The Ecological Consequences of Ancient and Traditional Maya Agricultural Practices and their Relation to Modern Agricultural Development in Belize, C.A.

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RÉSUMÉ

Au cours du développement de l'agriculture, l'homme a créé des systèmes agro-économiques différents de ceux issus de la nature. Ainsi les Mayas ont implanté trois types de techniques agricoles différentes: sur brûlis, par drainage, en terrasses. Les études effectuées sur ces types de systèmes ont permis d'une part d'approfondir les connaissances sur les anciens systèmes agricoles et d'autre part d'en dégager la trame écologique sous-jacente.

Les données récentes sur le système agricole itinérant pratiqué par les Mayas démontre clairement que l'agriculture sur brûlis est utilisée avec succès dans les cas de zone à faible densité de population, mais qu'il y a dégradation dès qu'il y a pression démographique. Le système de terrasses, utile et efficace pour prévenir l'érosion semble avoir engendré au fil des siècles la formation des sols argileux lourds et avoir altéré la composition des minéraux constitutifs de l'argile. Par contre, l'exploitation des plaines alluviales et des terres basses a donné des résultats excellents, qui ont permis l'éclosion d'un écosystème agricole et ancien (sédiments aux taux élevés en matière organique, rotation et complémentarité d'exploitation avec les zones des terres hautes...) devraient pouvoir s'appliquer à l'agriculture moderne de l'Amérique centrale au bénéfice des populations actuelles de ces régions.

ABSTRACT

In the course of the development of agriculture, man created agro-ecosystems that were different from self-sustained natural ecosystems. The Maya apparently practised at least three forms of agriculture in Belize: slash-and-burn, drained and raised field, and terrace. Investigation of these three systems has yielded information

* This paper was originally presented by the senior author at the Conference on Prehistoric Intensive Agriculture in the Tropics held at the Australian National University, Canberra, August 1981.

on the relative successes and failures inherent in them and broadens our perspective of the underlying ecological principles in agricultural systems. Data from modern Maya shifting agriculture indicate that slash and burn is successful in low-density situations but breaks down as population pressures increase. Ancient terrace systems may have initially been successful in overcoming problems of erosion and leaching, but probably led to the developn.ent of heavy claysoils and the weathering of clay minerals into forms with lower cation exchange capacity. Exploitation of river bottomlands and bajo lowlands was probably the most successful agro-ecosystem and probably supported the large Classic period population. The adva.ⁿtages of this systerm included a high annual input of organic matter and nutrients in sediments and complementary croppingg periods with upland agruculture. Modern agriculture in Central America could perhaps benefit by the reactivation of these presently unused river systems.

INTRODUCTION

Several thousand years of cultural evolution have resulted in an amazing variety of agricultural systems geared to produce food either for individual use, or for barter or trade. Today in Latin America we find both labour-extensive and highly mechanized intensive agricultural systems. Much of the labour-extensive system is subsistence agriculture practised by poor farmers on low fertility soil while the intensive system is associated with the production of luxury or cash crops (coffee, cocoa, bananas, pineapple) for export and is organized and managed by the local wealthy farmers and transnationals.

In Latin America, only one country, Brazil, is classified by F.A.O. as a food exporter. The rest are food importers, and fifty percent had an undernourished population greater than 15% in 1975 (Scrimshaw and Taylor, 1980).

Why is this the case? Throughout Latin America there is evidence of past successful civilizations that flourished for thousands of years prior to the Spanish conquest. During the life of their civilization, states had to rely on their own agricultural systems to supply their basic food needs. If natural disasters occurred, i.e., droughts, floods, hurricanes, they could not rely on neighbouring states to come to their aid as is the case today. Any group of people capable of building the structures and ceremonial centres they did and maintaining them for the length of time they did, must have had a successful agricultural system.

The problems countries face today regarding their ability to feed an increasing population are essentially no different from those faced by earlier cultures. These are the need for:

1. higher-yielding crops which are obtained by following a systematic breeding program;
2. storage of grain and root crops before consumption;

Acknowledgements

We thank Paul Healy for his critical review of the manuscript, and gratefully acknowledge the editorial assistance of Ms. Joan Haire. Research funds for the Belizean studies were received from S.S.H.R.C.C. Grant No. 410-80-0454.

3. better use of water either by improving drainage techniques to reduce excess water or using irrigation to guarantee sufficient water.

In this article we examine water use from the point of view of how the Maya utilized their knowledge of ecological principles to develop a number of different agro-ecosystems that appear ideally suited to their local environments. The potential pratical application of ancient and traditional systemss in modern agricultural development in Central America today is discussed.

In the Maya region of Central America, one extensive and two intensive systems were developed. By a quirk of history it is the more ancient extensive slash-and-burn agriculture which is still practised today, while the two intensive agricultural systems (fields and terraces) used during the height of the Maya Classic civilization (300 B.C.-A.D. 900) were discontinued after this civilization's collapse and the subsequent depopulation of the area.

