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ORIGINAL ARTICLE

Chapter 10. Intensification does not require modification: Tropical Swidden and the Maya

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Abstract

What is involved in finding fields? Agricultural intensification and its archaeological correlates are not always obvious. Archaeologists frequently equate *capital*-based investment and *arable* farming as the sole path to intensified production. The presence of terraces to slow water flows across land, canals to bring water to drier lands, and raised and drained fields to reduce water, are methods to bring *marginal* lands into productive use. Labor-based economies, especially those of the Americas before European conquest, present an entirely distinct pathway toward intensification based on tending the landscape. Tropical societies in general, and the Maya in particular, demonstrate a comprehensive knowledge of the natural world, cultivating biological capital as a product of their culture with skill, hand tools, scheduling, and fire. Asynchronous and embedded fields transform into forests in a poly-cultivation practice, emphasizing the diversity that prevails in tropical woodlands. As with most traditional land-use systems around the world, the Maya *milpa* cycle reduces temperature and evapotranspiration, conserves water, maintains biodiversity, builds soil fertility, inhibits erosion, and nurtures people. Labor investments *per se* do not leave direct evidence on the landscape, apart from the implicit density of settlement, yet the imprint of their management lies in the forest landscape itself.

KEYWORDS

agricultural intensification, Agroforestry Milpa cycle, land use, Maya civilization

INTRODUCTION

To appreciate agricultural landscapes, we need to find cultivated fields. It is fields and their use that are the source of agricultural production. Agricultural intensification is the process of increasing product yields by means of greater inputs. Such inputs can include anything from extending land in cultivation to increased labor expenditures, but archaeologists tend to use the term intensification specifically in reference to visible infrastructure, or landesque capital (Håkansson & Widgren, 2014; Marcus & Stanish, 2006; Sen, 1959; cf. Fedick et al., 2023). In the case of the ancient Maya, there is minimal evidence of visible land modifications, which has been seen as an obstacle by investigators seeking evidence of "intensification" (Adams et al., 1981; Beach, 1998; Culbert, 1974; Dunning et al., 2020; Turner II & Harrison, 1983; Turner II & Sabloff, 2012). Scholars have, without evidence, stressed the inapplicability of the ethnographic *milpa*[1] (Culbert, 1974, 37–41; Webster, 2002, 87–88). The impression that is given is that there are grave limitations to land use that relies on shallow soil and is rainfall dependent, as in the case of the Maya Forest (Whitmore & Turner, 1992, 2005). Consequently, scholarship has focused on identifying landesque features equating canals, terraces, and raised fields with the

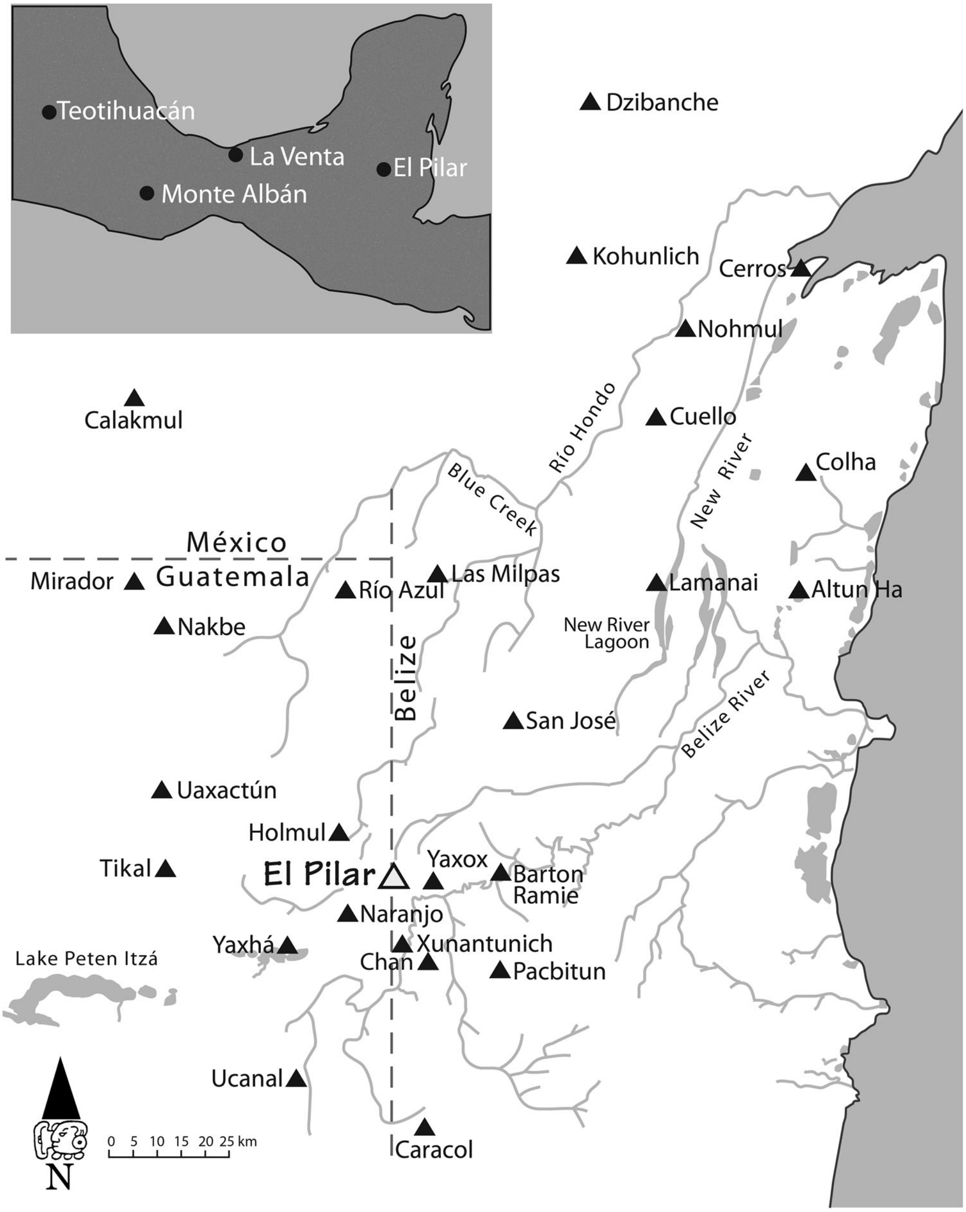

FIGURE 1 Central Maya Lowlands with Countries and Major Centers Indicated (credit ISBER/MesoAmerican Research Center, UCSB).

