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TITLE: Agroforestry and Ritual at the Ancient Maya Center of Lamanai

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ABSTRACT

Paleoethnobotanical data retrieved from caches of Late Classic to Early Postclassic origin at the ancient Maya site of Lamanai, Belize, revealed carbonized maize kernels, cob fragments, common beans, coyol endocarps, and an abundance of wood charcoal, from both conifer and hardwood tree species. *Pinus caribaea* (Caribbean pine) was the most ubiquitous species in the Late and Terminal Classic sample set and the weight of Lamanai pine wood charcoal was more than the combined weight of all known archaeobotanical collections from nearby contemporaneous sites. Pollen data from northwestern Belize showed that the pine pollen signature sharply declined during the Late Classic period, a trajectory in keeping with intensive exploitation of the nearby pine savannas as suggested by the contents of Lamanai caches examined in this study. Although Lamanai flourished far into the Postclassic period, pine charcoal use—based on present evidence—declined in Early Postclassic ritual contexts. Concomitantly, an increase in the local pine pollen rain indicated that pine timber stocks rebounded during the Postclassic period. The observed intensive use of pine at Late Classic Lamanai combined with a concurrent decline in the regional pine pollen signature is consistent with a hypothesis of over-exploitation of pine during the Late to Terminal Classic period.

HIGHLIGHTS

- Analysis of paleoethnobotanical remains recovered from ceremonial caches at Lamanai.
- Heavy pine charcoal use in ritual-associated deposits during the Late Classic period.
- Lamanai Maya likely exploited adjacent pine savannas for ceremonial activities.
- Pine charcoal use declined in the Postclassic and pine timber stocks rebounded.
- Study provides key insights into Classic Maya interaction with surrounding environment.

KEY WORDS

Ancient Maya; Paleoethnobotany; Agroforestry; Ritual; Wood Identification; Pine; Belize

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1. Introduction

Located on the banks of the New River Lagoon in northern Belize (Fig. 1), the Maya habitation and ceremonial site of Lamanai was occupied continuously from as early as 1,500 BCE (Metcalfe et al. 2009; Rushton et al. 2013) until colonial and even modern times (Graham 2011; Pendergast 1991, 1993). This study focuses on the agroforestry and ritual practices of the Lamanai inhabitants during the transition from the Late Classic to the Postclassic period.

Agroforestry, as explored in this paper, is a landuse system where trees are cultivated or managed and integrated with the agricultural landscape. Rituals are activities carried out in accordance with social customs that are often integrated with ceremonial acts, especially those associated with religion. Our objective in this research has been to gain an understanding of the interaction of this Maya community with its surrounding ecosystem, especially in regard to the management of forest resources and agricultural practices, as revealed by an analysis of paleoethnobotanical remains. Of particular interest is the sustainability of this interaction and how plant use activities may have been connected with the ceremonial life of the ancient occupants of Lamanai.

Throughout much of the Maya area, culture flourished during the Classic period (from about 500 to 900 CE), marked by exponential growth and construction at civic-ceremonial centers such as Tikal, Calakmul and Palenque (Coe 1990; Martin and Grube 2008). These same communities subsequently underwent dramatic population decline in what is often referred to as the "collapse" during the Late/Terminal Classic period, around 850 to 900 CE (Culbert 1973; Demarest et al. 2004). Many centers, especially those in the Central Maya Lowlands, were abandoned by the start of the Postclassic period (900-1500 CE) (Webster 2002). While many Classic Maya civic-ceremonial centers were being abandoned at the end of the Late Classic period, Lamanai thrived throughout the Postclassic period and lasted until the time of Spanish contact (Graham 2011, Jones 1989). No doubt, a contributing factor to the longevity of the center relates to its close proximity to the New River, a reliable and abundant source of fresh water. Notwithstanding the buffering effects that the consistent water supply must have offered through the droughts of the 9^{th} century, the evidence strongly suggests, as Pendergast (1986) has articulated, that stability at Lamanai was affected by the cultural changes surrounding them (Graham 2004, 2006; Howie 2012).

Fig. 1. Map of northern Belize and the adjacent region showing ancient Maya sites surrounding Lamanai. (2 columns)

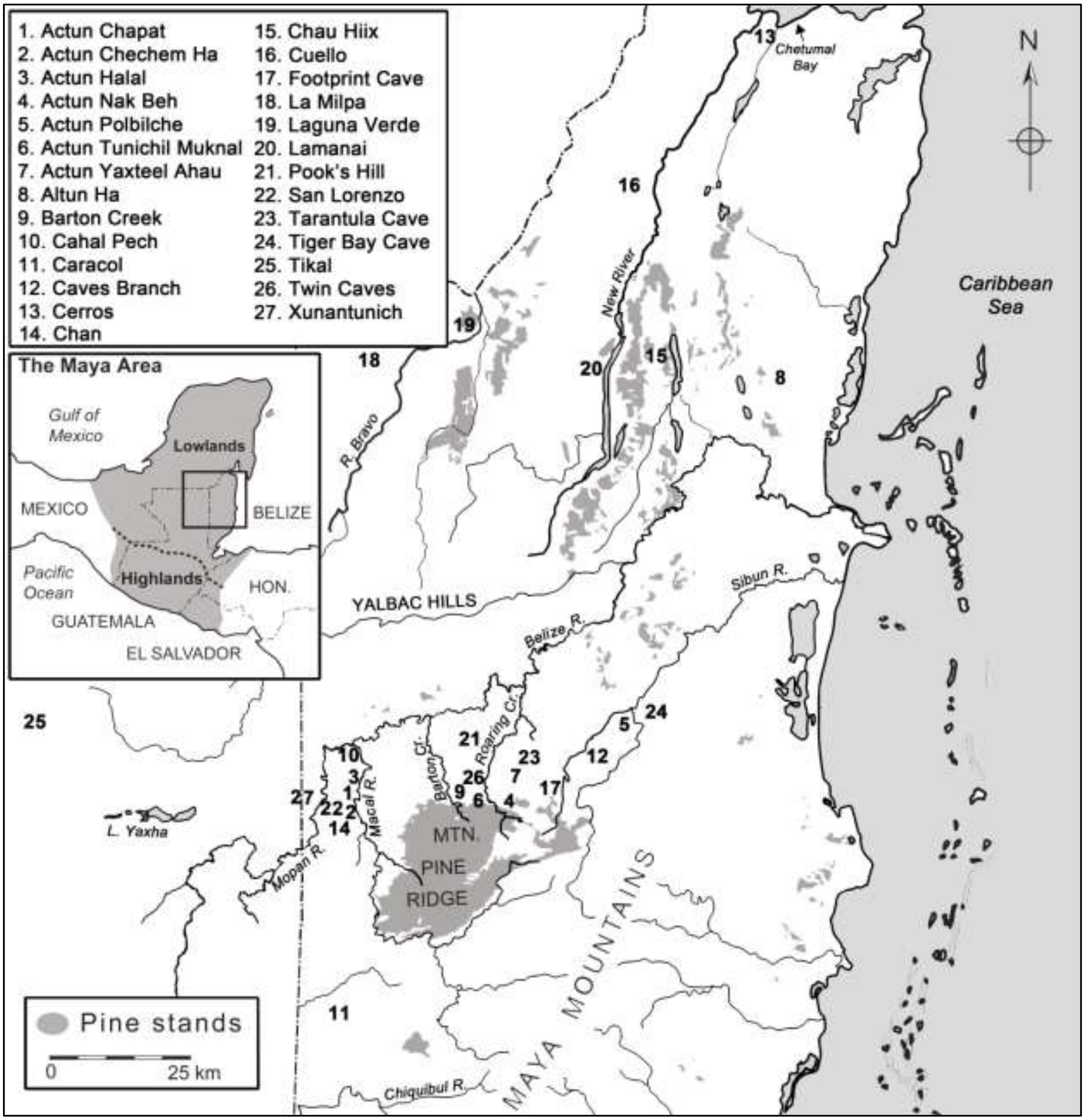
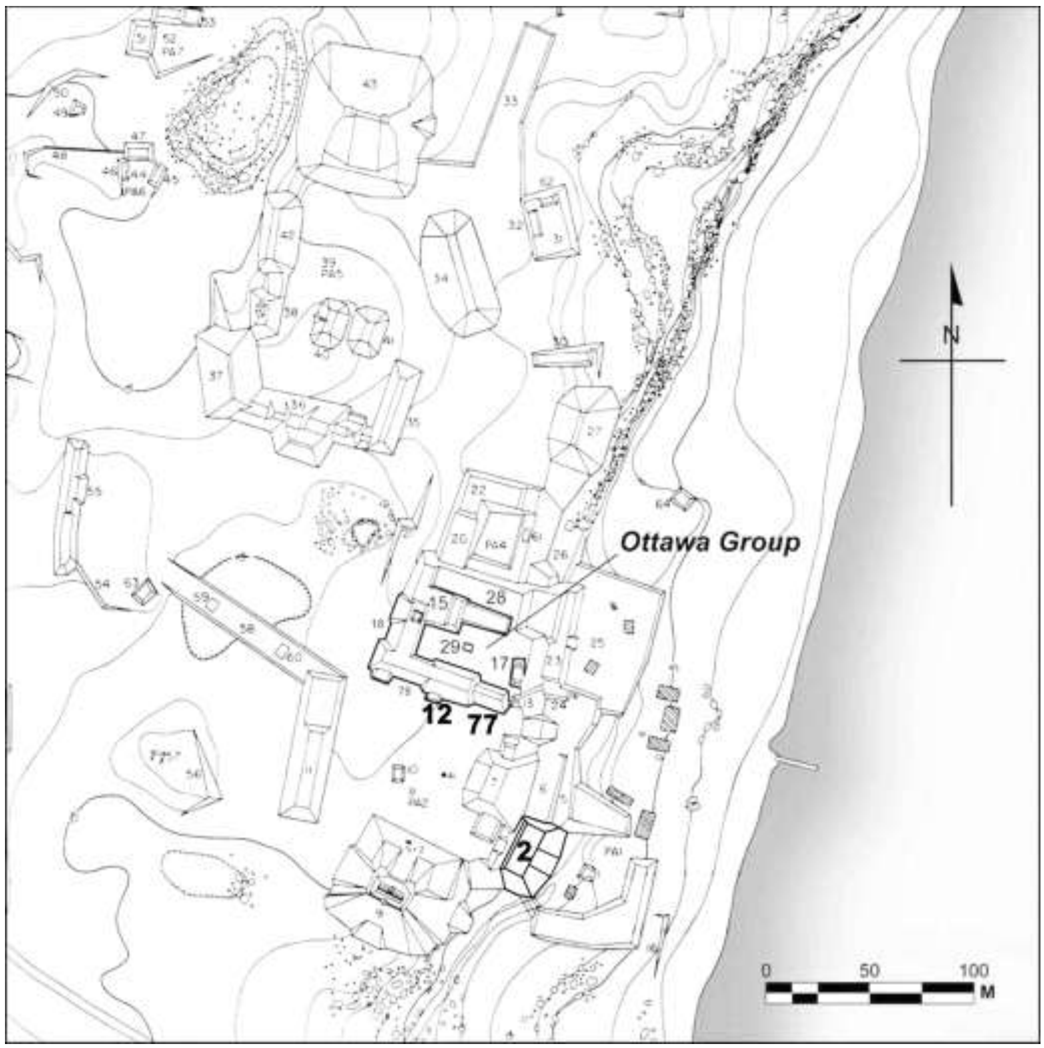