As the daily existence of the Maya must have been intimely tied to the immediate surroundings, it is assumed that the Maya were more objective in the utilization of their environment. The relative success of their physiographic modifications are reflected in their social and cultural evolution. However, we should not expect all modifications to have been successful. The adverse consequences of certain modifications might only have become evident years later. Then they may have been impossible to rectify with prevailing technology.

If we are to consider the ecological consequences of intensive agriculture we must understand how natural ecosystems operate before considering agro-ecosystems and the way they can affect the larger ecosystem in which they exist. The following functional approach has been modified from Odum (1971) and Shaw et al. (1977).

A. NATURAL ECOSYSTEMS

The ecosystem that ends succession is termed a climax. The chief properties of such natural ecosystems (Figure 1) are the following:

1. They are essentially stable, self-sustaining, partially open systems and are driven by solar radiation with relatively low productivity. Less than 5% of the solar energy received at the earth's surface is utilized in photosynthesis. Energy flows through the food webs and trophic levels of the system where it is dissipated in various ways. The greatest percentage of energy in the system, however, flows along the detritus pathway.
2. For the most part, macro-and micro-nutrients are cycled within the system, where they may be found in organic matter. In tropical systems nutrients are made available by mineralization of the organic matter by micro-organisms (decomposers). If these are not rapidly picked up (recycled), they may be lost through run-off or leaching, or they may be bound to other nutrients and therefore unavailable.
3. Undisturbed natural ecosystems are structurally and functionally diverse. The more complex the system, there will be the more niches there are, and the more possible links between different trophic levels in the cycling of nutrients.
4. Population levels are self-regulating. The capacity of an environment to support a population changes through time in relation to the availability of resources and the changing age and genetic structure of the population.

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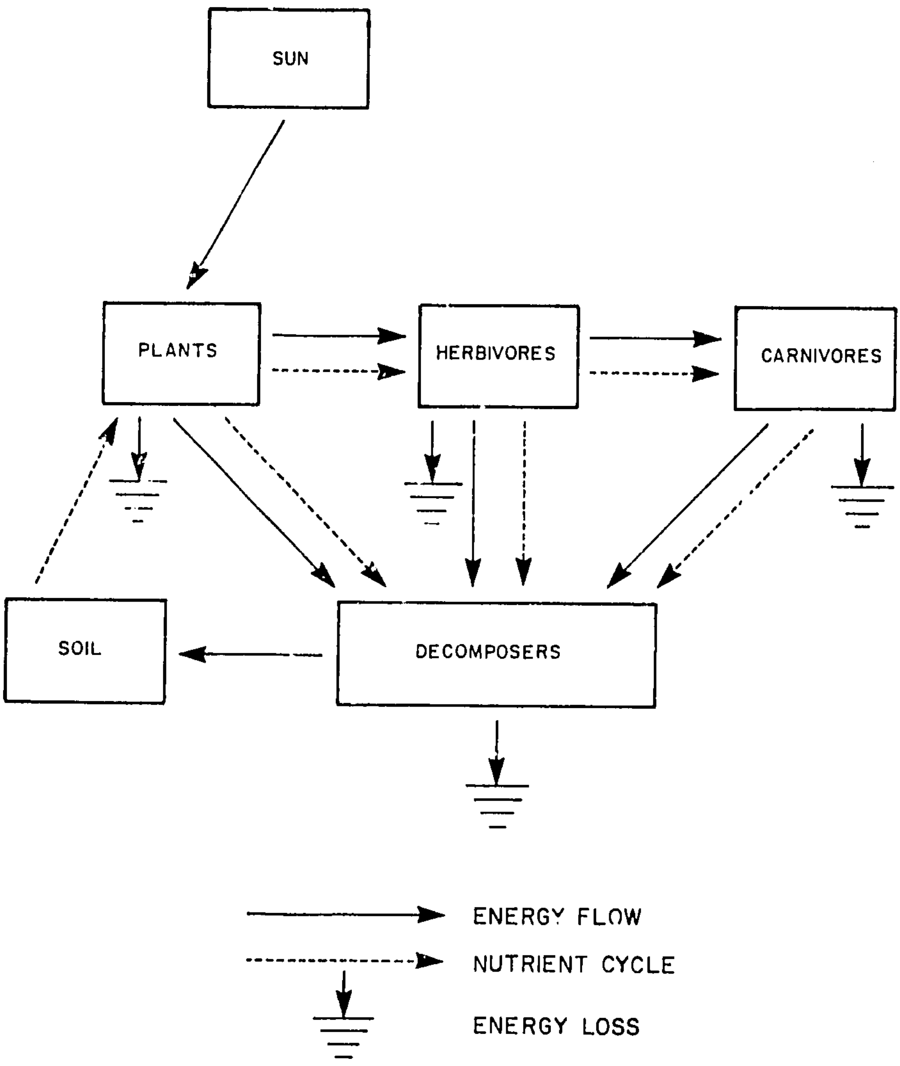
NATURAL ECOSYSTEM



5. The species richness or diversity of a natural climax ecosystem confers a degree of resilience on the system, allowing it to withstand all but the most damaging perturbations. Holling has defined resilience as the property which allows a system to absorb and utilize change (Holling, 1976). Stability is not a static equilibrium but a dynamic one which is normally highly fluctuating (Preston, 1969). Stability is the ability to recover, not to remain static once the climax has been achieved.