development of Maya complexity (Blaikie & Brookfield, 1987; cf. Sheehan et al., 2018). While such features have indeed been recognized in the Maya area, most land modifications lie outside the central lowlands, with the absence of landesque features at such major centers as Tikal.

Little attention has been given to the traditional milpa system as a design for intensification (Fedick et al., 2023), yet this system was recorded at the time of contact and has been successfully maintained over the succeeding centuries (Alexander, 2006; Dedrick et al., 2023; Ortiz Yam, 2009; Terán & Rasmussen, 1995). Archaeologists have viewed the traditional food production systems of the Maya (Figure 1) as unsophisticated and in conflict with the magnificent monuments built across the area. Yet the ancient Maya, who practiced rainfall-dependent farming, clearly developed an effective body of agricultural knowledge rooted in the skillful use of their basic tools of stone and fire. New World land-use strategies emerged in the absence of major capital investments such as the cows and plows of the Old World (Mt. Pleasant, 2011). The interrelationships among people and their observations of natural environmental processes formed the basis of subsistence adaptations across the landscapes of the Americas. In this sense, the Maya agricultural system and the strategies for intensification had to work with nature, developing over millennia of trial and error, essentially domesticating their landscape (Campbell et al., 2006; Ford, 2020; Ross, 2011). The long-term interactions that led to the domestication and widespread cultivation of maize provide a good example of such processes (Blake, 2015).

The tropical setting of the Maya area presents a specific case where exuberant plant growth is often perceived as an obstacle, instead of an opportunity, for agricultural development. No significant winter cold means that, in wet and dry periods, planting, growing, nurturing, and reaping constitutes a year-round occupation (Bates, 1952). The system of cropped fields of annual plants in the context of the perennial forest is referred to as "shifting agriculture," where the surrounding forest is referenced as simply "resting." Extensively clearing fields could diminish the forest, as Malthus (1798) feared. For the Maya, however, it was not a choice between cultivated fields and forest, as it appears to Western eyes, where *cultivable* has long been equated with *arable*.[2] Moreover, the regenerating forests, seen by Westerners as fallow (technically an unseeded plowed field), builds useful qualities in the succession of the milpa forest garden cycle (Ford & Nigh, 2015). Western agricultural terms have imposed prejudices, blinding an understanding of Indigenous systems (Mt. Pleasant, 2011). The sophistication of the Maya milpa land-use strategy resides in the skillful practices that manage stages of forest gaps and successive regeneration to benefit humans.

Agroforestry studies demonstrate that traditional Maya agriculture as practiced today is based on intimate interactions with the natural progressions of growth as well as the response to cutting and burning (Ford, 2020). These comprehensive subsistence and environmental management strategies focus on soil quality, food diversity, and production of materials for construction and medicine (Altieri & Toledo, 2005). The Maya direct tropical growth towards household necessities, resolving the needs of everyday life with labor, knowledge, and skill (Cook, 2016; Johnston, 2003; Kellman & Tackaberry, 1997; Martínez-Reyes, 2016; McNeil, 2012; McNeil et al., 2010; Steggerda, 1943; Stone et al., 1990; Wilken, 1987). Master forest gardeners say that without the field, there could be no useful forest, and without a useful forest there would be no productive field, recognizing each sprout as a recommendation. They describe a softscape of agricultural intensification rather than a hardscape of infrastructure. The development and expansion of Maya civilization was based on consistent and reliable resource management for the long term (Terán & Rasmussen, 1995). It was the management of the milpa field-to-forest cycle that left a substantial imprint on the forest itself (Campbell et al., 2006; Ford, 2008; Ford & Nigh, 2015). It is important to reiterate that the fields are part of the forest, and to find a field, one needs a different set of lenses.

BRIEF CONSIDERATION OF AGRICULTURAL CHANGE

Processes of agricultural transformations that track chronological changes are clearly fit for archaeological inquiry. Archaeologists can gather data that reflect dimensions of population and landscape relations to assess variations in growth and development. Boserup's (1965) critical work brought up potential relationships of settlement and environment by relating changes in population with changes in the intensity of land use (cf. Morrison, 1994). In Boserup's expanded work (1981), she takes a wider view of technological changes, providing room to appreciate how technological developments in general were fueled by population growth and the need for greater yields.

Boserup applied her ideas of agricultural intensification in broad strokes, and as always, the devil is in the details (cf. Johnston, 2003; Morrison, 1994). She generalized based on data predominantly from Europe, thus giving short shrift to other areas, in particular the Americas. Her thesis, however, provides archaeologists in the Americas with a strong basis to test the relationship between population change and agricultural development. Importantly for the Americas, where agricultural intensification required an intimate knowledge of the environment, change was subtle; where constraints of topography, rainfall, and geology influenced cultivation and the domestication of the landscape (Ford, 2020). The agricultural strategies and practices, by design, intervene in the natural processes to cultivate the biological capital required for sustenance. The requisite observation, connection, manipulation, and management of the resources, though more challenging for archaeologists to identify than terraces or canals, together created the legacy of intensification.

