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On Maya Silviculture*

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La presencia de selvas altas dominadas por árboles útiles en la zona Maya se utiliza como punto de partida para reconstruir un sistema de silvicultura hipotético de los antiguos mayas. Este sistema posiblemente se utilizó para construir y manejar distintos tipos de ecosistemas. La reconstrucción está basada un una serie de técnicas agrícolas y silvícolas que utilizan los mayas actuales en distintas zonas del área Maya. La silvicultura antigua Maya cuestiona seriamente las tendencias actuales del uso del suelo y los recursos bióticos de las zonas tropicales, y sugiere un nuevo enfoque para la conservación y el desarrollo de estas zonas, que puede mejorar notablemente el manejo de los recursos de las selvas en algunas regiones tropicales para beneficio de sus habitantes.

The Maya culture was one of the very few successful cultures that developed and flourished in a tropical forest environment. Their accomplishments are well known (7, 13, 32, 71). But it seems that there are many unanswered questions related to their subsistence systems, land use, and conservation practices. In recent years, some advances have been made in these fields (19, 26, 33, 58, 66, 67).

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Today, we know that the Maya had a very efficient and complex shifting agricultural system that many of their descendants still practice very skillfully (15, 35). We know that the ancient Maya used terraces extensively (64), but we do not know their purpose, nor the species they cultivated on them. The present-day Maya no longer use them in the lowlands. We also know that the Maya had extensive hydraulic systems with channels and raised fields (2, 41, 59), and they probably practiced intensive agriculture similar to the surviving *chinampa* system of the Valley of Mexico (6, 25). We still do not have convincing evidence of the main crops they cultivated on these fields, or the techniques used. The possibility of successfully applying the *chinampa* techniques on lowland tropical swamps was demonstrated recently (28), but we do not know whether the ancient Maya used them at all. There are suggestions that they used some of the channels for aquaculture (63), but up to now there is no proof. We know that the present-day Maya have very rich and diverse kitchen gardens, and we assume that they were extensively used in the past. Finally, we believe that the old Maya managed their forest ecosystems (1, 3), but we know almost nothing about how they did it; this subject is of great interest since today we are still struggling without success to find suitable methods for managing tropical forests (37, 43, 18).

In addition to these agricultural activities, the Maya appreciated and used a great diversity of wild plants (61). This is well known because the present-day Maya have kept and still use a great portion of that knowledge. A recent study on the medicinal plants of Yucatan (42), found that one-third of the plants have medicinal properties; it is probable that this is an underestimate and that the number will increase as a result of new ethnobotanical research. Other plants were used as sources of food, construction materials, ornaments, and fish poisons, and if these are added up, we may find that *all* of the flora of the Maya area was used! We do not have comparable ethnozoological studies (47) for the area, but from the richness of names applied to the native fauna (34) an extensive knowledge is suspected. The amount of information that the old Maya had about their flora and fauna was probably greater, since we presume that species diversity was greater in ancient times.

The Maya had, and still have, a profound knowledge of their soils. The classification they made is much better than any other known soil classification for the area (9). Their decisions on management were based on soil attributes, a method still followed by many present-day farmers. The same applies to their knowledge of vegetation; their classification of vegetation was based on "ecological"

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data from the successional process (i.e., age of the fallow, Figure 1), and also from the past management of vegetation (i.e., through species indicators), and on the agricultural potentiality of the site based on past yields and soil type (21).

Our lack of understanding of old Maya forest management and conservation methods is a significant gap in our knowledge about the reasons for the Maya collapse. Contradictory statements have been made on this subject. On the one hand, it has been said that the Maya destroyed their forests, and even has been suggested that their classic collapse was caused by the loss of soil productivity resulting from shifting agriculture, deforestation, erosion, and siltation of lakes. Many papers have been written on the pros and cons of the Swidden Hypothesis for the Classic Maya Collapse (65, 12). Some of the scientific evidence for the hypothesis comes from detailed studies of Maya lakes that have provided important information on the sedimentation produced by settlements and agricultural activities (16, 38, 54), and from broad statements concerning the short-