The opportunity for a particular insect pest or pathogen to move rapidly is not as great in a heterogeneous system as in one that is genetically uniform (homogeneous). A resilient system can absorb the induced balance of large fluctuations that occur annually in many of the populations in the ecosystem. Similarly, it can recover from an induced physical imbalance by attaining a new steady-state position or by returning to the former position. Changing precipitation and temperature patterns can lead to temporary shifts in species populations. Grazing and predation affect the diversity of the grazing and prey populations (Odum, 1971). Moderate predation can reduce the density of the dominants, allowing less competitive species greater access to resources and space. In a diverse tropical forest system severe grazing and predation are not common

Natural ecosystems tend to establish an ecological equilibrium. Rather than over-exploit their resources, they establish a pattern and rate of resource use which the environment can maintain indefinitely.

B. AGRO-ECOSYSTEMS

The principles that operate in natural ecosystems also apply to agro-ecosystems, yet those systems managed by man are often fundamentally different from natural ecosystems. Of the thousands of plants known to man, only 30 are considered to be of major importance (Harlan, 1976). The top six (wheat, rice, maize, potato, sweet potato, and cassava) each yield more than 100 million metric tonnes annually, more than twice the tonnage of the remaining 24. There are many more plants that have localized use in the world, a fact which reflects man's past close relationship to the land.

There are a number of important differences between natural and agro-ecosystems (Figure 2). They are:

1. Agro-ecosystems are not self-sustaining. They are managed open systems with high productivity. The flow of energy and cycling of nutrients are directed by man. A high percentage of fixed energy is removed from the system at each harvest.
2. The recycling of nutrients is minimal and the potential for losses is high. Nutrient supplements are needed in the form of mulch, fertilizer, or fallow. Changing the vegetation composition alters the pattern of nutrient uptake, as well as the seasonal patterns of primary productivity. In a managed system, major losses of soil can occur by erosion and major losses of nutrients by leaching.
3. Agro-ecosystems lack internal diversity and therefore resilience. Systems are dominated by many individuals of either one or a few preferred species. Predators' and decomposers' trophic levels are reduced or eliminated. For example, in the Maya area, susceptibility to herbivorous insects (*Sitophilus*), and mammals (*Quash*) or pathogen (maize mosaic virus) attack is greatly increased.

Simplification of trophic structure reduces inherent stability. The gene pool is restricted in a monocrop. Seed is artificially selected on the basis of a few characteristics rather than the broad variety of characteristic important in natural selection. Wild polymorphic strains are removed in cultivation.
4. Populations are not self-regulating. Neither crops nor animals are able to reproduce themselves so as to maintain current high levels of production. Population size depends on a managed energy flow input directed by man.
5. With no built-in resilience due to a lack of internal diversity, the system must be maintained by external (man-made rather than solar) energy inputs. There is a

