woody shrubs and trees to annual herbs and grasses provides evidence that the open phase of the milpa cycle is already advancing to the later reforestation stages. The stump-sprouts of the maize field speed up the reforestation process, building protection as well as the conservation of water and soil. These woody plants are vital to the succeeding stages of the milpa cycle.

Tree and shrub species that re-sprout in the field are the subject of selection or elimination, influencing the plant composition of the regenerating forest (Ford 2008:186). In the first years, the plants grow under the annual maize canopy, one that is replaced at least twice a year. When the short years of the maize field stage of the cycle come to an end, the surviving stump sprouts that have already established themselves in the milpa, will become a part of the later mature stages of the cycle. In this way, the open milpa field is a central tool in the creation, development, and maintenance of the Maya forest garden (Teran and Rasmussen 1994, Ford and Nigh 2009, Linares and Bey 2010). Rather than replacing the forest, weeds of the maize field initiate the trajectory of regeneration and the resulting active reforestation directs the forest composition to desired states of economic and cultural utility.

Far from becoming a savanna, the maize field is a diverse agroecological setting with plants of all habits, uses, and durations. The composition of the weeds does not lend itself to the dominance of grasses and herbs, and while the grasses and herbs are present, they remain in small proportions as part of the ecological process of succession. The paleoecological presence of herbs and grasses is consistent with the presence of the maize milpa, they are not the dominant plants nor do they represent a replacement of the forest. These results suggest that the "disturbance taxa" recorded in the paloeecological record support the interpretation of anthopogenic impacts, but do not support the interpretation of the savanna conversion.

Conclusion

An interpretation of the landscape of the Maya forest based on the dominance of wind borne taxa in the paleoecological record is premature. To understand the pollen data of the lake cores, one needs an appreciation of traditional uses of the tropical forest and the role of land use strategies. The agroecological dynamic of the milpa-forest garden depends on an understanding of the cyclical nature of the manipulated plots of the traditional Maya farmer. While open fields are part of the cycle, so are the succeeding reforestation stages. In structure, the opening of a Maya milpa is not unlike the gaps created in forests by natural events, such as tree falls and hurricanes that change the immediate composition of the landscape (Kellman and Tackaberry 1997:252-153). From gaps, to forest building, and on to the mature canopy, we recognize the stages of the milpa cycle from the open maize field, into the reforestation stages, and on to the closed canopy forest garden (Ford 2008). There will always be a proportion of the lowland Maya landscape in open fields, but there will also be a large proportion in the building and mature phases represented as well.

Today's Maya forest, part of the greater Mesoamerican forests that are among the most biodiverse in the world (Mittermeier et al. 2000:38), was left unmanaged after the Spanish conquest. Still, the forest today is dominated by the economic qualities that were part of the ancient Maya management system (Balick 2000, Campbell et al. 2006; Ross 2008). Many of these economic plants were capitalized in the colonial and historic periods (e.g. Logwood for dye, Mahogany for lumber, chicle for gum, Allspice for seasoning). The value of the forest is the product of millennia of selection by the Maya (see Ford and Nigh 2010) which is evident in the inherent knowledge and respect that traditional farmers have for the forest today (Atran 1993; Balick 2000; Campbell 2007; Ford 2008; Gomez Pompa and Kaus 1990; Nigh 2008; Roys 1976; Toledo et al. 2008; Toledo and Barrera-Bassols. 2008).

The open maize field is a significant component of the milpa cycle, as evident in the ancient pollen of the lake cores. While up to dozens of different domesticated crops may be concurrently grown in the maize fields, it is the diversity of the weeds recorded in these fields that is remarkable. Since the majority of these weeds offer utility for the farmer's household, it is difficult to exclude them in calculating the overall value of the plot. Those same herbs and grasses noted in the paleoecological record speak directly to the management strategies of the traditional milpa cycle. The promotion of plant diversity in the initial sun loving, maize-dominated field guarantees the continuity of diversity into the reforestation and canopy stages of the cycle. This complex composition plays a long-term role in the creation and development of the Maya forest as a garden.

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