MAYA SUCCESSION

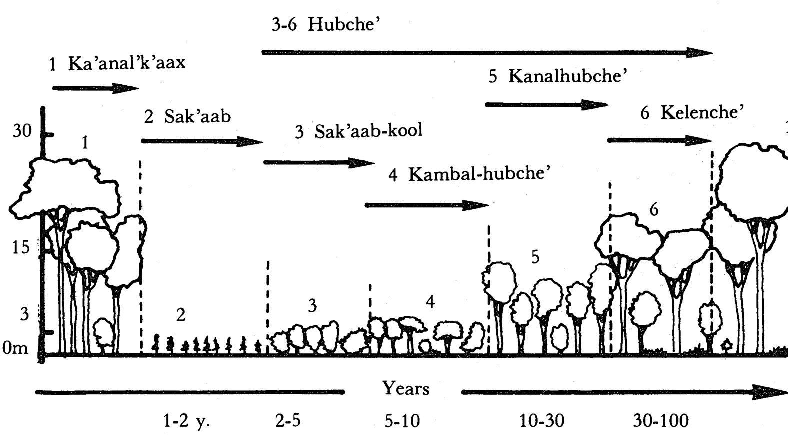

Figure 1 *Maya succession nomenclature*
1. Ka'anal'k'aax. Old tropical forest (30) or more years old).
2. Sak'aab (or Sak'ab). Second year milpa.
3. Sak'aab-kool. Recently abandoned milpa. Early succession.
3–6 Hubche'. Secondary vegetation.
4. Kambal-hubche'. 5–10 years old succession.
5. Kanalhubche'. 10–15 years old succession.
6. Kelenche'. 15–30 years old succession.

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ening of the fallow and the decline in properties of the tropical soil under shifting cultivation. However, it is now known that erosion in tropical soils under shifting cultivation in the humid tropics is not the problem that it once was thought to be (62). Arguments about Maya farming techniques have been used to connect the Maya collapse with population growth and resulting pressure on land resources. It is thought that the Maya reached population densitites of 100–200 people per square kilometer in milpa agriculture (14) and up to 700–1,150 (4) for the more intensively cultivated areas, much higher than today's density of ten people per square kilometer in the rural Maya area (23). However, the rate of growth of the Maya population in the past is still a matter of speculation (57).

On the other hand, and in contrast with the deforestation-collapse hypothesis, it has been found that the Maya protected and probably managed their forests as sources of many plant and animal products (45). Botanists exploring the region many years ago noted the abundance of useful tropical trees in the Maya ruins (39) and suggested that the old Maya had something to do with their presence (Figure 2). Even more, there is sufficient evidence that one tree species, the *Ramón* or *osh* tree (*Brosimum alicastrum*, Moraceae) may have played a central role in Maya subsistence (51, 46) as a complement to or substitute for corn, especially in dry years. This species is still used and is widely cultivated by the Maya. The use of the *osh* tree is not a unique feature of the Maya; the species has been found widely used for similar purposes in several other tropical cultures in Mexico and Central America. A closely related species, *Brosimum utile*, with its seven varieties, is widely used in northern South America (10).

In addition to the *osh*, the Maya had a great variety of other tropical fruits, the most important being: *Acrocomia mexicana, Annona spp., Byrsonima spp., Calocarpum mammosum, Casimiroa edulis, Chrysophyllum caimito, Cordia dodecandra, Diospyros digyna, Leucaena spp., Manilkara zapota, Muntingia calabura, Orbignya spp., Parmentiera edulis, Spondias spp., Persea americana, Pimenta dioica, Pithecellobium dulce, Pouteria spp., Psidium spp., Scheelea spp., Spondias spp., Talisia olivaeformis* and *Theobroma cacao*. All of these trees are assumed to have been present in the native flora. Most of these species were until recently very abundant in the different natural ecosystems of the region, and many of them are dominants in a number of communities. This fact, in my view, questions the assertion that the old Maya cut down these valuable forests to plant the annual crops of shifting cultivation. I do not think that was the case, and new evidence supports