Fig. 2. Site map of Lamanai showing the location of the Ottawa Group (Plaza Group N10 [3]). Localities discussed in this paper are in bold. (2 columns)



Lamanai structures N10-77 and N10-12 contained caches and other contexts with abundant charred plant remains that are described herein. Most of these caches were burned *in situ* which accounts for the carbonized condition of the plant remains and at the same time explains the context from which they were recovered. Other samples were from fill material, or burned, redepositied trash, that appeared in a bench (LA 1779 and LA 1778) and from within a wall of Str. N10-2 (Table 1). Str. N10-12 overlies N10-77 and is to the east of the adjacent, but unexcavated, N10-78 (Fig. 2) (see Graham 2004); all three structures border the south side of Plaza N10[3]. The structures around Plaza N10[3] are sometimes referred to as the "Ottawa" Group (Fig. 2), the name given to the group by the Canadian students who assisted H.S. Loten in mapping the site in the 1970s (Pendergast 1981). Two caches were associated with Str. N10-12, and 10 caches were associated with Str. N10-77 (see Fig. 2 and Table 1). Of the three remaining wood samples from Str. N10-77, one (LA 1764) was from the burnt stratum covering the final floor. A San José V-type basal-break bowl with pedestal base—a form and surface treatment typical of Terminal Classic ceramics—lay on the floor and had been burned along with room contents prior to infilling. The two remaining paleoethnobotanical samples from N10-77 (LA 1778 and LA 1779) were from secondary deposits located in the cores of benches.

Fig. 3. Ceramic containers from Cache N10-12/8, Structure N10-12 (LA 1894). Lip-to-lip caches of this type are believed to be symbolic of the Maya cosmos and are often associated with dedicatory offerings (Guderjan 2007). (1 column)

Of the two paleoethnobotanical deposits from Str. N10-12, Cache N10-12/8 (LA 1894) had been placed within the core of the platform that supported a perishable superstructure (Fig.

3), Str. N10-12, 1st (Graham 2004). The cache dates to the time when Str. N10-77, a masonry building, was razed and its rooms filled along with the infilling of the plaza/courtyard. The construction activity also marked a change from masonry to perishable superstructural architecture at this location. The occupation of Str. N10-12, 1st, is associated with the last years of the use of polychrome pottery, referred to as the Terclerp phase, which is considered to represent the Terminal Classic period at the site (Graham 2004; Howie 2012). The other deposit, LA 1742, was somewhat problematic. Str. N10-12, 2nd directly overlies Str. N10-12, 1st, and burials associated with N10-12, 2nd were cut through the earlier floors of N10-12, 1st and intruded into the core of the Terminal Classic, Terclerp-phase platform. The stone core material of the platform lacked any firm matrix, thus providing conditions in which artefacts could shift through the core. Nevertheless, the charcoal from LA 1742, when excavated, appeared to be associated with Buk-phase (Early Postclassic) pottery.

Str. N10-77, a masonry building, is Late Classic in construction. Its final phase spanned the time when Maya ceramics began to lose their glossy slips. The succeeding Str. N10-12, 1st, as noted above, was a perishable superstructure on a stone platform; the vessels associated with its caches maintain some Classic attributes, such as red-slipped rims on jars and use of polychrome decoration. The polychromes, however, are typically "cartoonish" and bear little resemblance to the great Classic period painting traditions. Str. N10-12, 2nd is a low stone platform that, like Str. N10-12, 1st, supported a perishable superstructure. Burials cut through floors in these structures are associated with Buk phase ceramics—Zakpah orange-red and Zalal incised (Walker 1990)—types typical of the Early Postclassic period at Lamanai.

The 10 caches and the sample from the burnt stratum associated with Str. N10-77 are primary to the ultimate and penultimate occupation phases. The charcoal and associated material in all of the 10 caches, with one exception, was found in cavities cut into floors. Because the samples in each cache were in tight clusters with no other obvious containment feature, we hypothesize that the material was originally contained in cloth bags or sacks; in only one case was the charcoal found to form the contents of a vessel: LA 1785, Cache N10-77/4. The charcoal samples from bench cores appeared to be from reused middens.