Tending the wild, as Kat Anderson (2005) portrays in her study of California, identifies the fundamentals of the prehistoric American adaptation that relies on strategic investment in labor, skill, and scheduling, with an essential commitment to the power of nature (cf. Bray, 1994; Stone et al., 1990; Toledo, 2022). The common ground of the prehistoric American agricultural experience is the dependence on rainfall, cast by Western ideology as a debility (Whitmore & Turner, 2005), yet was simply a viable reality of land use. This fundamental factor of dependence on rainfall impacts all forms of life, and, for the Maya, it underscores the necessary long-term attention to water conservation and the moderation of surface temperature with shade, impacting management of erosion and enhancing soil fertility (Fedick et al., 2023). In this setting, Traditional Ecological Knowledge (TEK) requires keen observation of the natural processes, trial and error, and experimentation that is not routinely reflected in any evidence of land modification.

For the case of the Maya, the use of agricultural intensification has fixated on terraces, canals, and raised fields. While such investments do occur, they occur where there are water limitations—its speed or its accumulation—that require modifications (see Blaikie & Brookfield, 1987; Darch, 1983; Fedick et al., 2023; Håkansson & Widgren, 2014). Yet these modifications are aggrandized over any other potential land-use evidence. The lack of landesque capital investment in agricultural modifications discounts the importance of residential settlement density, a clear reflection of intensity. Given that Maya farmers tend to live near their fields, the distribution of farming settlements should be, in itself, an indication of the location of the fields (see Folan et al., 1979; Isendahl, 2002; Zetina Gutiérrez, 2007; see also Fletcher, 2011).

Finding fields in the Maya area is exacerbated by interpretations of land-use potentials. A review of soil studies and cultivability classifications in the Belize valley (Jenkin et al., 1976) and in Guatemala's Peten (IGN, 1982) is revealing. These are areas of significant ancient Maya occupation yet the application of European standards to the Maya Forest landscape are perplexing. In the case of Jenkin et al. (1976), they specifically indicate that their analyses of land-use capability are aimed at what is arable or plowable. They assess the vast uplands around the major center of El Pilar as not suitable for agriculture, while the residential structure density ranges as high as 200 per square kilometer. Equally troubling is the evaluation of the areas surrounding Tikal as inappropriate for agriculture but suitable for forestry. These areas exhibit shallow soil and sloped lands, yet are fertile and workable (Fedick, 1989; Fedick & Ford, 1990). These areas have a high density of ancient settlement; these were certainly farmers, as we know that the ancient Maya civilization was agrarian. Reexamining the soil attributes of the Belize study produced a predictive model based on fertility, drainage, and slope demonstrating Maya settlement favoring the fertile and friable well-drained ridge lands and avoiding the poorly drained clays targeted for plowing (Ford et al., 2009). Perhaps the Guatemala forestry assessment supports the proposal of the Maya milpa forest gardens (Ford & Nigh, 2015).

The natural potential of the land itself encourages low-tech solutions as the first choice, such as increasing or decreasing investments in labor, skill, and scheduling (see Johnston, 2003; Stone et al., 1990). When these first choices do not suffice and fertility is not an issue, landesque capital investments may emerge as options, as land modification represents areas where limitations were confronted (Darch, 1963; Marcus & Stanish, 2006). These landesque investments have been recorded in the terraces to slow water movement, for example, in the Rio Bec area of Mexico and at Caracol, Belize, and in the raised and drained fields created to reduce waterlogging around Rio Hondo and the New River, Belize. The presence of such landesque capital investments reveals the insufficiency of the preferred lands that could support the needs of the populace without modifications. In other words, intensification can take on many aspects. Investment in landscape modifications to expand cultivation represents more effort and would be reluctantly undertaken in the absence of limitations. In this chapter I explore the implications of intensification without modification.

MAYA FOREST OF SOUTHERN MESOAMERICA

Appreciation of the Maya Forest begins with an understanding of the geography (West, 1964; White & Hood, 2004). The limestone geological foundation is based on a karst platform that influences the spatial distribution of all resources, but especially water. Local variations in limestone are expressed in drainage features and seasonal water distribution. The porous limestone absorbs rainwater, with variations in precipitation from the dry northwest Yucatan Peninsula to the more humid south. In the central area, where the majestic ancient cities of Tikal and El Pilar stand (Figure 1), rainfall ranges from 1500 to 2000 mm per year. Rainfall today is distributed variably over the year, with the major warm monsoonal rains beginning in late May followed by the minor cool rains of late November. Little to no rainfall registers in March through May. Vegetation cover over the limestone base depends on local climate, rainfall, and slope conditions, with upland forests replete with magnificent towering trees that thrive in the fertile shallow soils and are cultivated for a range of economic uses (Reina, 1967, 1984).

The Maya Forest today is a legacy of eight millennia of human-environment interactions and the consequence of ancient Maya management strategies, which were driven by a complex settlement hierarchy that arose 3000 to 4000 years ago. The result, witnessed in ethnohistorical and ethnographic observations, is revealed in infield home gardens and a wide array of intensive outfields embedded in a regenerating forest. This settlement interaction was impacted by and responded to effects of management practices across the region. With knowledge and practice, the Maya imposed their will on the landscape as the environment provided constraints on that will.

Human impacts on the Maya Forest are registered in the archaeology and paleoecology of the area. There is little doubt that the productivity of Maya land-use strategies financed the development of Maya civilization and its transformations over time (Table 1). The ancestral Maya responded to uncertainties with the ongoing adaptations of resource-management practices, interacting with and adjusting to tropical forest ecological regimes. The milpa forest garden strategies were necessarily flexible to adapt to varied circumstances of deluge and drought (Tuxill, 2004). The high-performance

TABLE 1 Occupation chronology: 8000 years in the Maya Forest.