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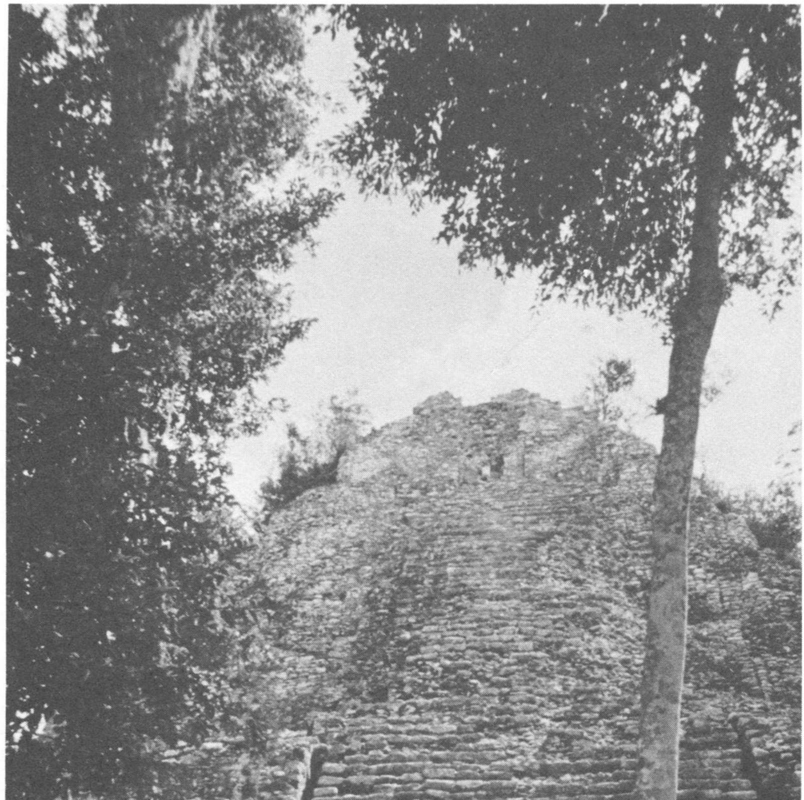

Figure 2 The abundance of useful trees in archaeological sites like this one in Cobá suggested the possibility of a silvicultural system of the old Maya.

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the idea that the Maya probably not only protected these forests, but planted them for future use (29).

The question now is, How did they do it? From a series of isolated clues accumulated in the past years of research on the old and modern Maya, a new concept of the Maya silviculture has emerged. This Maya silviculture has a series of methods and techniques, many of which still exist and are practiced in different parts of the area.

These isolated techniques (Table 1) are not all practiced in any one place, but all occurred in the Maya area and, for this reason, I

Table 1 *Silvicultural Techniques of the Maya*

Cenotes
- Introduction of useful trees

Dooryard Gardens
- Germination of seeds in *caanchés*
- Tree planting
- Selection of wild useful trees at beginning

"Natural" forest ecosystems
- Conservation of forest patches
- Selection of useful trees
- Introduction of useful species

Pet Kot
- Selection of forested sites
- Selection and protection of useful wild trees
- Introduction of useful trees

Raised fields
- Trees in borders of fields
- Tree plantations (cacao?)

Shifting agriculture
- Selection and protection of trees
- Coppicing of selected species in slash
- Tree planting before fallow

Tolché
- Different sizes and forms of forested belt

Tree plantations
- Fruit trees
- Cacao plantations with shade legume trees

Other
- Living fences
- Trees in urban and religious centers
- Sacred groves
- Trees in terraces ?

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assume that they were integrated at times in the past. They explain the presence of useful "natural" forests in the zone and their role in Maya subsistence. The Maya silviculture consisted of a series of activities of protection, cultivation, selection, and introduction of trees in their milpas, fallows, plantations, natural forests, houses, living fences, cenotes, and urban centers.

Trees in Shifting Cultivation

In the process of shifting (milpa) cultivation, several techniques related to silviculture are used. The first is the selection of useful tree species on the site chosen for cultivation. The best individuals are protected, and remain standing. The species to be saved are determined by the interest, knowledge, and needs of the farmer, a factor which explains the high biological diversity in fallows and in old secondary forests. When the field is abandoned to recuperate its fertility, the protected trees may play an important role in the succession and also in the future structure of the forest. The presence of rare species in a Maya forest may in fact reflect the taste of an ancient Maya farmer! Selection for usefulness probably included consideration of many properties in addition to food values, such as hardness of the wood and toxicity of bark and wood. Religion also played a role in the selection and protection of tree species, as is the case, to the present, of several species of *Ceiba*.

In the slash phase of Maya milpa cultivation, the farmer performs an additional and more massive selection. Some useful species, mainly fast-growing secondary types, are identified and slashed to a height of approximately fifty centimeters (a sort of pruning and coppicing), leaving the stumps ready to take advantage of the fallow that will occur when the area is abandoned two to three years later (Figure 3). During the selection other criteria are considered. These include potential use of the tree as firewood, and its contribution to the recovery of fertility of the fallow soil (as in the case of legume species that are protected for this purpose). Trees also are evaluated as possible sources of building materials, medicines, and edible fruits. This selection process is the most fundamental aspect of the management of the secondary vegetation by the Maya. It is well known that coppicing is a key factor in the successional process. Any advantage in the competition for light enhances the success of those individuals that survived the fire after the slash. The individuals protected as stumps which survive (and are selected by) the fire will have the further advantage of already being established, with nutrients stored in the roots. After the initial cut, part

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Figure 3 A typical slashed site in the Maya area for shifting cultivation. Many protected stumps in the slash vegetation will coppice leaving an ''ecological imprinting'' for the forest fallow.

