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Trees, shrubs, and forests at Joya de Cerén, a Late Classic Mesoamerican village

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ABSTRACT

The Late Classic Maya village of Joya de Cerén's extraordinary preservation caused by the Loma Caldera volcanic eruption around 650 CE allows for a unique opportunity to understand what plant species ancient Mesoamerican farmers utilized in their daily lives for food consumption, medicinal applications, fuel, and construction purposes. While Cerén has unusually good preservation of earthen-made household structures, gardens, and extensive outfields growing maize, manioc, and numerous weedy species, this article will review the collection of anthracological remains recovered from excavations at the site since 1978. Wood charcoal recovered via flotation samples taken throughout the archaeological site reveal the surrounding ecosystems that Cerén villagers would have exploited to regularly obtain their wood resources. Additionally, various fruit trees were cultivated within the village center, as evidenced by limb, trunk and fruit impressions preserved as plaster casts. The data collected from the long history of archaeobotanical research at Cerén suggests that these ancient rural agriculturalists practiced sustainable land management strategies and incorporated a diverse assemblage of tree species into their daily practices. The ancient agriculturalists effectively coped with an ever-changing landscape and opportunistically established their settlement in a biodiverse setting that had plentiful resources from a range of ecosystems available for their daily needs.

1. Introduction

Wood charcoal is undeniably among the most abundant and ubiquitous plant macro-remains recovered from archaeological sites. After carbonization, the cellular structure of wood remains quite well preserved where most diagnostic wood anatomy features are still distinguishable and allows for the identification of wood species that were once present at archaeological sites (Théry-Parisot, 2010). However, due to the spectacular preservation of organic material at Joya de Cerén that typically do not preserve elsewhere in Mesoamerica, the identification of woody taxa has not been the focus of paleoethnobotanical analyses thus far. Cerén offers a unique and exciting opportunity to study the daily lives of Mesoamerican villagers and their household contexts during the Late Classic Maya period in modern El Salvador, because the village experienced a sudden deluge of 5 m of fine volcanic ash that was deposited from the eruption of Loma Caldera circa 650 CE (Sheets, 2002). Along with the rapid burial, this eruption caught many of the thatch roofs on fire, effectively leading to exceptional preservation of earthen architecture, agricultural fields, as well as any materials left *in situ* when the village was rapidly abandoned. While Cerén has spectacular preservation of earthen-made household structures, gardens (Farahani et al., 2017; Lentz and Ramirez-Sosa, 2002), and extensive outfields growing maize, manioc (Sheets et al., 2011, 2012), and numerous herbaceous species (Slotten et al., 2020), this review will focus on the anthracological (wood charcoal) remains recovered from the site since excavations beginning in 1978 that identify the trees and shrubs growing within and nearby the village.

Preservation of arboreal material at the site takes the form of wood charcoal, carbonized macrobotanical remains such as seeds, pits, and fruits, as well as plaster casts and impressions formed from voids created from the rapid inundation of ashfall where floral remains were located at the time of the eruption. The trees and shrubs identified at Cerén reveal the human-environmental interactions of these Late Classic Mesoamerican rural farmers as well as how they met the pressures and resource demands of their village community using knowledge of their ecological surroundings (Robinson and McKillop, 2013:3585). Anthracological remains suggest that the Cerén village was situated within a landscape actively recovering from previous geophysical and anthropogenic

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disturbances. Such rich preservation of plant remains provides an opportunity to not only understand what species the ancient inhabitants of this village utilized in their daily lives, but also how the villagers perceived and managed the greater landscape surrounding their homes.

2. Regional setting

Joya de Cerén was a rural Mesoamerican village within what is now the Zapotitán Valley of El Salvador (Fig. 1), situated at an elevation of 450 masl and latitude of 14°N. The numerous dormant volcanic cones in this region of Central America attest that it is one of the most seismologically active regions in the world. This leads to a volcanically rich history of the region and the archaeological site. The ancient Cerén village was established sometime after the eruption of the Ilopango volcano (c. 539 CE), arguably one of the greatest explosive eruptions of the Holocene in the Americas (Dull et al., 2001). Ilopango is situated in the center of El Salvador, and its mid-sixth century eruption would have created an uninhabitable environment for flora, fauna, and people within 1000 km for perhaps as long as a century (Sheets, 2009: 61). After weathering, however, the ash deposited from the volcanic eruption was likely full of nutrients and laid the foundation for verdant emerging ecosystems, as is exhibited by the paleoethnobotanical assemblage recovered from the village site of Cerén. The small, localized eruption of Loma Caldera buried the village sometime around 650 CE, thus preserving the site as a snapshot of life in a small farming community during the Late Classic period. This timing suggests that the ancient inhabitants at Cerén were almost certainly pioneers onto this recently transformed and uncontested landscape, taking advantage of the rich, fertile volcanic soils.