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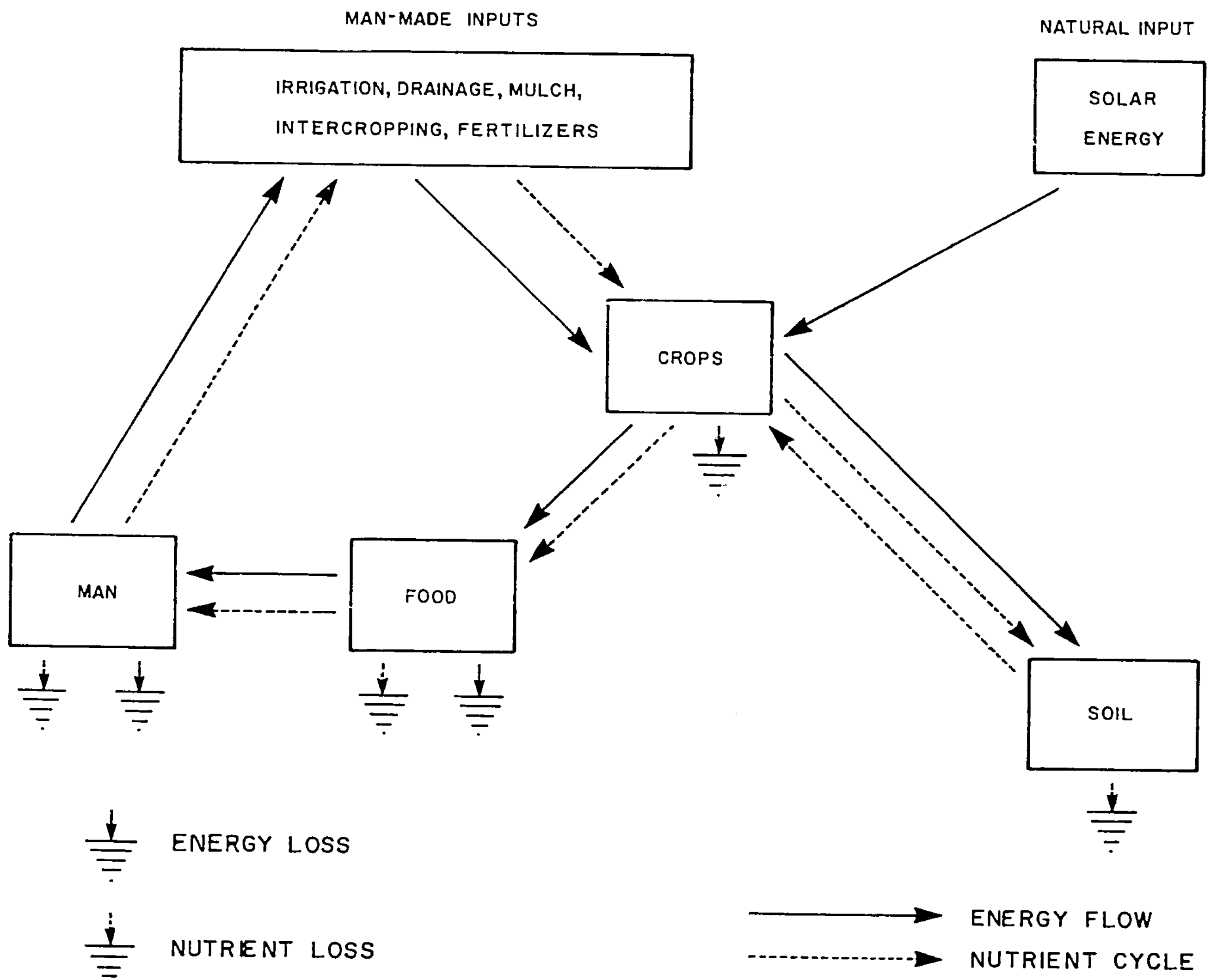
LABOUR INTENSIVE AGRO-ECOSYSTEM



continual need to breed for high yield, disease resistance, and drought resistance. Man-made energy inputs are used to increase the percentage conversion of photosynthetically active radiation reaching the crop.

6. Agro-ecosystems are maintained under constraints set by society, i.e., political and economic constraints. What makes sense biologically or ecologically is not necessarily economically worthwhile.

The agro-ecosystem is established by clearing the natural vegetation. In a tropical forest environment a large biomass is rewmoved along with its nutrient reserve. Nutrient, hydrologic, and biological cycles are broken. The micro-climate is changed. The soil is exposed to different forms of weathering and erosion than those experienced under the natural forest. Changes in soil micro-climate force micro-organism populations to adapt or to be replaced.

Two important nutrient leaks are introduced with the conversion of the forest ecosystem to an agro-ecosystem: (1) natural erosion and leaching can be expected to increase; and (2) a substantial reserve of nutrients is removed when seed crops are harvested. Root crops are less demanding on the nutrient pool as they are essentially only a source of carbohydrate.

C. CROP STRATEGIES

With any form of agriculture, man reduces the diversity of the system and exposes his crops to a multitude of noxious pests. The principal means of combatting insects, diseases, and weeds has been through host resistance, biological controls, and cultural controls. Seed would have been selected from mature resistant varieties not only for resistance to pests, but for many other characteristics. Such selection has given us the hundreds of distinct varieties that we know today. The genetic diversity of such varieties has conferred a partial resistance or tolerance to environmental stresses and insect attack.

A recent paper by Chacon and Gleissman (1982) discusses the biological role of good and bad weeds in traditional agro-ecosystems in Tabasco, Mexico. Farmers have developed a system to avoid, favour, introduce, or eliminate non-crop plants from the cropping system. Certain weeds are therefore considered by farmers to be important components of traditional agro ecosystems.

Inter- and multi-cropping are two important cultural controls. The value of inter-cropping (maize, beans, and basic needs (nutrients, light, and water), they make maximum use of the environment at different times (daily and seasonally) during the growing period. This allows for better soil use, since plants with varying environmental demands can be crowded together more compatibly than plants which respond identically. With inter-cropping, competition is reduced. In addition, the combination gives diversity and resilience to the agro-ecosystem. One crop may provide a suitable habitat for predators of insects which attack the other crop. Squash, with its prostrate growth form, both inhibits weed growth and helps to minimize surface soil moisture evaporation. Squash can also play a role in holding nutrients that become available when plants are malched or burned each year.