Carbonized material also was analyzed from Str. N10-2 (Pendergast 1981); Cache N10-2/2 (LA 34/1C, LA 34/2C) contained cultigen seeds as well as wood from forest trees. Carbonized plant material from wall construction comprised another sample (LA 115) (Table 1). All of the samples from Str. N10-2 represent the same construction phase, Str. N10-2, 4th, which is associated with a Buk phase (Early Postclassic) burial and ceramics (Pendergast 1981, 1982),

1.1 Environment

Lamanai is situated along the west bank of the New River Lagoon in the Orange Walk District of northern Belize. The New River flows northward from the lagoon for ca. 130 km and empties into Chetumal Bay. A vegetation study of Lamanai conducted by Lambert and Arnason (1978) reported a prevalence of secondary forest as opposed to primary (semi-evergreen seasonal) forest in the area. According to their study, the site’s location on a Cretaceous Age limestone plateau with calcareous soils, high groundwater and high sediment content of the New River drainage have influenced site vegetation. Vegetation zones, according to Lambert and Arnason, include Shoreline, Cohune Ridge, Pine Ridge, Bajo and High Bush. Shoreline vegetation consists of species that can thrive despite being subjected to seasonal flooding, including *Bucida buceras* L. (bullet tree), *Pachira aquatica* Aubl. (provision tree) and *Bactris major* Jacq. (biscoyol). Portions of the Lamanai area also include Cohune Ridge with visually dominant *Attalea cohune* Mart. (cohune) palms along with other species, such as *Spondias* *mombin* L. (jocote), *Guazuma ulmifolia* Lam. (wild bay cedar) and *Enterolobium cyclocarpum* (Jacq.) Griseb. (guanacaste). Soil in the Cohune Ridge is relatively deep and rich due to moisture and nutrient content provided by the cohune leaf litter layer. The Pine Ridge, essentially a savanna, lies across the lagoon from Lamanai to the east and is composed primarily of sedges interspersed with pine (*Pinus caribaea* Morelet) and various angiosperm tree species, including *Crescentia cujete* L. (calabash), *Curatella americana* L. (chaparro) and *Byrsonima crassifolia* (L.) Kunth (nance). The Bajo, a seasonal swamp to the northwest of Lamanai that desiccates during the dry season, has woody plants, such as *Haematoxylum campechianum* L. (logwood) and *Spondias mombin*, and vines characteristic of thickets. The remaining areas surrounding the ruins are referred to as High Bush (secondary growth) and include *Nectandra* spp. (timber sweet), *Coccoloba belizensis* Standl. (papaturo) and *Ficus* spp. (figs), among other tree species. Finally, the vegetation covering the Lamanai site itself is primarily composed of *Protium copal* (Schltdl. and Cham.) Engl. (copal), *Melicoccus oliviformis* Kunth (kinep), *Pimenta dioica* (L.) Merr. (allspice) and *Brosimum alicastrum* Sw. (ramón), a common tree on Maya ruins.

1.2 Maya Archaeological Plant Evidence

Paleoethnobotanical analysis of plant remains from numerous Maya sites has helped to establish an understanding of ancient Maya plant use practices and the relationship of the Maya to their environment (Lentz et al. 2012, 2014b, 2015; Morehart et al. 2005; Wiessen and Lentz 1999). Variable access to natural resources created trade opportunities across the Maya realm (Graham 1987; Lentz et al. 2005a, 2005b; Pendergast 1982).

Economically useful trees were exploited by the Maya for construction and fuel, as well as ritual use. Among the many recorded tree remains from Maya sites (often in the form of charcoal, though unburned wood samples have also been recovered) are: pine (*Pinus sp.*), and various genera and species of angiosperms, in such families as the Arecaceae, Fabaceae, and Sapotaceae. Certain species seem to have enjoyed a ritual use, especially pine and copal (*Protium copal*), the resin of which was burned as an incense (Standley and Steyermark 1946a). Although pine certainly served utilitarian purposes as a building material and as fuel, as seen at Yarumela, Honduras (Lentz et al. 1997) and other sites, it also was associated with ritual contexts, for example in burials (Morehart, et al. 2005) and ceremonial offerings (Lentz et al. 2005b).

2. Methods and Materials

Carbonized archaeobotanical samples examined in this study were collected by Graham during excavations in 2002 and 2003 from contexts in two structures, N10-12 and N10-77, as described above. Archaeobotanical samples were collected opportunistically when encountered visually during excavation. No flotation, dry sieving or wet sieving took place in the collection of paleoethnobotanical specimens. Samples from Str. N10-2 were collected by Pendergast during excavations in 1974 and subsequently radiocarbon dated by Geochron Laboratories in 1977. Although the destruction of a small portion (approximately 5%) of the archaeological plant sample from N10-2 for radiocarbon dating prior to paleoethnobotanical analysis is regrettable, in the larger sense it seems unlikely that the loss of those fragments would have changed our conclusions significantly, other than to possibly add to our inventory of species identified. The unused portions of the Str. N10-2 archaeobotanical samples were added by Graham to the set of carbonized plant samples from Strs. N10-12 and N10-77 that were submitted to the Lentz' Paleoethnobotany Laboratory for identification. Samples (19 total) were stored in aluminum foil to protect against contamination and handled with sterile tools to allow for additional radiocarbon testing. Items were sorted and weighed, then assigned a sample number with fivedigits such as 10001 and 10002. Additional radiocarbon dating, conducted after paleoethnobotanical identification, was carried out by T. Higham at the Oxford Radiocarbon Laboratory.

Archaeological plant samples from Lamanai were analysed using standard sorting and identification techniques. Samples presented to the paleoethnobotanical laboratory were analyzed in their entirety and not subsampled. Each sample was separated into particle sizes using standard geological sieves of 1 and 2 mm mesh. Sample contents were rough sorted using a Leica S6D light stereomicroscope with a capability of 4x to 63x magnifications. After passing each sample through the sieves, everything greater than 2 mm was sorted into two major categories: 1) carbonized vascular tissue and 2) other plant parts. The vascular tissue was then sub-divided into three broad categories: 1) gymnosperm, or coniferous, wood, 2) angiosperm or hardwood, and 3) Arecaceae, or palm, vascular tissue. The coniferous wood was exclusively pine and the hardwood portions of the samples were subdivided into "types." The cell structure in hardwoods can be observed in broad outline with a stereomicroscope, but identification to species is extremely difficult with this equipment and more easily accomplished with electron microscopy. The palm vascular tissue, technically not wood, remained identified as carbonized Arecaceae tissue. The non-vascular plant component of the Lamanai samples generally consisted of seeds, endocarps, cobs or other plant parts that often could be identified to species using the stereomicroscope. Sieve layers smaller than 2 mm were examined for seeds and micro-debitage content only. Secure identification of wood fragments in this size range is extremely difficult if not impossible.

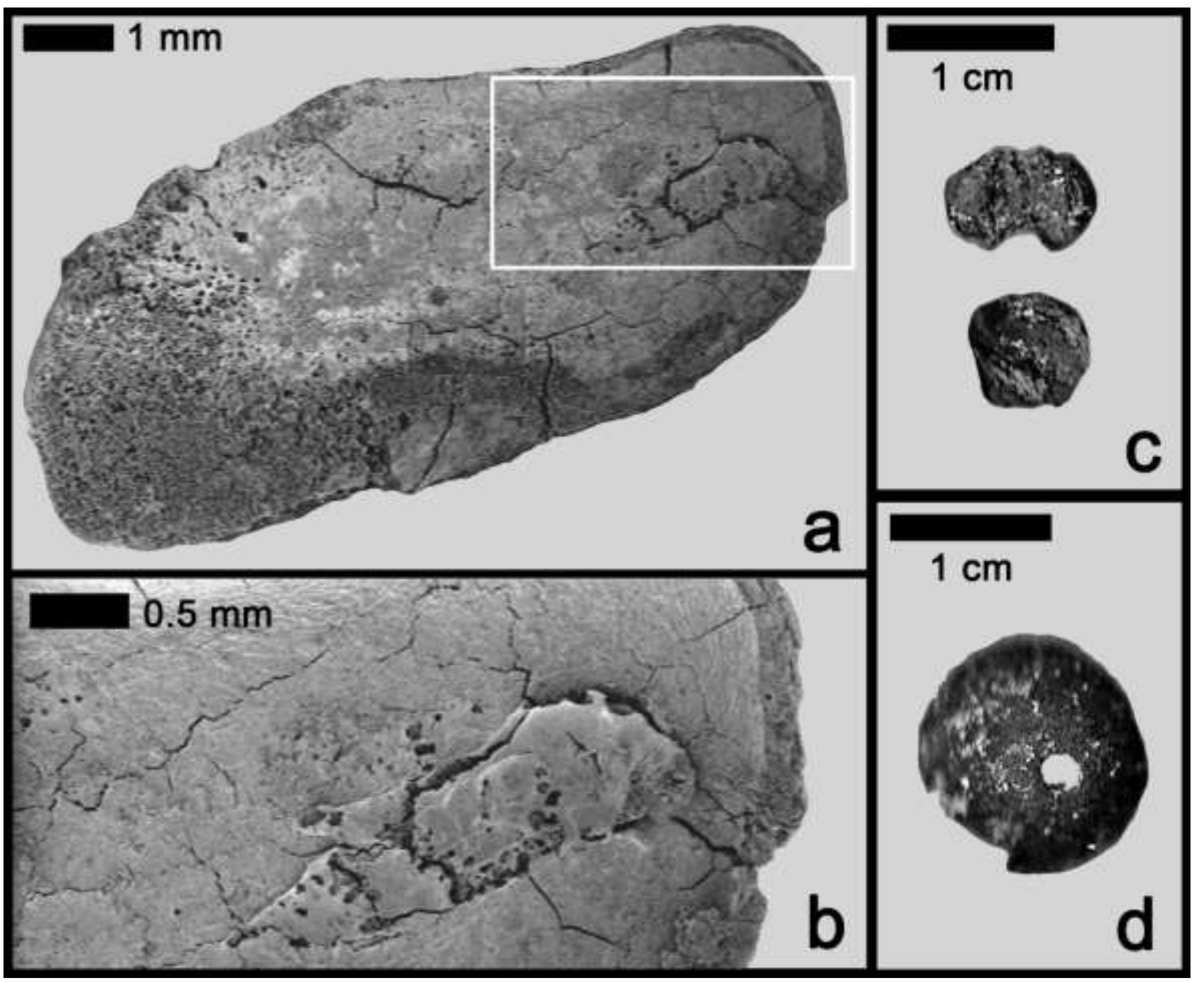
After initial sorting, a representative portion of each wood "type" was prepared for electron microscopy. Carbonized wood specimens and selected seeds were attached to individual aluminum SEM stubs with colloidal graphite, dried, then sputter-coated with gold. Electron micrographs of 50x to 5000x were obtained using an Amray Scanning Electron Microscope housed at The Field Museum of Chicago SEM-EDS lab. For identification, micrographs were compared to wood reference manuals (Chichignoud et al. 1990; Détienne and Jacquet 1983; Kribs 1959; Mainieri and Chimelo 1978; Uribe 1988; the Inside Wood website (http://insidewood.lib.ncsu.edu/; Wheeler 2011) and Lentz' Central American wood reference collection. Results were compared to paleoethnobotanical assemblages at other contemporaneous, nearby Maya sites. Our means of comparison relied upon ubiquity and total weight found in grams of pine, angiosperm hardwood charcoal, and other recovered botanical materials.