Years before present	8000–4000	4000–3000	3000–2000	2000–1400	1400–1100	1100–800	800–500	500–present
Human ecology	Hunting and gathering	Early settlement	Emergent Preclassic centers	Civic center expansion	Center and settlement growth	Civic center demise	Settlement refocus	Conquest depopulation
Land use	Mobile horticulture	Settled horticultural forest gardens	Settled forest gardens	Expanding milpa forest gardens	Centralized milpa forest gardens	Community milpa forest gardens	Dispersed milpa forest gardens	Disrupted milpa forest gardens
Cultural period	Archaic	Formative Preclassic	Middle-Late Preclassic	Late Preclassic-Early Classic	Late Classic	Terminal Classic Postclassic	Late Postclassic	Colonial, national, global

milpa (Wilken, 1987), as the key to the milpa-forest garden cycle, is the axis of the resource-management system that has dynamically shaped the Maya Forest. This system provided the basis to sustain early settlements, fueled the growth and development of the Classic Period Maya, and was observed by the Spanish as they set about to conquer the region at the outset of the 16th century.

BACKGROUND ON THE ANCIENT MAYA

The peopling of the Maya area dates back more than 15,000 years ago, as hunter-gatherers moved into the Americas. The area was cool and arid until 8000 years ago, when it became the warm and humid area so familiar today. The next ca. 4000 years were largely stable with a drying trend that persists today (Ford, 2022). Climatic instability and uncertainty marks the Early Preclassic, when the region witnesses the widespread emergence of permanent settlements (Ford & Nigh, 2009). For nearly 2000 years thereafter, climate chaos is reflected in the precipitation data for the region (Haug et al., 2001; Medina-Elizalde et al., 2016; Mueller et al., 2009; Vela-Pelaez et al., 2018) and consequent vegetation impacts provided an impetus to invest in landscape management. The scant archaeological data indicates that these early occupants were mobile horticulturalists (Ford, 2022; Ford & Nigh, 2015).

In the context of an overall drying trend, by the Middle Preclassic, some 3000 years ago, settlements spread in the well-drained uplands of the Maya area. About 2000 years ago, all major uplands in the Maya area have settlements (Fedick & Ford, 1990). These settlements were the bases for Preclassic Maya cities, such as Mirador and Cuello, and later the likes of Tikal, El Pilar, and others that became major players in the administrative hierarchies of the Classic Period.

The emergence of the Classic Maya civilization is marked by the growth of settlements in the 1st millennium CE. Monumental architecture with plazas, palaces, and temples are hallmarks of the major civic centers of this time. Large, relatively dense occupation of the well-drained ridges, first settled during the Preclassic (Canuto & Auld-Thomas, 2021; Ford, 1986; Ford & Nigh, 2015), experienced infilling over time with increasing evidence of social complexity. Residential settlements dominate the uplands of the central lowlands (Bullard, 1960; Fedick & Ford, 1990). This growth is evidence of subsistence intensification that continued to support the growing populations of the Late Classic, from 500 to 900 CE (Culbert & Rice, 1990). Land use, as indicated by the abundant ancient structural remains, was intense.

Population and density estimates for the Late Classic are a subject of major debate. Certainly, the expansion of the Maya civilization over centuries, if not millennia, underscores success (Ford & Nigh, 2015). Population and land use plainly must have aligned to support the development of the Maya; with centuries of growth as confirmation (Ford et al., 2021).

The Terminal Classic marks a major change in the character of the Maya civilization, featuring increasing neglect of monumental architecture. The current leading candidate provoking this change is overpopulation, resulting in deforestation and soil degradation (Turner II & Sabloff, 2012). Yet the actual associations are difficult to match. The so-called Classic Maya “collapse” is worth reevaluating as more a transformation in reaction to economic and political disruptions (Demarest, 2004; Lucero et al., 2015; Yaeger, 2020). The consequence was a redistribution of farming populations (Ford & Nigh, 2015).

The Postclassic, dating from 1000 to 1500 CE before the brutal Spanish conquest, marks political change and reorganization that was a consequence of the upheavals of city centers across the Central Lowlands. As centers in the lowlands fell into neglect, centers in the north expanded. During this period, farming populations, unconstrained by taxation and corvee labor, continued living in the tropical woodlands (Fisher, 2020). This was the setting witnessed during the ruthless Spanish conquest (Alexander, 2006; Dedrick et a., 2023; Ortiz Yam, 2009).

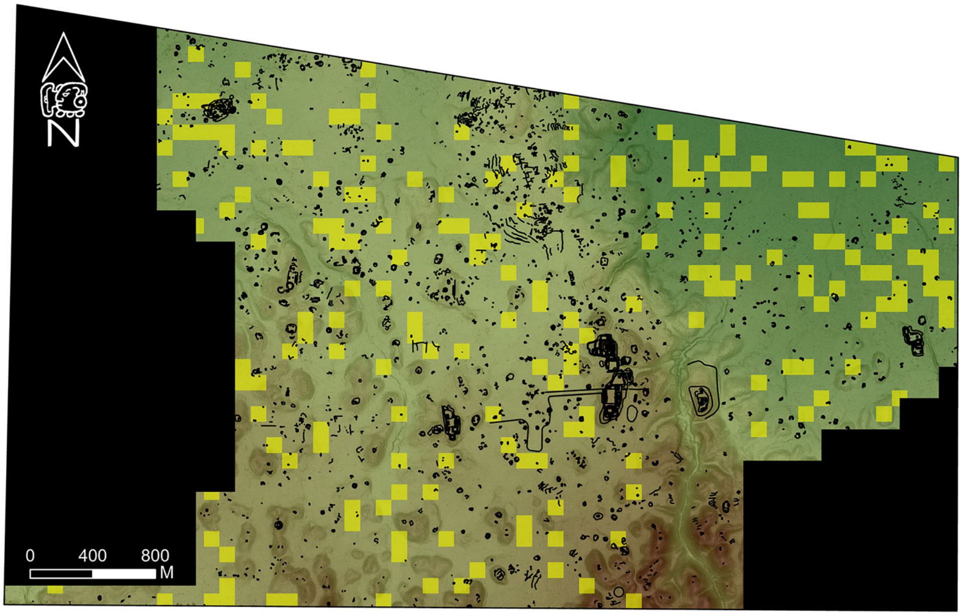

FIGURE 2 Lidar based map of El Pilar showing only open fields in yellow amid the surrounding forest. The concept of shifting agriculture is based on the acknowledgement of only the cropped fields where the surrounding area is viewed as idle, unused, and wasted (credit ISBER/MesoAmerican Research Center, UCSB).