D. SYSTEMS OF CULTIVATION

Intensive agriculture required farmers to develop new land-use technologies. The construction of terraces, drained and raised fields, and the many other systems were essentially innovative ways of concentrating or removing water from land surfaces. Whatever system the Maya devised for a specific environment had to work, as there was little opportunity to import foodstuffs if the crop failed. That the Maya had the knowledge and skills to modify their local environments is evident in the increasing number of localities of intensive cultivation which have been identified in the Central Maya Lowlands during the past decade. It must be assumed that not all food-producing systems would have been productive over time. How the Maya attempted to cope with such problems will never be known.

Within Belize we have observed and studied several different natural and modified land forms which were used for food production. Physiographically they can be divided into:

Upland		Lowland	
Slash & Burn	Dry Terraces	Raised Fields (poorly drained)	Drained Fields (well drained)

The identification of other forms is based on whether one is a "lumper" or a "splitter". What we are interested in is: (1) whether we can determine the environmental conditions the Maya were attempting to modify in order to utilize the natural resources for food production, and (2) what were the ecological consequences of such modifications.

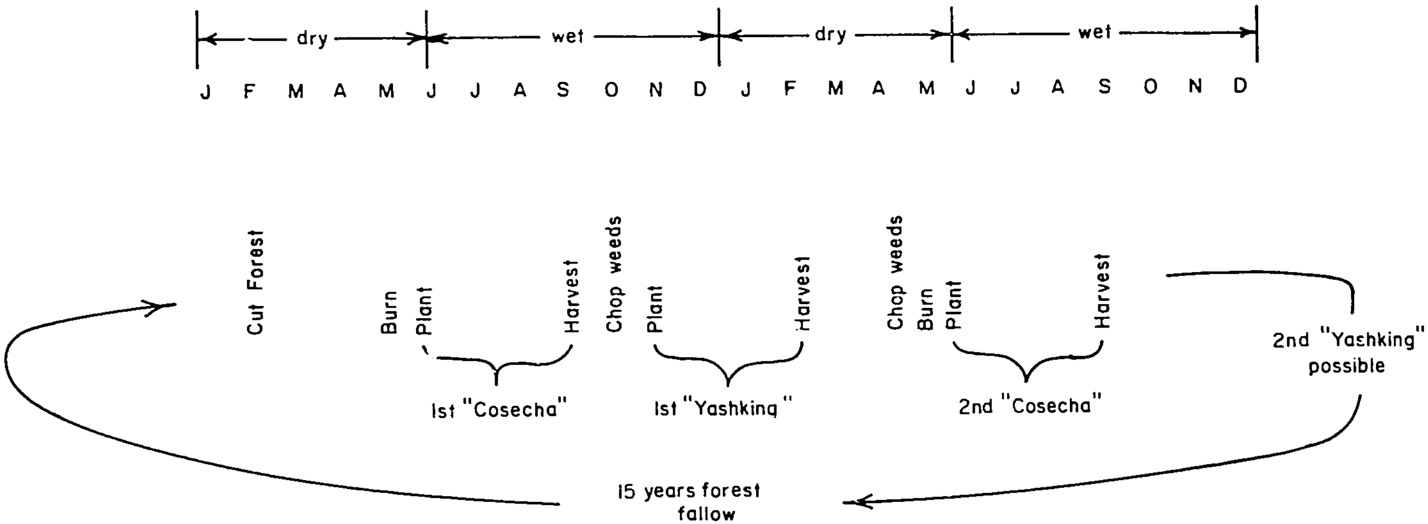
E. EXTENSIVE AGRICULTURE

Shifting cultivation, slash-and-burn, milpa, or the easy-way agriculture are generally thought of as primitive (Boserup, 1965). F.A.O. (1957) condemned the system as wasteful of land and human resources. The system, however, is both economically efficient and ecologically sound. Tribes and family units have used the system for thousands of years to supply their basic nutritional needs (Boserup, 1965; Chacon and Gleissman, 1982; Harris, 1978; Lambert et al., 1983; Wilkinson, 1973).

Such a system exists in response to two major features of the tropical environment: (1) rapid depletion of soil nutrients following burning, and (2) a rapid increase in insect pest and weed populations (Cox and Atkins, 1979). In ecological terms, shifting cultivation represents the periodic exploitation of the nutrient capital of the natural forest; in economic terms, it represents the maximum energy return for minimal energy expenditure.