3. Results

Table 1 presents a listing of recovered and identified macroremains from the Plaza N10[3] Ottawa Group and from Str. N10-2 at Lamanai. The column labeled "cultural period" represents the stratigraphic sequence of the caches and other contexts. Most of the macroremains emanate from a period spanning the end of the Late Classic through the Terminal Classic period, with one cache from N10-12 that was possibly Early Postclassic in origin, and another from N10-2 that was definitely Early Postclassic.

Charred wood remains identified from these samples (Table 1) included: *Annona* sp. charcoal, *Casearia* sp. charcoal, *Haematoxylum campechianum* L. charcoal, *Mosannona depressa* (Baill.) Chatrou charcoal, *Manilkara* cf. *zapota* (L.) P. Royen charcoal, *Nectandra* sp. charcoal, *Pinus* cf. *caribaea* Morelet. charcoal, *Pouteria* sp. charcoal, Sapotaceae charcoal, and *Stizophyllum riparium* (Kunth) Sandwith charcoal. Other plant remains included *Acrocomia aculeata* (Jacq.) Lodd. ex. Mart. endocarps, *Zea mays* L. kernels, cob fragments, *Phaseolus* *vulgaris* L. seeds, and a burnt tuber of uncertain origin (Figs. 4 and 5). Burned palm (Arecaceae) vascular tissue was identified in structure N10-2. Although a small collection, it nevertheless provides useful information about the ecological context of Lamanai during Late Classic through Early Postclassic times, as well as the agricultural system, ceremonial activities, and the conservation practices of the inhabitants. The significance of each plant taxa represented in the collection from Lamanai will be discussed below.

Figure 4: Carbonized plant macroremains from Lamanai: a) *Phaseolus vulgaris* cotyledon, b) *P. vulgaris* embryo close-up, c) *Zea mays* kernels, d) *Acrocomia aculeata* endocarp. (1.5 columns)



4. Discussion

The discussion of the plant remains found during the Lamanai excavations begins with ecological information and then relates what is known archaeologically and ethnographically about each plant. First in the discussion will come the plants identified by their charcoal, or burned wood, and then the plants identified from other anatomical parts, such as seeds or cobs.

Annona sp. (Annonaceae) is a genus of small to medium-sized trees and shrubs. Balick et al. (2000) list seven species in Belize, all of which bear edible fruit. In general, these are understory trees found in tropical deciduous forests. Burned wood from an annona tree was found in Late Classic deposits in Cache N10-12/8 at Lamanai. Although we cannot be certain if this charcoal came from a wild or domesticated fruit tree, one of the possible domesticated species would have been *guanabana* (*A. muricata* L.), a tree widely cultivated in Central America prior to European contact for its delicious fruits (Lentz 2000).

Casearia sp. (Salicaceae) is a genus of generally small trees or shrubs that grow in tropical deciduous forests or secondary growth. Common names include *limoncillo*, drunken bayman wood and, wild lime. The plants are widely used for construction, medicine, food, and poison (Balick et al. 2000). *Casearia* charcoal was found in a ceramic jar at Lamanai in cache N10-12/8 along with shell fragments, bone and a rodent tooth. The charcoal may have been in this context because of its medicinal properties or it may have been an accidental inclusion as a result of wall fall or ceiling collapse.

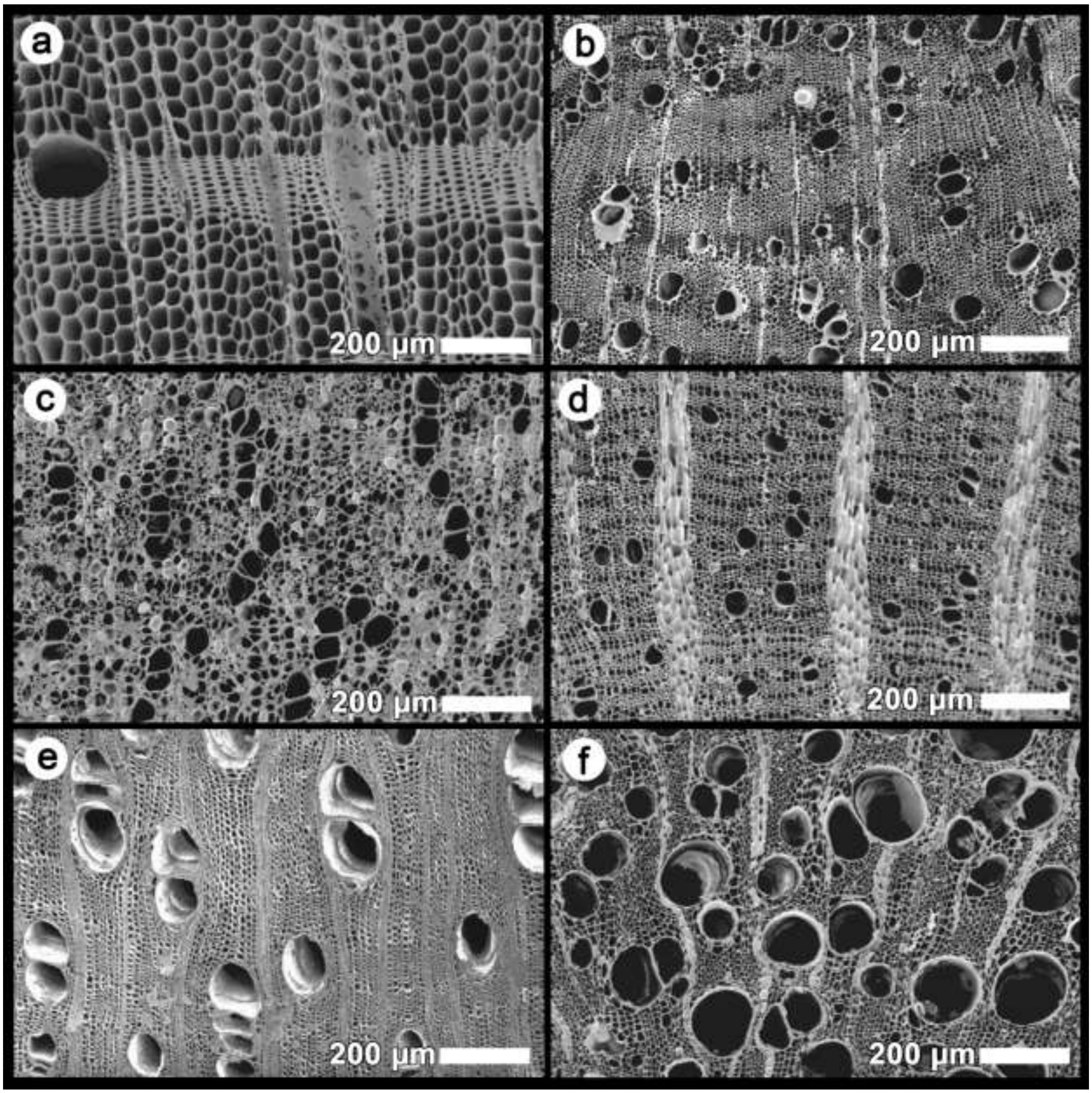
Haematoxylum campechianum (Fabaceae, subfamily Caesalpinioideae), called logwood in English, tinta in Spanish or *ec* by the Yukatek Maya, was of major import to the Maya long before Europeans arrived in Central America. *H. campechianum* grows in swamps, or *tintales*, in Yucatan, Mexico as well as northern Guatemala and northern Belize. The trees grow rapidly and regenerate quickly, but are hard, dense, and have a high tensile strength. The ancient Maya used logwood for construction (Lentz and Hockaday 2009) and probably as a source of textile dye or as a medicine because of its astringent properties (Standley and Steyermark 1946b; Atran and Ucan Ek' 1999). At Lamanai, logwood charcoal was recovered from the ceramic jar in cache N10-12/8 along with shell fragments, bone and a rodent tooth. It may have been in this context because of its medicinal properties or it may have been an accidental inclusion.