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of the root system dies, contributing additional nutrients to the milpa crops. *Each abandoned milpa is an empirical experiment in directed succession*.

Even though the milpa is planted mainly with a mixture of annual crops, principally corn-bean-squash, some Maya farmers plant perennial crops intermingled with the corn, to create a perennial garden that may include trees. By doing so, they create an agroforestry system very similar to the remarkable *taungya* (8). The *taungya* is a widespread silvicultural system based on the original shifting cultivation method of Burmese traditional cultures. Unfortunately, this technique is only used by the contemporary Maya in the more humid southern areas on the cacao or coffee plantations. The first step in the establishment of the plantation is the planting of shade trees (mainly legumes) in the milpas. At a later date, cacao and coffee are planted below the mature shade trees. It seems that the use of legume trees as shade trees for cacao is a pre-hispanic practice now also used for coffee (11, 36).

Another technique related to shifting cultivation is the conservation of a strip of ''old'' arboreal vegetation surrounding the milpa. This belt of vegetation is known by the Maya name of *tolché* and is a key factor in the regeneration process of the fallow.

Maya Forest Gardens

One of the striking features of present-day Maya towns is the abundance of trees in the kitchen gardens. These gardens have a great diversity of tree species (1, 60, 68) and their composition, structure, and function should be studied in a more comprehensive manner. In the kitchen gardens (also called dooryard gardens, orchard gardens, or, in Spanish, *solares or huertos familiares*), trees play a most important role, producing shade, firewood, useful flowers, fruits, seeds, and green forage. Many of the most common trees are the same species that are found in the ''natural'' vegetation (such as *Brosimum, Manilkara, Calocarpum, Cordia, Sabal*, etc.). In addition to these, there are several new introductions (such as lemon, orange, and other citrus fruits). In the light gaps, or in the shade of the trees, a series of other indigenous and exotic species of herbs, shrubs, vines, and epiphytes are grown (cacao, *nanche*, chile, roses, *chayote*, pineapple, orchids, coffee, corn, beans, onions, and tomatoes, among others). Mixed in the garden are found a number of wild species that became established and were not weeded out by the owner of the garden. *Each orchard garden is an experiment in structural design of an agroforestry system and much can be learned from such gardens*.

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The "tree gardens" probably originated with the ancient Maya (68) and played a very important role in the domestication or semi-domestication of many plants and animals. In these gardens, the Maya probably germinated the seeds of forest trees that would subsequently be transplanted. This procedure has been observed in a study of the Maya *caanché* technique of the present, which consists of an elevated bed constructed with wood and filled with organic materials and soil. The *caanché* is used mainly to grow vegetables, but also occasionally for germinating tree seeds for later transplanting (53, 69). The purpose of elevating the bed is to prevent damage by the animals of the household. Similar beds have been found in many parts of tropical America (22). These seed beds may have played a very important role in the domestication of tropical plant species. A variety of domestic animals were raised in the gardens; peccaries, deer, dogs, turkeys, and other animals were raised by the old Maya (48, 31).

Other Man-Made Forests

In the study of the vegetation of northern Yucatan, a series of small patches of tall forests (twenty meters tall) have been found immersed within the dominant vegetation type of the area, which is a low deciduous forest (eight to ten meters tall). Some authors (40) have identified these patches as the original climax vegetation and the rest as secondary forests. A closer study of these patches has shown that they are composed of the same series of useful trees mentioned before (*Brosimum, Manilkara, Sabal*, etc.) mixed with many other species of herbs, shrubs, climbing plants and epiphytes. It is even more remarkable that some of these patches are surrounded by old stone walls. The Maya call these areas *pet kot*, meaning a circular wall of stones. By inquiring among the local Maya, we learned that these patches were made by the "old" Maya, for the purpose of concentrating useful plants in one spot. These small patches of forests are very similar in structure and floristic composition to the "natural" forests of the Maya area, and may indeed represent the "missing link" between the kitchen forest gardens and the tropical forests. Similar forest gardens have been found in several cenotes, *sascaberas*, and *rejoyas* (patches of deeper soils in the karst). These protected patches of forests are similar in function to the *huastec te'lom* (5). Another possible place for arboriculture by the old Maya could have been at the edges of their raised agricultural fields. *Salix bonplandiana* is cultivated in a similar way at the present time in the *chinampas* of the Valley of Mexico (6).