ORIGINS OF MAYA LAND USE

Complex landscape management strategies that rely on rainfall and that are rooted in the forest itself are found around the world where traditional tropical swidden is recorded (see Conklin, 1954, 1957; Dove, 1983, 1993; Fedick et al., 2023; Geertz, 1963). Casual references to “slash-and-burn” and “shifting agriculture” focus only on annual crops (Fedick et al., 2023) and imply that the majority of the landscape is idle (Figure 2). Studies of swidden systems show this is far from the case, as every bit of the landscape is subject to attention and varying degrees of management. Recent research has demonstrated the economic importance of second growth (Chazdon, 2014), including its value for products and animal habitat. Mature forest, always given the highest value, may not have been as critical yet undoubtedly was a source of perennial resources as well as critical ecological services (e.g., Lambpeter et al., 2005).

Today, the Maya Forest is recognized for its remarkable variety and abundance of useful plants (Balick & Arvigo, 2015; Campbell et al., 2006; Fedick, 2020; Fedick & Santiago, 2022; Ford et al., 2021; Gómez-Pompa & Kaus, 1999; Gómez-Pompa et al., 2003; Ross, 2011; Roys, 1931). Forest products yield a diversity of goods from the tall canopy trees to the lower undergrowth. The cycles of land use of the field-to-forest cropscape creates tiers of trees, palms, shrubs, vines, epiphytes, forbs, and grasses destined for uses in daily household activities (Altieri & Toledo, 2005; Toledo, 2005; Toledo et al., 2003). The vegetation matrix develops through an interactive process of people and their landscape (Toledo, 1994; see also Martinez-Reyes, 2016) based on an inherent respect for nature and its power (Toledo, 2022). Human intervention into tropical growth is based on a constant imposition of natural recommendations and human selection. Adjusted to the natural systems through trial and error, this management aims to minimize risk by maximizing inputs toward the long-term preferences for utility (Ford, 2008, 2020). This goes for the immediate infields around homes to the scattered outfields and forest beyond (Ford et al., 2021). There would be concentric zones of investments around residential settlements exposed to degrees of management and tending, with a deep acknowledgment of the forces of nature (Toledo, 2022).

Since fields are spatially separated across space and asynchronously cycled over time, locating a field is dynamic. The result is an ever-changing mosaic of resources and habitats (Figure 3). This was not clear to the Spanish conquistadores when they coined the persistent term “milpa.” Originating from the Nahuatl term *milli pan* where “milli” is “to cultivate” and “pan” is “place”— milpa really means a cultivated place (Bierhorst, 1985; Karttunen, 1983). One can easily imagine the Spaniards identifying maize as the local grain of preference dominating the canopy of open fields, not recognizing the other crops in the fields, and asking directly what this space was. The answer that it was a cultivated place is correct, but had they asked the farmer to take them to a *milli pan*, they may have been directed to an orchard or a managed forest. The contraction that has become the common term “milpa” has evolved to mean a Mesoamerican annual cropped field of maize

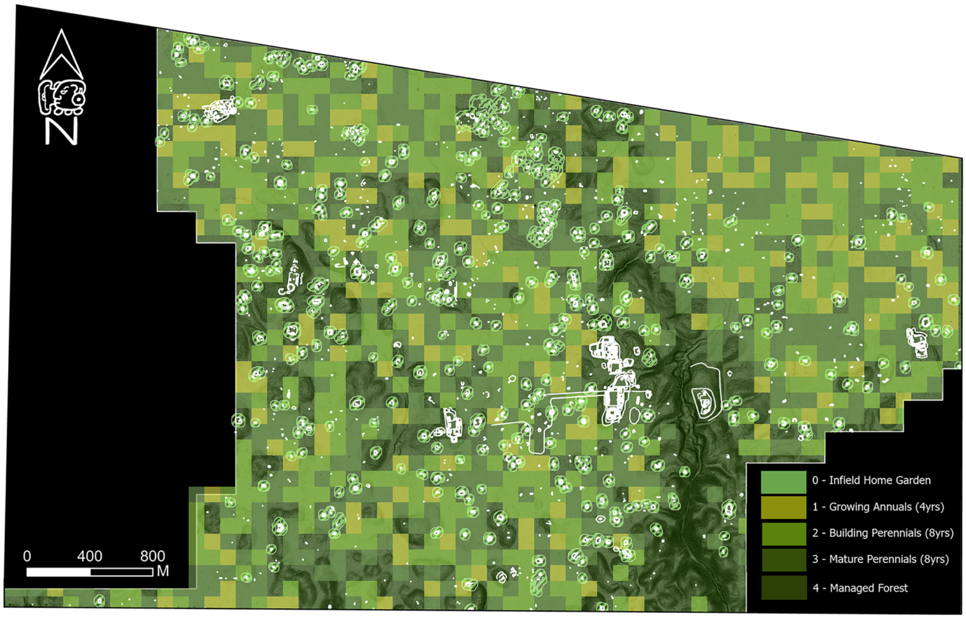

FIGURE 3 Lidar based map of El Pilar revealing the milpa forest-garden cycle where color differences—yellow to light green to green amid dark green managed forest—represent one year in the sequence of each productive stage of the milpa and the regeneration of growing perennials and mature forest for resources for daily life (credit ISBER/MesoAmerican Research Center, UCSB).

without recognition of its true meaning or origins or its actual role in the cultivated landscape.