Mosannona depressa (Baill.) Chatrou (Annonaceae, formerly *Malmea depressa* (Baill.) R.E. Fr.), called *che-che* or *itz-imul* in Belize today, is a small understory tree of tropical forests that produces edible fruit (Balick et al. 2000). *M. depressa* is the only species of this genus found in the region (Balick et al. 2000), so we feel confident of the identification. A small amount of charcoal of this species was recovered from Cache N10-2/2, likely a Postclassic context.

Manilkara cf. *zapota* (L.) P. Royen (Sapotaceae) was an important building material and food source of the ancient Maya (Lentz and Hockaday 2009; Lentz et al. 2014a). There are three species of *Manilkara* known from the region (Balick et al. 2000), of which *M. zapota* is the most common (Lentz and Lane 2014; Schulze and Whitaker 1999; Standley and Williams 1967; Thompson et al. 2015). In our reference collection, we have only one species, *M. zapota*, and our archaeological specimens compare favorably to the reference material in terms of vessel diameter, vessel arrangement, parenchyma arrangement, ray width and other characters. It has long been cultivated by the Maya for its *sapodilla* fruits (Atran and Ucan Ek' 1999), as well as its use as a building material because of its resistance to decay, smooth finish and strength (Standley and Williams 1967). Sapodilla charcoal was found in the Late Classic fill of a bench in

Room B3 in structure N10-77 at Lamanai. It possibly represents redeposited trash or construction material from an earlier structure.

Figure 5: Micrographs of Lamanai woods in transverse sections: a) *Pinus caribaea*, b) *Haematoxylum campechianum*, c) *Pouteria* sp., d) *Annona* sp., e) *Nectandra* sp., f) *Stizophyllum riparium*. (2 columns)

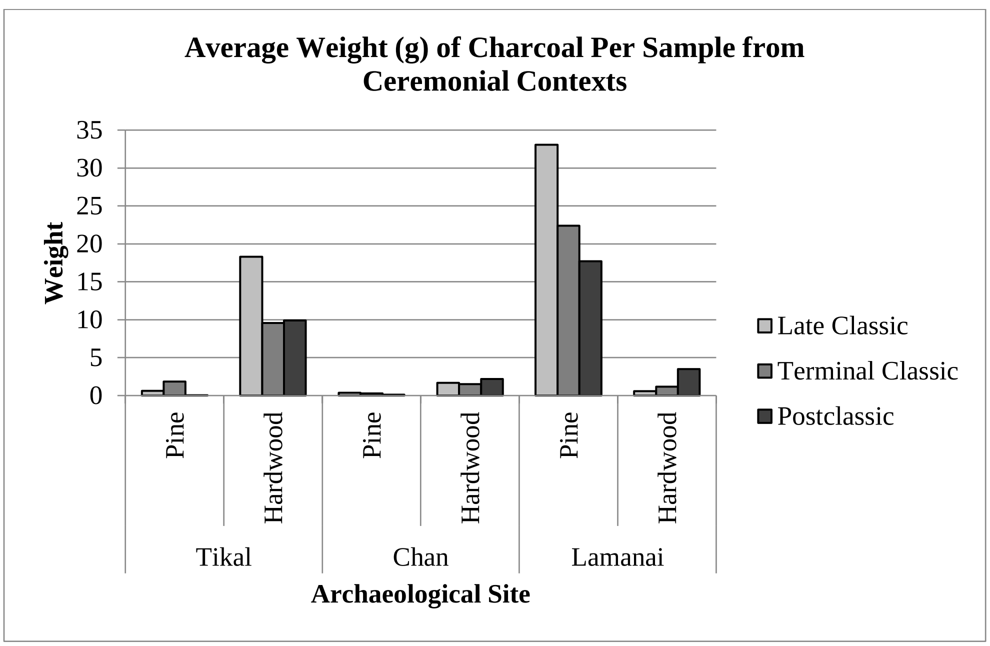


Nectandra sp. (Lauraceae) is a genus of understory trees and shrubs, often called "laurel" or "timbersweet" in Belize (Balick et al. 2000). They are widely used for construction or fuel. At Lamanai, burned fragments of *Nectandra* wood were found in wall fill in Structure N10-2, probably representing redeposited trash.

Pinus caribaea (Pinaceae, formerly *P. hondurensis* Loock), or pine, as discussed previously, was of major ceremonial and economic importance to the Yukatek Maya, who called it *hubhub* (Standley and Steyermark 1958). The Itza Maya used pine for building, for firewood, and for torches, and used its resin as incense (Atran and Ucan Ek' 1999). Pine charcoal was an integral part of ancient Maya ceremonial activities, undoubtedly because of the abundant smoke it created when burned (Morehart et al. 2005). Because of its use as a fuel (Dussol et al. 2016) and special ritual value, pine charcoal appears to have been actively processed and exchanged as a commodity by the ancient Maya (Lentz et al. 2005). *P. caribaea* can be found in mixed forests and pine savannas on hillsides and in plains at low elevations (less than 600 meters) in many areas of northern Belize and the southeastern Petén, Guatemala (Standley and Steyermark 1958). At Lamanai, pine charcoal (Fig. 5 and Table 1) was found in all of the caches. The only context where pine was not found was in the fill of Bench 3 in Room B3.

Overall, the amount of pine found at Lamanai in ceremonial contexts was remarkable; there was more pine, measured by weight, at Lamanai than any other site in the Maya Lowlands where paleoethnobotanical data were collected from ceremonial provenances (Table 2 and Fig. 6). In fact there was more archaeological pine at Lamanai than all other sites in the area combined! Moreover, if we compare the weights of pine from ceremonial Late Classic contexts at Lamanai to similar contexts at Chan and Tikal (two habitation sites for which we have comparable data), the differences are highly significant (Table 3). These results were calculated using a Kruskal-Wallis (Kruskal and Wallis 1952) rank sum test. This test was employed because the data were not normally distributed. The Kruskal-Wallis test was followed by a Dunn post hoc multiple comparison test (Dunn 1961) which demonstrated that none of the data sets grouped together, at least at the $p = 0.05$ level. Pine quantities at Lamanai ceremonial contexts during the Late Classic period significantly exceeded those at Chan and Tikal. Pine charcoal remains have been recovered from many Maya sites such as Copán (Lentz 1991), Cerén (Lentz et. al. 1996), Cahal Pech, Pacbitun (Weissen and Lentz 1999), Xunantunich (Lentz et. al. 2005), Tikal (Lentz et al. 2014a), and others, but the weight of ceremonial pine charcoal at Lamanai, notwithstanding the relatively small sample set, is astounding.