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Natural Forests and Conservation

All of these silvicultural techniques assume the existence of some kind of natural ecosystem from which the Maya could draw the species that they needed from time to time. It is clear that the first colonizers of the Maya area, whoever they were, found a rich and diverse mosaic of ecosystems in which they lived and from which they derived their subsistence. They managed and used their environment for an unknown length of time, starting a selection process that the Maya have continued up to the present.

In order to accomplish this hypothetical silviculture, there must have been a good biological conservation strategy involving a plan of resource management that ranged from intensive crop cultivation in the raised fields to the creation of artificial forests, and to the conservation of some natural ecosystem. In between, they had many production systems in which biological diversity was the rule. Probably this is why, in spite of the fact that the Maya area was highly populated and intensively used in the past, no evidence is available that mass extinctions of species occurred, or that species diversity or richness was diminished, by the actions of the inhabitants. The proof of this can be found in the flora of the Maya area (61), rich in endemic species, from the humid areas of the Lacandon rain forest to the drier deciduous tropical forests and swamps of the Yucatan Peninsula. It is important to mention the special richness of the secondary successional flora, and this may be another gift that the old Maya gave to us that is worthy of investigation (30).

The regeneration of the ecosystems of the Maya area after successive abandonments (the last one after the Conquest), was possible only because of the existence of seed banks in managed and protected "natural" ecosystems in the area (27), and of land uses that did not cause irreversible damage to the soils.

It is clear that Maya silviculture played a very important role in past success and also in the biological and ecological conservation of the area and its resources. While we still do not know the reason for the Maya collapse, at least I think we have enough evidence to discard the hypothesis of poor management of soils and deforestation as its cause.

Most of the techniques that the Maya used to manage their forests are not unique; they have been found scattered in many other traditional cultures, not only of the New World (24, 17), but also in the Old World (52, 70). This is not surprising since we know that efficient subsistence techniques and useful species spread very rapidly and it is not improbable that they might also have been discovered independently. The presence of man in the tropical forest

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environment has been mentioned for a long time (56), and if we look carefully, it can be discovered almost anywhere—as has been the case in the (once thought) virgin Amazon rain forests (44, 49, 50, 55). It is probable that many rain forests, savannas, swamps, and other "primary" vegetation types have been influenced in their structure and composition by old selections of traditional cultures.

Lessons from the Past

It is clear that there are more questions than answers in relation to the hypothetical silvicultural system of the old Maya. But I suggest that several conclusions emerge from the available information that may be of utmost importance for our future attempts to conserve and manage tropical forests.

Shifting agriculture, as practiced by the Maya, can feed more people than we had assumed, while conserving a biological diversity for future use. It should be seen as a starting point for future permanent agriculture and silviculture in the lowland tropics, and it should not be seen as only a destructive technology. Secondary successions (fallow) in the lowland tropics can be managed in the Maya way to produce a combination of useful species for multiple purposes.

Small forest patches (natural or managed) can help to maintain a high level of diversity in the lowland tropics. They should be considered as additional areas to be stimulated for conservation of biological diversity. Artificial forest gardens for biological conservation can be designed and created by man if he wishes to do so, in order to preserve species that he chooses to preserve.

Biological diversity can be conserved, even in densely populated tropical lowland areas, if appropriate resource use practices are followed. The regeneration of rain forests from heavily used areas is possible if germplasm pools are conserved.

Many tropical traditional cultures that still exist today have a great knowledge of their environment and resources. This knowledge is a human heritage that we should not lose. It has been valuable in the past, and it could be of utmost importance for the present and future. Present-day agriculture is the result of an accumulated folk knowledge obtained from hungrily watching thousands of generations of food plants.

When studying a tropical area that has been inhabited in the past, we should pay close attention to notable distributional patterns of species, since these are likely to be the result of man's actions.

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Figure 4 Bulldozer deforested area in the Valley of Edzna where a large unsuccessful agricultural program was attempted in the same site where the old Maya probably had raised field agriculture, and silviculture.

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The population density found in the lowland tropical areas of southeastern Mexico is not a problem today. The problem lies in management practices, incorrect technology, and lack of broad ecological consideration in land use planning. The present-day activities of doubtful agricultural projects, extensive grazing, and timber harvesting on the same sites where the old Maya had temples, towns, intensive hydraulic agriculture, permanent agriculture, and artificial and "natural" forests, should cause us to doubt our wisdom and the congruency of our actions (Figure 4).

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