Under slash-and-burn cultivation there is no modification of the land base. The farming cycle traditionally begins in December or January when farmers select their land for clearing (Figure 3). Such sites should exhibit moderate to good drainage, with few areas where water may accumulate during the rainy season. In Belize the preferred forest type is the Cohune Ridge dominated by the palm *Orbignya cohune*. Because the tree lacks secondary growth it burns rapidly on drying, leaving a relatively clear area for the farmer to plant his seed. The major crops are maize,

MILPA AGRICULTURE IN CENTRAL AMERICA



"Cosecha" crops: corn and climbing beans, planted together

"Yashking" crops: corn or bush beans, planted seperately beans, and squash. Other crops inter-cropped with maize include jacama, yams, sweet potato, and sesame.

Immediately following the burn there is a sharp increase in the soil chemical properties (Table 1). The degree and duration of such changes depend on the original vegetation composition, soil properties, and local climate. Our data indicate that the reason for abandoning slash-and-burn fields in Belize after two or three years is due to increased weed growth and not because of a decline in soil fertility. It is assumed that in the past the Maya would have followed a systematic land-use policy of inter-cropping, multi-cropping, and mulching. High yields could have been maintained for periods of longer than two years. Shifting cultivation as practised today is seldom capable of supplying more than just the basic needs of the farmer and his family. This is not the fault of the system; it is just that any more than the family needs is wasted.

The system has been practised by Maya farmers for millenia. Why does such a system break down and become unproductive? The system does not break down ecologically if families are left alone. One reason for its demise in the past would have been a rapidly increasing population that would have necessitated shorter fallow periods. Shorter fallow periods lead to declining soil fertility, resulting in lower yields. All this gives rise to the need to change the methodology of cultivation. It is considered wasteful today because people are confined to small areas where fallow periods are impossible due to encroachment by sedentary intensive forms of agriculture (Gross et al., 1979). The soils quickly degrade when family groups are restricted in the land area they may use for cultivation. In our study at Succotz, Belize, low levels of phosphorous and zinc were found to limit crop production, and soil erosion leads to coarser textured soil with low water retention (Arnasson et al., 1982).

Table 1: Physical and chemical data* from selected agricultural areas in Belize, C.A.

	Slash & Burn Indian Church	Drained Field New River		Slash & Burn Succotz	Terrace Caracol	
		Layer 1	Sediments		Upslope	Downslope
OM%	13	18	46	14	17	17
Co_3%	8	13	28	13	2	13
Sand%	21	19	25	65	5	11
Silt%	47	5	20	21	4	1
Clay%	32	76	55	14	90	88
pH	6.9	6.2	7.5	7.1	7.9	7.7
C/N	15	14	12	13	13	13
N%	.4	.6	1.7	.5	.6	.6
P ppm	21	20	160	11	50	40
K ppm	350	150	450	640	420	360
Ca ppm	16900	7200	60000	30000	34000	30000
Mg ppm	7900	1900	4000	8100	1700	1000
Na ppm	20	670	300	30	10	20

* All samples were taken between 0 and 15 cm. Indian Church milpa – 1 year old. Succotz milpas have been used for ca. 100 years. Drained fields were sampled following burning and Layer 1 does not reflect the nutrient flush. Caracol soils are from forested slopes.

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F. INTENSIVE AGRICULTURE

Labour-intensive permanent agriculture is a response to an increasing population and it requires a modification of land forms and methodology to maximize production. In pre-Hispanic Central America, the system maximized the role of ecological mechanisms, emphasized the use of renewable resources, and was maintained by human labour. Permanent agriculture made use of local environmental conditions and allowed for the continued use of land under cultivation. Both lowland and upland systems depend on precipitation for moisture and take advantage of natural water flow or direct water through irrigation channels.

1. Upland systems

In upland sites the most obvious need is to minimize any downslope movement of soil and nutrients in the water flow. Terrace walls at Caracol, in the Maya Mountains, can be either a double wall of large outer boulders with an interior filled with small stones and fines or a single wall of large boulders backed by smaller stones. Both types would allow subsurface seepage water to pass downslope. The type of wall construction is probably an indication of precipitation patterns, surface flow and angle of slope.

Two basic processes would have been involved in the development of the terrace soils. Mechanical weathering would lead to disintegration of aggregates and decomposition would be responsible for chemical changes. The decomposition and/or burning of plant materials would help to maintain adequate organic matter and nitrogen levels. All three processes acting together would result in a nutrient-rich soil. Colour descriptions were made for all horizons but, as particle size analysis indicated little difference between horizons, the colours are likely the result of leaching humic acids from decomposing organic matter.

Having no proof other than a lack of terraces at upper elevations, we have assumed the Maya left a forest cover on hill summits. The vegetation cover would have intercepted a proportion of any precipitation, thereby reducing the amount of water flowing over the lower slopes. On passing through the vegetation and soil profile, precipitation would have carried aggregates and nutrients to the lower slopes, which would have helped to maintain nutrient richness. The tree zone would have also served as a biological reservoir, and a source of wood, food, and medicinal plants. Flow of water over and through the limestone terrace walls would also have resulted in the additional release of aggregates and Ca, Na, Mg, and K ions.