Figure 6: Comparison of wood use in ceremonial contexts at Lamanai to similar contexts at Tikal and Chan sites. Note that paleoethnobotanical samples from Chan and Tikal were retrieved both opportunistically and through a systematic flotation retrieval strategy while Lamanai archaeological plant specimens were collected opportunistically without the benefit of flotation. Thus, the quantities observed here for Lamanai are probably under-represented.



Pouteria sp. (Sapotaceae) is a Neotropical genus of large to medium-sized tropical forest trees. Balick et al. (2000) list nine species in this genus in Belize. It is difficult to distinguish the wood of these different species, but of these *P. sapota* (Jacq.) H. E. Moore & Stearn, called *zapote* or *mamey*, is commonly cultivated for its succulent fruits and has been for many centuries as evidenced by zapote fruit remains at other Maya sites (Lentz 1999). Charred *Pouteria* wood was found in Cache N10-77/4 at Lamanai.

Stizophyllum riparium (H.B.K.) Sandwith (Bignoniaceae). The common name in Belize is "mahogany vine" and it is a liana of wetland forests. A few burned fragments of this wood were found in Cache N10-12/8. As a vine, this item in the cache may represent something that was used to tie together a bundle or an offering. Alternatively, vines are commonly used in traditional Maya construction to fasten beams and uprights together (e.g., Wisdom 1940: 123) so the vine fragment in the N10-12/8 sample may have been part of an adjacent building where it served in a similar fashion.

Arecaceae (palms) burned trunk fragments were discovered in Cache N10-2/2, which likely dated to Postclassic times. Why burned palm would have been found in this cache is not certain, but the presence of burned palm stems may be a reflection of increased Postclassic palm growth in the area as indicated by pollen evidence (Rushton et al. 2013).

Acrocomia aculeata (Arecaceae, formerly *A. mexicana* Karwn. ex. Mart. or *A. beliziensis* L.H. Bailey), grows in lowland forests at or below 1000 m above sea level, often with pines (*Pinus sp.*), on dry hillsides, or in open plains throughout Central America, where it is common. The fruits of *coyol*, its common name, are eaten and the sap can be consumed fresh, or allowed to ferment to form an alcoholic beverage called *vino de palma* (Standley and Steyermark 1958). Also, a flavorful cooking oil can be extracted from the fruits (Wiesen and Lentz 1999). Coyol endocarps have been recovered in abundance from ancient Maya sites such as Copán (Lentz 1991), where the palms appear to have been cultivated, and found in middens at Cahal Pech, Pacitbun (Weisen and Lentz 1999), Tikal (Lentz et al. 2014a, 2015), and elsewhere (Lentz 1990). Charred coyol endocarps were recovered from wall fill in structure N10-2 at Lamanai, probably representing a redeposited midden.

Phaseolus vulgaris (Fabaceae, subfamily Papilionoideae), the common bean, called *bul* or *buul* by the Yukatek Maya, was a staple food, along with maize (*Zea mays* L.). Beans can be grown fairly quickly and can survive on poor or heavy soils (Standley and Steyermark 1946). Archaeobotanical bean findings are generally not abundant at Maya sites, owing to their poor preservation properties. However, analysis of cotyledon markings in carbonized specimens from Lamanai, led to their identification as *P. vulgaris*. The beans were found in Postclassic cache N10-2/2 (Fig. 4) and may have been included as part of a food offering. Macroremains of beans have also been recorded at Tikal (Lentz et. al. 2014a), Copan (Lentz 1991), Cerén (Lentz et. al. 1996), Cahal Pech, Pacitbun (Weissen and Lentz 1999) and most other Maya sites where paleoethnobotanical studies have taken place.

Zea mays L. (Poaceae), *maize*, is a staple of the Maya diet (Swallen and McClure 1955), along with beans (*Phaseolus vulgaris* L.), squash (*Cucurbita* spp.), and root crops. There are many varieties, owing to the duration and importance of maize cultivation. Maize kernels and cob fragments were recovered from Cache N/10-2/2 at Lamanai, likely representing a food offering. Although this is not a large sample, it documents the presence of this important plant at Lamanai. Elsewhere in the Maya Lowlands, maize remains have been identified from almost every site where systematic ancient plant retrieval techniques have been applied (Lentz 1999).

The plant remains retrieved from Lamanai represent an informative collection. In many ways, the data set is reflective of plant use practices seen at other ancient Maya sites, yet the plants identified also reveal patterns unique to Lamanai. Maize and common beans were in evidence and document the use of these two annual crops at Lamanai, most certainly part of the agricultural underpinning of Maya subsistence as clearly demonstrated at other sites (Lentz 1999; Lentz et al. 2014). The coyol palm evidence demonstrates palm use at Lamanai. Coyol, a productive and useful plant, was cultivated by the ancient Maya as seen in the paleoethnobotanical remains at other sites (e.g., Lentz 1991) and may well have been used similarly at Lamanai. These results help to explain, at least in part, why the palm pollen signature taken from Lamanai lagoon sediments increases dramatically during Late Classic times (Morse 2009). Likewise, the *Pouteria* sp. and *Annona* sp. charcoal suggest the use of the succulent fruits of zapote and guanabana, respectively. Evidence for the cultivation of fruit trees is quite common throughout the Maya Lowlands and the same pattern is reflected in the archaeological plant remains from Lamanai.

Several tree species in evidence represent general construction, fuel use, or forest fruit extraction from the local forests. *Manilkara zapota* and *Haematoxylum campechianum* were both hardwood species preferred by the ancient Maya for the construction of temples, palaces, and other cut stone structures because their timbers were strong and resistant to decay (Lentz and Hockaday 2009). Charcoal of *M. zapota* and *Mosannona depressa* indicated the use of these trees by the Lamanai inhabitants because of the highly-valued wood and likely their edible fruits, as well. Other tree species *Nectandra* sp., and *Casearia* sp. also were in evidence at Lamanai and probably were used for fuel and general construction purposes.

Undoubtedly the most evocative discovery at Lamanai, however, was the extraordinary quantity of pine charcoal in ceremonial contexts. Pine seems to have been deposited in different ways at the site, reflecting the difference in its use. For example, in some cases, pine was the fuel for a ceremonial offering as in sample number 10006. In other cases it may have been used as the material from which to manufacture an object as in sample number 10000. Finally it appears in middens as in samples 10013 and 10014 where it may have been the remains of hearth fires or a structure that burned. In any case, the quantities of pine charcoal by weight in each ceremonial context at Lamanai were exceptionally large (Table 2). Pine weights from Late Classic ceremonial contexts at Lamanai were compared to those of Tikal and Chan (two other contemporaneous sites with comparable data sets), and the differences were highly significant (Table 3) with the pine weights per sample at Lamanai being far greater. One possible explanation for this unusual disparity is that the Lamanai elite intended to create more opulent smoke displays as a component of ritual offerings than elsewhere during the Late Classic period. These extravagant displays evidently required large amounts of pine wood. The excessive use of pine involved in rituals, however, seems to taper off during the Terminal Classic (Fig. 6) and this cultural shift is consistent with Graham's observations of other contemporaneous cultural changes at Lamanai (e.g., in political infrastructure, ceramic manufacturing, architectural styles, and burial practices) following the Late Classic period (Graham 2000; Graham et al. 2013).

A second explanation for the greater use of pine at Lamanai was the disparity in access to pine resources. At Tikal, there was a stand of pine (180 ha) located 20 km to the northeast of the city (Fialko 2001). A detailed population genetic study was completed on this pine stand and the results showed that the stand of trees was of ancient origin, likely predating the Maya occupation (Dvorak et al. 2005). Because it was a small stand and its wood contents were of significant value to the Maya, they apparently carefully managed it, otherwise it would have been quickly eliminated by the large populace of Tikal and the surrounding polities (Lentz et al. 2015). The Chan site residents, on the other hand, probably obtained pine charcoal from the Mountain Pine Ridge in the Maya Mountains, but likely had to obtain it on an exchange basis

(Lentz et al. 2012). By contrast, Lamanai sits adjacent to an extensive pine savanna (‘pine ridge’) just across the New River Lagoon (see Fig. 2) where stocks of pine presumably were there for the taking. It seems reasonable to suggest that the increase in Late Classic pine use at Lamanai was a result of a combination of availability and human agency attempting to appease their deities during stressful circumstances.