Resources of the milpa field-forest dynamic are managed spatially in terms of diverse habitats, creating a horizontal matrix with vertical distinctions related to the regenerative succession sequence. The result is a complex and heterogeneous cropscape based on the milpa forest garden cycle—an orchestrated succession from annuals to perennials founded on practices of TEK (Ford & Nigh, 2015). Value is gathered over generations, centuries, and millennia, building on a regenerative cycle that is a flexible and sophisticated low-tech strategy (Watson, 2020) and demonstrably resilient under variable climactic and ecological conditions.

This system, however, is largely misunderstood and maligned as primitive, artless, inefficient in resource use, and inadequate to account for complex civilizations (Culbert, 1974; cf. Van Vliet et al., 2013). The interpretation of "shifting cultivation" does not concede the importance of perennial plants in the daily needs of life. The Maya lived in perishable structures; where would their building materials come from if not perennial plants? Seasonal fruits from trees and palms, important food sources, are also found in the archaeological record (Dussol et al., 2017; Machuca et al., 2020; Morell-Hart et al., 2022; Thompson et al., 2015), and utensils, furnishings, and medicines were necessities that would be obtained from forest materials (Balick et al., 2000; Cook, 2016).

The very activities involved in milpa cycle management produce a complex landscape arrangement based on inputs embedded in the recommendations of the forest itself and the choices of the manager. The habitats represented in the landscape may be driven by the maize requirements of the population. Estimating the stages of the landscape cycle based on existing descriptions (Cook, 2016; Evans et al., 2021; Ford et al., 2021; Hernández Xolocotzi et al., 1995; Roys, 1931; Schwartz & Corzo Márquez, 2015; Villa Rojas, 1945; Zetina, 2007; among others), rarely more than 20% of the cultivated spaces are open field gaps at any one time (Ford & Clarke, 2019; Ford & Nigh, 2015; Ford et al., 2021). The remaining lands, as much as 80% in this example, would contain regenerating perennials in the process of transforming from polyculture fields to selectively managed and well-stocked forests. The milpa cycle is concentrated on appropriate slopes, in the context of managed forest and other forested areas too steep or too wet (Ford & Clarke, 2019; Tran & Ford, 2023). The sequence repeats, eventually cycling back to fields, in an asynchronous and directed pattern of succession from annual crops to perennial trees (for an animation of a 20-year milpa cycle at El Pilar, see https://ibb.co/RgfnYKK [Ford & Tran, 2024]). Nothing is left idle and nothing is resting; everything is gauged to be productive, directly managed, as with the lands within the cycle, or indirectly nurtured outside the cycle. This produces a landscape of different types of "fields" managed for annual foods and perennial fruits (Fedick & Santiago, 2022), construction materials, medicine, as well as important animal habitats managed for meat protein.

Using fire to clear land has been cast in the negative, yet this practice is a critical component of land management and was a skill brought by the first peoples to enter the Americas. This important component of the milpa forest garden cycle relies on strategic fire management skills, and those that master fire in the Maya area are known as *Yum Ik'ob*, or Lords of Wind (Nigh & Diemont, 2013). Opening field spaces with fire enriches the soil with ash (Handelsman, 2021), while burning fields in a cycle systematically reduces the fuel load on the landscape at each repeating sequence. The milpa cycle thus acts as fertilizer and fire insurance.

The sophisticated application of labor and skill resulted in the Maya Forest garden (Ford et al., 2021). Plants and animals inhabiting diverse habitats, from home gardens/infields to varied outfields and regenerating forest growth, are integral to the Maya Forest garden system (Emery & Thornton, 2008; Linares, 1976; Stahl, 2014). Drawing from ethnohistoric and contemporary accounts, the interspersed dynamic fields of the cycle repeated across space and time, distributing floral and faunal resources consistent with traditional swidden sequences from around the world (Dove, 1983, 1993). The repetition builds value through experimentation over generations, and this regenerative cycle was as well-known to the Maya of the past as it is to their descendants today (Terán & Rasmussen, 1995). The Maya Forest is currently classed as a biodiversity hotspot (Mittermeier et al., 2000; TNC, 2022), and in this case it is an example of how interactions between humans and their tropical environment can be constructive.

FINDING FIELDS IN THE MAYA FOREST

Looking at a summary of the paleoecological data from cores (Figure 4), we can suggest broad relationships of climate and culture that can help in understanding the development of the Maya agricultural system and aid in finding evidence of their fields. As peoples expanded through the Americas from the Arctic Circle to Tierra del Fuego and back, hunter-gatherers who initially encountered the Maya area found it dry and arid. The four millennia period of the Holocene Thermal Maximum began 8000 years ago, transforming the Maya area into a warm and humid environment akin to the one encountered today (Ford & Nigh, 2015). The major distinction was in precipitation: interpretations of these data suggest that this early tropical climate was significantly wetter than today (Haug et al., 2001) and over the succeeding millennia there was an overall drying trend (Ford, 2022). The result today is a distinct dry period that impacts land-use management.

Around 4000 years ago, the period of climate chaos is evident worldwide with extremes in precipitation, and consequent vegetation regimes as a feature of the Maya area. The pollen proxy for forest is linked to the *Brosimum* type tree commonly known as ramon (Ford, 2022; Ford & Nigh, 2015, 87–91). The register of ramon begins to drop at this time, reaching a nadir about 2500 years ago (Figure 4). As we consider the pollen sequence, recall that most pollen that readily reaches lakes is weighted toward the windborne pollen (Bradley, 1999; Kellman & Tackaberry, 1997), and that the Maya Forest is characterized by animal-pollinated plants (Ford, 2008). Ramon, one of the 20 dominant plants of the Maya Forest, is the only tree that is wind-pollinated.