If cultivated soils were close to or level with the top of the walls then overflow could be expected during the rainy season. To stop surface erosion, the top of the wall would need to be above the soil surface. The problem then is that the back wall serves as a dam to particle flow. Such materials, however, could be easily redistributed at a later date over the terrace surface.

Except for the occasional buried stony layer, there is an almost total lack of particles larger than 1 mm on the sampled profiles. This would suggest that all the stones were removed for the construction of the terrace walls. Particle size analysis of Caracol terrace soils reveals a very high clay content for alld recognizable horizons (Table 1).

The reason for such high clay levels could be due to intensive agriculture which reduced the percentage of aggregates and led to an increase in percentage of silt and clay. In time, these small particles could have clogged the larger pores between the larger aggregates and stones, decreasing infiltration. At the time of abandonment the soils could have been impervious to air and water. Water would either flow over the surface or puddle. On drying, the soils would be hard and dense. Since structural aggregates would not have been easily broken down, tillage would have been difficult.

The terraces, we believe, would have replaced slash-and-burn cultivation as the local population increased. The cultivation of the primary crops is suited to both types of land use and would not have required the introduction of new varieties or crop species. However, farmers would have had to synchronize their crop moisture requirements with the available soil moisture supply. Such soil water levels would have been different on slopes used first for slash and burn and later terraced (terraces could be assumed to be more poorly drained).

Charcoal fragments present in the terrace soils suggest that cultivar remains and weeds were burned to clear the soil for planting and to provide nutrients (Healy et al., 1970). Trees and large shrubs would have been an unlikely component of the terrace system because their root systems would have been destructive to the walls.

The ecological consequence of terrace cultivation is that over time the physical properties of the soil become dominated by clay particles which can seriously inhibit soil water infiltration rates. The accompanying change in bulk density would have a water control system has been established, the three agricultural advantages of cleared for agriculture today, they would be difficult to work once the organic matter in the upper horizons was depleted.

II. Lowland systems

a) Drained Fields

There are no large river systems in the Central Maya Lowlands. Because the region is subjected to seasonal flooding, the soils of river systems offer a suitable site for agriculture. However, because most of the region is underlain by limestone, these soils are calcareous alluvial soils with a high $CaCO_3$ content and a pH above 7.0. Ecologically, river valleys are classified as bottomlands and characterized by seasonal flooding and usually moderately well drained soils.

Upon drainage, the deposited sediments are incorporated into the soil profile by the combined activities of animals, plants and micro-organisms. The rate of homogenization of the sediments has important agricultural implications, because where biological homogenization is limited, agricultural potential is also limited. Use of the alluvial soils requires control of drainage, irrigation, and flooding. Once a water control system has been established, the three agricultural advantages of alluvial soil can be exploited: (1) ease of water distribution; (2) minimum erosion, and (3) annual deposition of alluvium.

We have called the modified land forms associated with the New River floodplain system at Lamanai "drained fields". The term also fits within the definition proposed by Denevan (1979). Border fields described by Turner and Harrison (1981), at Pulltrouser Swamp, down river from Lamanai, as well as similar features in the Rio Hondo (Puleston, 1977), come under the definition of "drained field". Similar surface patterns occur along the east shore of the New River Lagoon. They cover an area of approximately 2,000 hectares. Wilken (1973) has identified floodplain regions in the Peten and along the Copan River where intensive farming might have been possible.

The drained fields at Lamanai are submerged for approximately six months of every year, from June to December. At times canals appear to be regular, as though they were manmade, but they can also follow natural water flow channels. A large flint blade, charcoal, and pottery found in an archaeological trench in the fields are evidence of man's presence. Such indicators could be used to suggest that the Maya understood the value of the floodplain and recognized the need to dig additional canals and/or to modify existing natural flow channels if they were to make optimal use of the area.

With flooding, water stress is eliminated, weed control is easier, and the availability of nutrients, particularly P, Ca, Mg and Fe, is increased. At the same time, the pH approaches neutrality. Sediments deposited during the flood period have been shown to be in excess of 1,700 kg/ha. Physical and chemical properties of the drained field soils clearly indicate the agricultural potential (Table 1).

There is no need to burn each year to remove unnecessary plants. Such a system could ostensibly be used as long as flooding occurs, providing it is practised objectively. Cultivation over time would have no detrimental ecological effect. By removing the forest cover, the present-day farmers would find a soil suitable for agriculture during the dry season; they could make use of a resource their ancestors almost certainly recognized and exploited (Lambert et al., 1983).

b) Raised Fields

Raised fields are man-modified land forms that occur in areas of flooding where water loss is restricted primarily to evapo-transpiration. In Belize they have been identified by Siemens (1978) in both floodplain (riverine) and bajo habitats. Their morphologies are varied and largely related to their position within the system.