Interestingly, pollen evidence from the New River Lagoon cores indicated that the pine pollen signature declined during the Late Classic period (Rushton et al. 2013). The contemporaneous co-occurrence of the Lamanai macroremain evidence and pollen data collected from the site and the adjacent New River Lagoon, respectively, suggest that the Maya of Lamanai were heavily exploiting the pine resources in the area to the extent that they were causing a reduction in the pine pollen rain. Based on available evidence, pine use in caches declined during the Early Postclassic period at Lamanai (Fig. 6), while the pine pollen percentages increased (Rushton et al. 2013). These data indicate that the reduced demand on pine resources by the Postclassic Lamanai inhabitants may have allowed the local pine stocks to rebound.

The combined paleoethnobotanical data relating to pine at Lamanai provide a hypothesized scenario whereby the Late Classic Maya adopted unsustainable land use practices to fuel ritual and other activities that impacted local stands of pine. Terminal Classic and Postclassic paleoethnobotanical data suggest a modification in ritual activity at Lamanai that may have occurred as a result of reduced resources, changing elite leadership, or both. In any case, it is clear that the ritual contexts at Late Classic Lamanai reveal an intensive use of pine and this practice, if undertaken broadly, likely had a dramatic impact on local forest reserves.

A parallel to such a strong emphasis on Late Classic resource exploitation was observed at Tikal where the Maya removed the last of their carefully protected old-growth *Manilkara zapota* trees to build Temple 4. After that, when the last of their sapodilla trees of large girth were gone, they had to switch to *Haematoxylum campechianum,* a usable but less desirable tree (Lentz and Hockaday 2009). This appears to be congruent with a pattern of Late Classic conspicuous consumption related to ceremonial activity at Lamanai. Viewed from a larger perspective, this set of events at both Tikal and Lamanai may signify a growing need during the Late Classic period to supplicate the gods to maintain some kind of homeostasis when events related to climatic factors and agricultural productivity were spiraling out of control in the surrounding region.

5. Conclusion

Analysis of the contents of caches and other contexts from three elite-associated structures in the Central Precinct at Lamanai indicate continuity of ceremonial activities through a time of widespread social upheaval in the Maya Lowlands at the end of the Late Classic period (Graham 2004; Pendergast 1981, 1986, 1998, 2006). Large quantities of wood charcoal were found in several caches dating to the latter part of the Late Classic, the Terminal Classic, and the beginning of the Early Postclassic period. Burned wood in offertory contexts was accompanied, in some instances, by jade and obsidian artifacts, as well as shells, cinnabar, and ceramics. Conifer charcoal was the predominant plant material in all caches, although maize and bean remains also were identified. Another cache sample, taken from the core of the platform of Structure N10-12, yielded pine charcoal, several species of hardwood charcoal and palm fruits. The prevalence of such a prodigious amount of pine charcoal in all these caches indicates consistent ceremonial activities that continued from possibly as early as the 7th century through the Terminal Classic and into the very Early Postclassic period (early part of the 11th century), when many other Maya sites had already fallen into decay. The abundant charcoal also suggests that pine, as an important component of ceremonial practices, was readily available to the Lamanai occupants and intensively exploited, especially during the Late Classic period.

Perhaps the most interesting aspect of this study is the interplay between the exploitation of a major commodity, in this case pine wood, and the environment from which it was obtained. During the Late Classic period, macrobotanical remains suggested an increase in pine use associated with ritual activity while the contemporaneous pollen evidence from the New River Lagoon indicated a sharp decline in the pine pollen rain at the same time, indicating a reduction in the surrounding pine tree population. In the Postclassic period, pine use appears to decline with a concomitant rebound in the pine savannas. From this macabre dance with nature, the Lamanai Maya demonstrated the dramatic impact that even stone-age low-density urban communities can have on their local environment.

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Table 2. Summary of pine and hardwood macrobotanical remains recovered through time from ceremonial contexts at Maya archaeological sites near Lamanai (Lentz et al. 2005b, 2012, 2014a, 2015; Morehart 2011).

Table 3. A Kruskal-Wallis test (Kruskal and Wallis 1952) was conducted to evaluate differences among sample weights of pine charcoal from Late Classic ceremonial contexts at Lamanai, Tikal and Chan. Because these data were not normally distributed, we elected to use a non-parametric test. The differences in the three pine weight data sets were highly significant (χ^2= 27.067, df = 2, p <0.001). In a post hoc multiple comparison test (Dunn 1961), all three data sets were significantly different at the p=0.05 level with Lamanai having significantly greater weights of pine charcoal per sample than Tikal or Chan.

Table 1. Plant macroremains from Lamanai (*=carbonized).

Provenience	Plant	Part	Weight	Sample #	Cultural period	Calibrated ^{14}C range	Context
LA 1742, N10-12 boulder core	*Pinus caribaea*	wood*	14.63g	10001	Terminal Classic-Early Postclassic	900 to 1025 CE	Charcoal apparently associated with sherds from Buk pedestal-based jar, Terclerp/Buk ceramics
LA 1894/8, cache N10-12/8 from N10-12	*Pinus caribaea*	wood*	9.38g	10024-10025	Start of Terminal Classic	715 to 890 CE	Contents of lip-to-lip shallow bowls covered by another vessel (with a bird bone fragment and a dirt concretion both painted with cinnabar).
LA 1894/6, cache N10-12/8 from N10-12, 1st	*Pinus caribaea*	wood*	57.25g	10004-10005, and 10021-10023	Start of Terminal Classic	665 to 770 CE	Contents of jar in cache N10-12/8 (with *Spondylus* sp. shell fragments, ceramic sherds, bone fragments, and a rodent tooth). Contents were deliberately placed in the vessel although some of the organic remains may have entered the vessel after the cache was deposted. This represents the first phase of the construction of N10-12.
	Annona sp.	wood*	0.11g				
	Casearia sp.	wood*	0.25g				
	Haematoxylum campechianum	wood*	0.26g				
	Stizophyllum riparium	wood*	0.18g				
	Angiosperm	wood*	2.77g				
	Dicot	stem*	0.02g				
	Dicot	burnt tuber	0.06				
LA 1764, N10-77 Room B2	*Pinus caribaea*	wood*	0.57g	10006	Start of Terminal Classic	655 to 770 CE	Burnt stratum from room B2 covering rooms B2 and B3. Terclerp ceramics. Pine wood likely used as fuel in ritual.
LA 1777, N10-77 Room B2, cache N10-77/2	*Pinus caribaea*	wood*	1.87g	10007	End of early facet of Late Classic & start of late facet of Late Classic	600 to 665 CE	Cache sealed by final plaster floor of Room B2 with jade, *Spondylus* sp. shell & obsidian. Burnt remains possibly in perishable container
LA 1778, N10-77, Room B3, core of bench 3	*Manilkara zapota*	wood*	0.71g	10012	Early facet of Late Classic	585 to 660 CE	Non-primary fill material from bench core; may represent a time long before actual bench construction.
LA 1779, N10-77, fill in bench 4, Room C	*Pinus caribaea*	wood*	1.60g	10013-10014	Late facet of Late Classic	615 to 685 CE	Non-primary: found along with bones and sherds from Late Classic pottery, redeposited midden used as fill.
LA 1783, N10-77, cache N10-77/5, Room B2	*Pinus caribaea*	wood*	130.91g	10015-10017	End of early facet of Late Classic & start of late facet of Late Classic	670 to 770 CE	Charcoal in cavity in penultimate floor of Room B2; at initial end of final occupation phase; just west of cavity with jade fragments.
LA 1784, N10-77, cache N10-77/3, Room B2	*Pinus caribaea*	wood*	5.17g	10018	End of early facet of Late Classic & start of late facet of Late Classic	660 to 770 CE	Charcoal in shallow cavity in doorway of Room B2 with obsidian, sherds.

Table 1 (continued). Plant macroremains from Lamanai (*=carbonized).