The drop in the forest proxy of ramon and the rise of the indicators of disturbance has led to the hypothesis that the Maya deforested the area as they increased agricultural fields (see Turner II & Sabloff, 2012). This entrenched and simplistic view is based on the generalization of the pollen data, pitting a single tree as the proxy for forest against multiple taxa as the proxy for disturbance (see Rice, 1996). New macrobotanical data from archaeological contexts are mounting and add new evidence of many forest trees used by the ancient Maya, indicating that the tree resources are comparable to those found in the forest today (Dussol et al., 2017; Machuca et al., 2020; Morell-Hart et al., 2022; Thompson et al., 2015).

A review of Figure 4 shows the forest pollen proxy is replaced by the so-called "disturbance" taxa, where disturbance is the catch-all term reflecting human presence. The record of the components of the plants classified as disturbance is evident in the annual and perennial forbs, part of the dynamic regeneration that characterizes the milpa cycle. The majority of these identified disturbance taxa are found by ethnobotanists in contemporary milpa fields and their regenerating plots (Ford, 2008; Kellman & Adams, 1970; Steggerda, 1943). An alternative explanation for these pollen data is that the relationship between the tree proxy and the forb proxy represents the establishment of the milpa cycle, the field-to-forest succession that underwrote the wealth of the Maya civilization. A fresh look at the disturbance taxa of the pollen cores emphasizes a wide variety of annual and perennial wind-pollinated forbs found in the open fields and second growth, contributing to a landscape mosaic (Chazdon, 2014). The proportions of forbs are, indeed, a signature of human impact, but in the form of the diverse land cover characteristic of the milpa cycle.

From around 2000 years ago, the milpa forest garden patterns were established (Ford & Nigh, 2015), as can be seen in the stability and continuity of the forest to forb proxies through time. Even after the Maya "collapse," forbs persist until the Spanish conquest (Alexander, 2006). We know that the region was occupied in the 1500s during the conquest based on Cortes' and Diaz's accounts (Cortes, 1971; Diaz del Castillo, 1927), and the use of infield forest gardens and outfield milpas was amply documented (Farris, 1992; Schwartz, 1990), though not appreciated by the Spanish (Ortiz Yam, 2009; Roys, 1952). Fields were spread about in a way that confused the conquerors who thought that the grain, maize, was all that was cultivated. As the origin

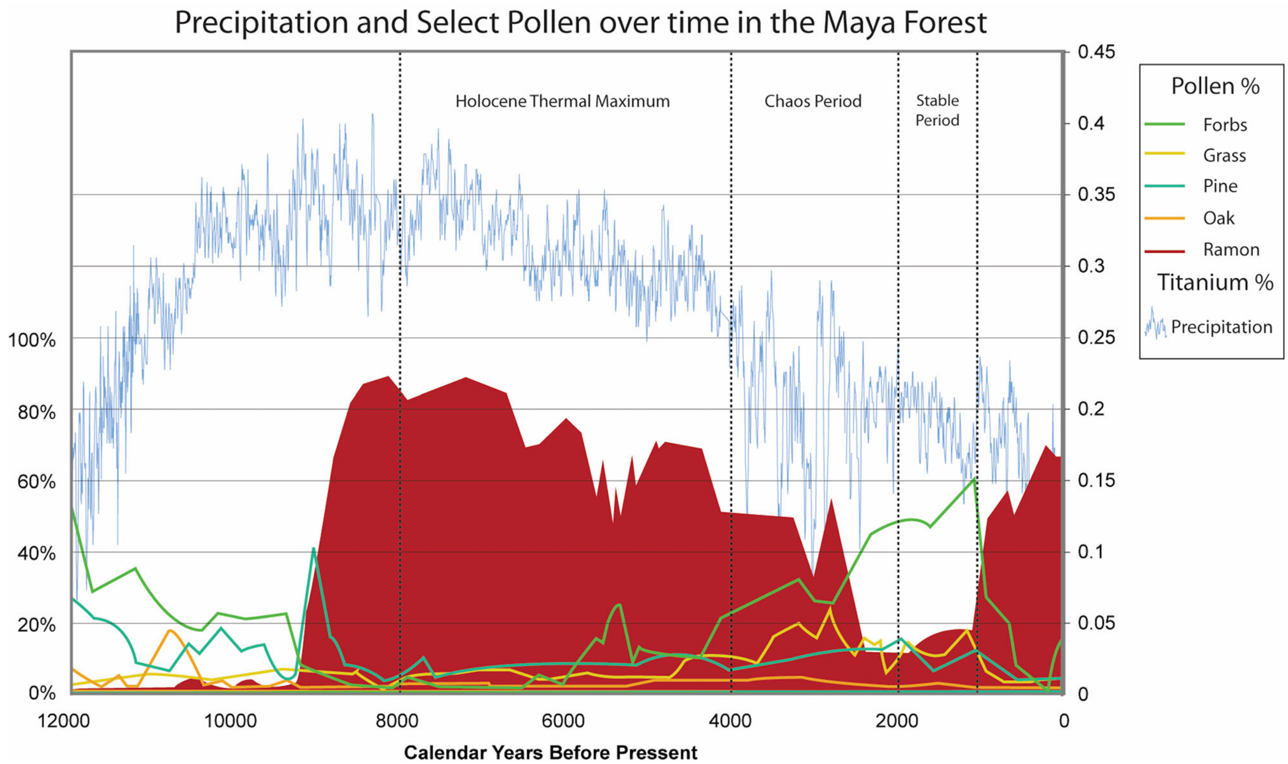

FIGURE 4 Precipitation and select pollen over 12,000 years in the Maya Forest with percent pollen on left and percent titanium on the right (compiled by ISBER/MesoAmerican Research Center, UCSB; data on pollen scaled from Brenner et al., 2002; Curtis et al., 1998; Leyden, 2002; Cariaco Ti precipitation proxy from Haug et al., 2003).

of the term milpa comes from the Spanish contraction of the Nahuatl *milli pan*, the Spaniards only recognized maize fields and not the importance of the cycle that created the domesticated landscape (Ford, 2020; Ortiz Yam, 2009; Terán & Rasmussen, 1995), even as they benefited from it.