At Pulltrouser Swamp the canals are considered regular in form. A mottled silty zone overlies a buried organic layer and is itself topped by a humus layer. The thickness of the fill varies between the individual raised fields and is probably an indication of past water levels and periods of agricultural use. The surface organic layer would be added to each year by the deposition of sediments brought into the swamp by surface runoff from surrounding terrain, muck from the canals, and possibly by floodwater overflow from the New River.

Providing that climatic and hydrologic conditions have not changed, and there is no reason to believe that they have, the raised fields, like the drained fields, could be cultivated indefinitely. Their fertility is based on an annual deposition of nutrient-rich sediments. The six-month period of exposure means that they cannot be used continuously throughout the year and that other forms of cultivation (slash and burn or terrace) must be used.

c) Kitchen Gardens

A form of intensive cultivation pursued by most families was and still is, the "kitchen" garden. The role of gardens has been discussed by many observers from

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the Landa (1956) to Wilken (1971). Gardens would have played an important role in supplying the immediate daily needs of the family—spices, vegetables, fruits, and shade. Useful medicinal plants would also have been cultivated. Gardens would have benefited from household wastes and animal excreta. Evidence of such gardens can be determined by inorganic phosphorus analysis. If not immediately recycled, when returned to the soil it becomes tightly bonded to Ca, Fe, or Al and therefore is unavailable (Eidt, 1977).

The development of a particular set of natural resources (physical and biological) is indicative of the adaptability of man. When the environment cannot sustain the resource level, a society must develop adaptive kinds of technology. The question then is how many particular kinds of technology can be developed through time before the system can no longer maintain the balance between the demand for resources and what the environment can supply.

The transition from ecosystem-manipulation to ecosystem-transformation (Harris, 1978) was, we suggest, accomplished without change in inter-cropping and multi-cropping techniques. We are assuming that the crops which we know today were already in use and that the principle of diversity (inter-cropping) was well understood by Maya agriculturalists at the manipulation stage. The need to maintain biological diversity would have been recognized both from the viewpoint of supplying a nutritious diet and that of providing a method of crop protection. The major change would have been in the modification of certain land forms and their hydrological systems.

Where the hydrological changes were related to improved drainage, at Caracol, the sites still appear today to have agricultural value. Terrace construction on slopes to manage water has resulted in the development of soils with a high clay content. If the organic content of such soils was reduced to less than 3%, then the soils would have had low agricultural potential (Jones and Eck, 1973). The re-established forest cover has resulted in the present-day soil organic content of more than 15%. The result is a soil with a highly active clay-humus complex capable of retaining mineral elements in exchangeable form. The problem with such soils if they were to be used today is that if the humus content declines appreciably, one good rain would be sufficient to wash out the highly soluble salts as carbonates of potassium, magnesium, and ammonium. We would, therefore, suggest that large population centres that arose in mountainous regions and relied on dry terrace agriculture were probably short-lived. Centres that used a diversified land-use system, slash-and-burn and drained-field or raised-field agriculture would have seldom been short of food. Lamanai on the New River Lagoon is not considered a large Maya centre. Pendergast (per. comm.), however, considers that it has had an extremely long continuous occupancy, from ca.600 B.C. to A.D. 1250.

A stage inevitably seems to be reached in a society's cultural evolution when it exhausts the environment of its agricultural base. If the culture is to survive it must move into another environment. In Europe, when this stage was reached, it moved into an industrial environment (Rifkin, 1980). This was not the case in Meso-america: the system of large semi-autonomous city states collapsed, and rather suddenly it appears. Today we tend to think of our agricultural technologies as not only being the most advanced but also the most suitable ever devised for the situation. We are, therefore, amazed at what earlier "less advanced" cultures were able to do without the use of an industrial-based technology. On objective analysis we find that many of the early technological innovations developed by the Maya clearly show that they had a very good understanding of plant breeding, cropping systems, hydrology, and pedology.

CONCLUSION

Of the cultivation systems discussed, only the dry terraces have no built-in recovery system. Slash and burn, as used by small population groups, replenishes its nutrient pool and rids itself of weeds during the fallow period. Drained fields annually receive a deposition of nutrients and mineral sediments from flood waters. Such additions are not only beneficial for crop growth, but they also help to another establishing weeds. Through necessity, the Maya were forced to use the extensive, poorly drained bajo/lowland sites for cultivation. That so much of the Central Lowlands are now being shown to be covered by raised fields suggests that the Maya recognized the natural fertility of such areas and had both the knowledge and skills to modify a resource base to their economic advantage. Through a system of canals and the raising of the ground surface above low water levels, they turned what are essentially inhospitable environments into agricultural oases. If local farmers were to remove the forest cover from raised and drained field areas today, they would have available good agricultural land. This would not be the case, however, with terrace soils.

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