Provenience	Plant	Part	Weight	Sample #	Cultural period	Calibrated ^{14}C range	Context
LA 1785/1, N10-77, cache N10-77/4, Room B2	*Pinus caribaea*	wood*	21.30g	10000	End of early facet of Late Classic & start of late facet of Late Classic	660 to 770 CE	Contents of a ceramic vessel (black-slipped, grooved vase) placed upside down in a cavity in the penultimate floor of Room B2 and sealed by the final floor (with slate). Possibly a wooden artefact that was burned and placed upside down in the vessel.
	Sapotaceae	wood*	1.50g				
LA 1785, N10-77, cache N10-77/4, Room B2	*Pinus caribaea*	wood*	119.15g	10019	End of early facet of Late Classic & start of late facet of Late Classic	660 to 770 CE	Contents of a ceramic vessel (black-slipped, grooved vase) placed upside down in a cavity in the penultimate floor of Room B2 and sealed by the final floor (with slate).
	Pouteria sp.	wood*	3.00g				
	Sapotaceae	wood*	1.15g				
LA 1798, N10-77, cache N10-77/8, Room C	*Pinus caribaea*	wood*	49.24g	10008-10009 and 10020	Late facet of Late Classic	665 to 770 CE	Cut into Floor 1 and capped at or just below floor level following final floor construction and preceding filling of the space for construction of Str. N10-12 (with obsidian and *Spondylus* shell fragments).
LA 2522, N10-77, cache N10-77/10, Room C	*Pinus caribaea*	wood*	4.74g	10002	End of early facet of Late Classic and start of late facet of Late Classic	665 to 865 CE	Offering placed before the laying of the final floor (sealed by Floor 1, Room C). Material may have been placed in a perishable container.
LA 2524, N10-77, cache N10-77/12, Room C	*Pinus caribaea*	wood*	7.03g	10026-10027	Late facet of Late Classic	670 to 775 CE	Cache N10-77/12 in Floor 2 of Room C, west of the center of the eastern doorway, sealed at upper floor level. Probably burnt in situ and capped by a stone slab mortared in place.
LA 2525, N10-77, cache N10-77/13, Room C	*Pinus caribaea*	wood*	19.14g	10003 and 10011	Late facet of Late Classic	645 to 770 CE	Cache N10-77/13, cut into Floor 1, Room C, and sealed at floor level; lay immediately north of cache N10-77/12. Capped by a mortar layer containing small pieces of facing stone, possibly burned in situ (with quartzite fragment). Like Caches N10-77/8 and 12, represents activity during the use-life of Room C following final floor construction.
LA 2532, N10-77, cache N10-77/19, Room C	*Pinus caribaea*	wood*	3.68g	10010	Early facet of Late Classic to start of late facet of Late Classic	685 to 875 CE	Cache N10-77/19, centered in eastern doorway of Room C, cut into Floor 2 and capped by Floor 1. Articulates with final floor construction of Room C,

Table 1 (continued). Plant macroremains from Lamanai (*=carbonized).

Provenience	Plant	Part	Weight	Sample #	Cultural period	Calibrated ^{14}C range	Context
LA 34/1C, Cache N10-2/2, 'Gom' phase. South side of Str. N10-2, associated with a burial.	*Zea mays*	kernels*	5.33g	20001	Early Post-classic	1055 to 1255 CE	South side of stair block of Str. N10-2,4th. With freshwater snail shell. Contemporaneous with abandonment of Str.N10-2, 4th. Burnt as part of an offering with Sample #20002
	Zea mays	cob fragments*	2.28g				
	Pinus caribaea	wood*	2.16g				
	Phaseolus vulgaris	seeds (2)*	0.01g				
LA 34/2C, Cache N10-2/2, 'Gom' phase, Structure N10-2, associated with a burial	*Mosannona depressa*	wood*	0.02g	20002	Early Post-classic	No date.	South side of stair block of Str. N10-2,4th. Contemporaneous with abandonment of Str. N10-2, 4th but carbon did not yield a date at Oxford .Burnt as part of an offering with Sample #20001
	Phaseolus vulgaris	seeds*	3.96g				
	Pinus caribaea	wood*	18.61g				
	Arecaceae	vascular tissue*	3.04g				
	Angiosperm	wood*	3.92g				
LA 115/1C, Str. N10-2, from within the walls of 'Gom.' Structure N10-2	*Casearia* sp.	wood*	0.03g	20003	Early Post-classic	1020 to 1155 CE	Dates the construction of the phase N10-2, 4th; material assembled just prior to the time of construction. Contains young wood. Probably wattle with clay and trash mixed together.
	Nectandra sp.	wood*	0.04g				
	Angiosperm	wood*	12.41g				
	Acrocomia aculeata	endocarp*	1.71g				

Table 2. Summary of pine and hardwood macrobotanical remains recovered through time from ceremonial contexts at archaeological sites near Lamanai (Lentz et al. 2005, 2012, 2015; Morehart 2011).

		Pine			**Hardwood**		
Archaeological Site	**# of contexts**	**Total Weight (g)**	**Avg. Weight (g) per context**	**%**	**Total Weight (g)**	**Avg. Weight (g) per context**	**%**
Preclassic							
Chan	5	41.96	8.39	57.24%	31.35	6.27	42.76%
San Lorenzo	1	0.06	0.06	2.10%	2.8	2.80	97.90%
Tikal	7	10.06	1.44	8.42%	109.46	15.64	91.58%
Totals	**13**	**52.08**	**4.01**	**26.61%**	**143.61**	**11.05**	**73.39%**
Early Classic							
Actun Chapat	2	0.65	0.33	26.21%	1.83	0.92	73.79%
Actun Nak Beh	4	4.88	1.22	99.59%	0.02	0.01	0.41%
Chan	2	14.06	7.03	59.30%	9.65	4.83	40.70%
Tikal	30	27.32	0.91	6.04%	425.01	14.17	93.96%
Totals	**38**	**46.91**	**1.23**	**9.70%**	**436.51**	**11.49**	**90.30%**
Late Classic							
Actun Chapat	1	0.25	0.25	0.94%	26.33	26.33	99.06%
Actun Halal	5	1.86	0.37	17.22%	8.94	1.79	82.78%
Actun Chechem Ha	23	101.04	4.39	100.00%	0.00	0.00	0.00%
Actun Nak Beh	5	46.28	9.26	69.50%	20.31	4.06	30.50%
Barton Creek Cave	10	4.43	0.44	7.32%	56.06	5.61	92.68%
Chan	24	9.32	0.39	18.89%	40.03	1.67	81.11%
Lamanai	11	363.83	33.08	98.28%	6.36	0.58	1.72%
Twin Caves 2	1	2.60	2.60	96.65%	0.09	0.09	3.35%
Tikal	32	20.32	0.64	3.35%	585.75	18.30	96.65%
Totals	**113**	**549.93**	**4.87**	**42.51%**	**743.87**	**6.58**	**57.49%**
Terminal Classic							
Chan	30	8.50	0.28	15.71%	45.6	1.52	84.29%
Lamanai	3	67.20	22.40	94.96%	3.57	1.19	5.04%
Tarantula Cave	1	1.86	1.86	32.24%	3.91	3.91	67.76%
Tikal	8	14.88	1.86	16.27%	76.57	9.57	83.73%
Totals	**42**	**92.44**	**2.20**	**41.62%**	**129.65**	**3.09**	**58.38%**
Postclassic							
Chan	4	0.38	0.10	4.19%	8.69	2.17	95.81%
Lamanai	2	35.40	17.70	83.53%	6.98	3.49	16.47%
Tikal	1	0.04	0.04	0.40%	9.89	9.89	99.60%
Totals	**7**	**17.21**	**2.46**	**48.09%**	**18.58**	**2.65**	**51.91%**

Table 3. A Kruskal-Wallis test (Kruskal and Wallis 1952) was conducted to evaluate differences among sample weights of pine charcoal from Late Classic ceremonial contexts at Lamanai, Tikal and Chan. Because these data were not normally distributed, we elected to use a non-parametric test. The differences in the three pine weight data sets were highly significant (χ^2= 27.067, df = 2, $p < 0.001$). In a post hoc multiple comparison test (Dunn 1961), all three data sets were significantly different at the $p=0.05$ level with Lamanai having significantly greater weights of pine charcoal per sample than Tikal or Chan.

Dunn Post Hoc Multiple Comparison Test

Sites	Chan	Lamanai
Lamanai	-3.216389* p <0.001	
Tikal	2.275526* p=0.0114	5.174651* p<0.001

*represents the Z value