THE MAYA FOREST: MANAGING BIODIVERSITY

How can a region recognized as a biodiversity hotspot be at the same time the cradle of Maya civilization? This is clearly the legacy of ancient Maya land use imparting value to the forest. It is the plants themselves, subject to thousands of years of human interaction, that tell of the milpa forest garden cycle from open field gaps to mature closed canopy forest. For the Maya, the forest was not simply the source of agricultural produce, it was the resource for all the necessities of life. The forest gardens needed to contain a diversity of resources to meet the short- and long-term requirements of food and shelter for families, farming communities, and the elite rulers of complex polities. The hierarchical elites themselves needed to support this remarkably productive system to underwrite their ambitions. It may well be those ambitions that led to the oft-touted Maya collapse, as the farmers were still there centuries later when the Spanish arrived.

The Maya developed ingenious strategies that left traces in the nature of the forest, which provided a wealth untold before and after the conquest. It was in the forests that the Maya became attuned to varying environmental conditions necessary for food production and the provisioning of construction materials, utensils, fibers and spices, and habitats for game animals. All these were part of the utilities required for dwelling in the forests. The upland ridges, interspersed wetlands, and transitional zones provided the stage on which the Maya developed deliberate vertical and horizontal vegetation preferences designed to address human needs and mitigate vagaries of rainfall and fire hazards, all largely without land modification.

Ancient Maya settlement patterns reflect a continuum of land-use intensity, ranging from densely occupied upland ridges, sparsely inhabited lowlands, and logically unoccupied wetlands. Not all spaces served for settlement (Ford et al., 2009), but all spaces were given attention for management. The complex spatial mosaic formed by the gradation among uplands, lowlands, and wetlands provided access to diverse habitats that facilitated life within the Maya Forest. Labor-based agricultural practices favor well-drained, fertile, and necessarily friable soil, where settlement densities were the highest. These would be the most intensive infields and related outfields that could be worked by hand, unfazed by rocks and shallow soil but avoiding steep and poorly drained areas (Fedick, 1989).

If such preferred lands were unavailable, as was the case where low-lying lands were the norm or where steep slopes dominated, then the fertile areas with limitations were the next choice (Fedick & Ford, 1990). Those too wet or too steep could be modified and adapted as new niches when first-choice lands were unavailable. This is where we would expect drainages for the wetlands and terraces for the steep slopes. In all areas, fields used and regenerated would be subject to selection for useful plants. Not only are the dominant plants of the Maya Forest all useful (Campbell et al., 2006; Ford, 2008; Ford & Nigh, 2015), there are several hundred favored trees recognized and conserved by the Maya (Ford & Nigh, 2015, Appendix B; Ford et al., 2022). Importantly, an abundance of edible plants used by the Maya today number nearly 500 (Fedick, 2020; Fedick et al., 2023), of which a large percentage are drought resistant (Fedick & Santiago, 2022). These essential qualities of the Maya Forest today are a product of field selection over generations, centuries, and millennia. The cultivated places comprised cropped fields but also regenerating and mature forests that were literally domesticated to fulfill everyday needs within the natural forest context.

REFLECTING ON FINDING FIELDS OF THE FOREST GARDENS

Planned to minimize risk over the long term, the fields of the Maya are embedded in the landscape and part of the environment (see Conklin, 1954, 1957). This embeddedness has been unrecognized from the time of the violent Spanish conquest (Dedrick et al., 2023). The skills acquired over millennia and intensive investment in the domesticated landscape of the forest gardens are flexible and adaptable under unpredictable climate regimes over time and across space. Having developed in reaction to the major climate shifts and chaos experienced over the Holocene, the strategies and practices grew to their height in the Classic Period, supporting the expansion of Maya civilization. Maya poly-cultivation practices could never compete with the vigorous nature of the tropics; it was necessary to work with natural processes and, thus, may be perceived as invisible. Yet, infields surrounding the home base were recognized and legislated against (Ortiz Yam, 2009; Roys, 1952) and outfields developed and cycled within the forests were called shifting agriculture! All the time, the milpa cycle emphasized the diversity that prevails in the tropics.

Traditional Maya Forest gardeners demonstrate a full awareness of their natural world; an ability to cultivate biological capital without infrastructure as a product of their culture. Even the Milpa sequence that is practiced to this day is coordinated with annual precipitation and the growing cycles (Kramer & Hackman, 2021), showing resilience that provides a model response to current threats of climate change. Cultivated places are, in essence, fields; careful recognition of the forest-to-field dynamic will result in finding fields.

The dynamic Maya Forest landscape depended on the elasticity of the relationship between managed fields and forest, not fixed in space but a system responsive to variations in family size, labor availability, and scheduling constraints. The development of the Maya civilization is a story of success. The ancient Maya growth was based on an agriculture system that unavoidably engaged with the natural environment through labor, knowledge, and skill to direct energetic tropical growth towards human needs. These are the natural resources found in the Maya Forest today and that provisioned the ancient Maya economy at the household, community, and center scales. The open field is the foundation for the useful forest; and the dominant trees of the Maya Forest recorded by economic botanists represent the evidence of this management. The expansion of Maya civilization over millennia was based on reliable land management practices, accommodating climate changes with flexible and resilient strategies and practices still witnessed today, and presents an opportunity to achieve a balance of forest conservation and food sovereignty in the region.

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CONFLICT OF INTEREST STATEMENT

The author declares no conflicts of interest.

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ENDNOTES

[1] In Mesoamerican literature, a milpa is characterized as a shifting, slash-and-burn field of maize, beans, and squash without recognition of the cyclical significance of the sequential regeneration of perennials important for edibles, medicinals, and construction.

[2] The technical meaning of arable is plowable according to the Oxford English Dictionary.

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