The region has a tropical lowland climate with an average of 1700 ± 300 mm of precipitation annually at an elevation of 450 masl (Sheets, 2002). There are pronounced wet seasons from May to October with nearly all of the annual rainfall occurring during this time, and hot, dry seasons from November to April. The average temperature for the area is 24 °C (75 °F), with a slight decrease during December making the lows generally around 22 °C (72 °F) and an increase in April of up to 26 °C (79 °F) (Sheets, 2002). The village is conveniently situated just southwest of what is now known as the Rio Sucio (Fig. 1), which would have provided a nearby water source for the ancient inhabitants and hosted a variety of useful flora. This river was clearly of great significance to the local residents, since the domestic, religious, and political structures at the site are all oriented 30° east of north, thus aligning the built environment with the waterway (Sheets, 2006).

Prior to Spanish colonization, the Zapotitán Valley likely was covered with a tropical deciduous forest dominated by tree species such as breadnut (*Brosimum alicastrum* SW.), Spanish cedar (*Cedrela mexicana* M. Roem.), ceiba (*Ceiba pentandra* [L.] Gaertn.), guanacaste (*Enterolobium cyclocarpum* [Jacq.] Gresb.), and quebracho (*Terminalia amazonia* [J.F. Gmel.] Exell. In Pulle) (Daugherty, 1969). Palynological evidence collected from highland areas roughly 70 km to the west of Cerén at Laguna Verde depict the forest to have been dominated mainly by pine (*Pinus*), oak (*Quercus*) and Urticales (Dull, 2004). Prior microbotanical research at Cerén has offered some indication of the landscape as it was at the time of the Loma Caldera eruption. Phytolith evidence shows that the Cerén landscape was primarily grassland with some additional phytoliths representing maize and squash (Sheets et al., 2012:

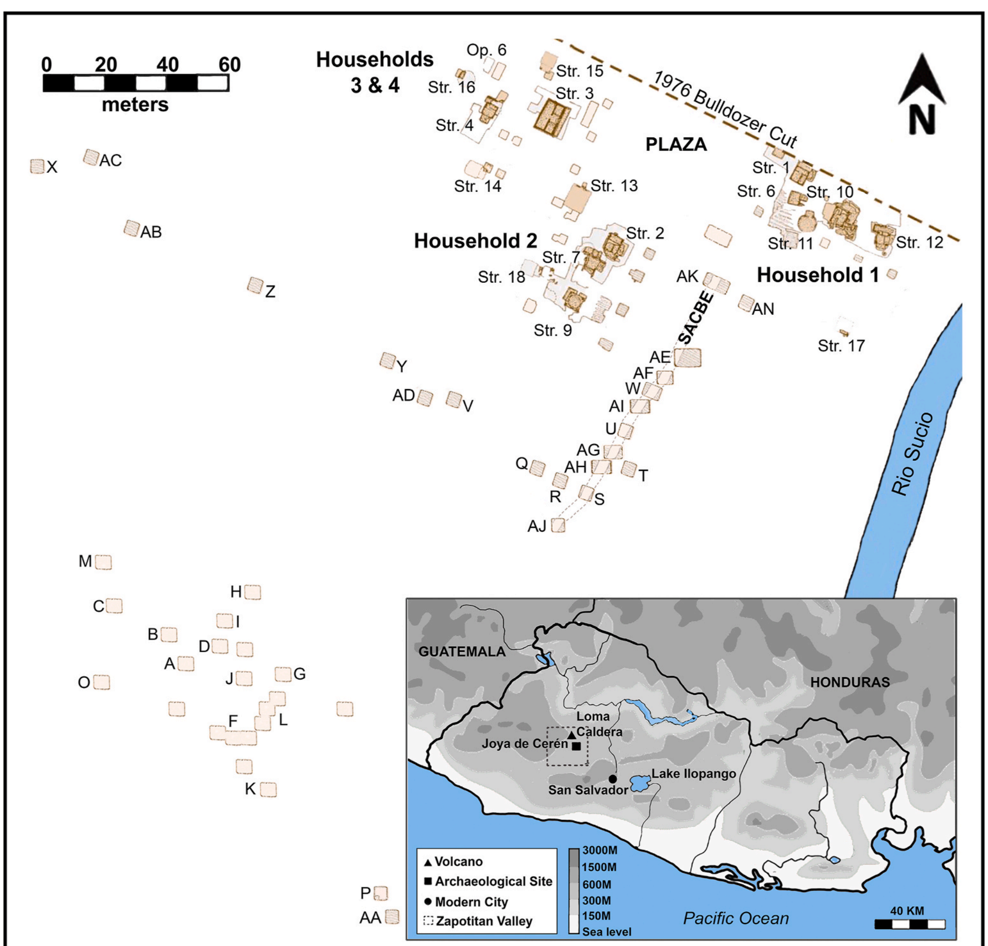

Fig. 1. Map of the Cerén archaeological site with all excavated operations noted.

277). Much of this grassland may have been dominated by *Trachypogon spicatus* (L.F.) Kuntze, the material used as thatch roofing on the earthen house and storage structures (Lentz et al., 1996b). Reconstructions of the past vegetation in the Zapotitán valley rely primarily on historical accounts and microbotanical data (Daugherty, 1969; Dull, 2004; Sheets et al., 2012), thus the macrobotanical data incorporated into this study supplies an additional line of evidence to be considered when depicting this past landscape.

Modern comparisons of the flora for this valley today are challenging, since much of the original vegetation has been cleared for agriculture and urban development. It is unclear, however, whether or not such distinctions between natural and cultural forests are meaningful given the antiquity of intensive human impact in much of Central America over several millennia where vegetation has adapted to both geophysical and human disturbances (Bush et al., 1992; Dull, 2001, 2007; Hecht et al., 2006; Pohl et al., 1996). Even though El Salvador is commonly depicted as a country that has been extensively deforested and thus suffering from a lack of biological richness (FAO, 2001; Kovar, 1945; Terborgh, 1999), there has been a strong countertrend of forest resurgence in part due to the processes of globalization that have actually enhanced forest regeneration (Hecht et al., 2006). Today, forested spaces in El Salvador include coastal plains, riparian evergreen forests, mid-level semi-deciduous forests, oak-pine mixed forests, cloud forests, and mangrove forests (Hecht et al., 2006). Roughly one third of the country is forested today, with approximately 700,000 ha of tree cover (Hecht, 1999; Hecht et al., 2006; Komar, 1998).

3. Material and methods

Since excavations at Joya de Cerén began in 1978, the paleoethnobotanical recovery efforts have employed a variety of methodologies. Early work collected botanical remains that were preserved directly within storage vessels, as carbonized remains encountered during excavations, or as plaster casts of noticeable voids within the deposited ash layers. When hollow voids were encountered during excavations, dental plaster was poured into these spaces that created a plaster cast mold of the plants that were present at the time of the eruption. Soil samples have been systematically collected and designated for recovery of macrobotanical remains via water flotation, resulting in a total of 179 flotation samples amounting to 371 L of soil since excavations began in 1978. The 2009 and 2011 field seasons utilized a modified Apple Creek water flotation system (Hood, 2012), whereas in 2013 with the improvement of the Joya de Cerén water supply, flotation samples were processed using a SMAP-style tank with a mesh size of 0.2 mm (Pearsall, 2000:27; Slotten et al., 2020). Excavators have also collected *in situ* macrobotanical samples when large carbonized wood fragments were noticeably visible in an excavation, resulting in roughly 4245 *in situ* samples collected in this manner.

Operations conducted at the site excavated through roughly 5 m of tephra, which was deposited by the eruption of Loma Caldera (c. AD 650). Excavations halted once the Tierra Blanca Joven surface was exposed, a tephra that resulted from the eruption of Ilopango Volcano roughly a century prior to that of Loma Caldera. Paleoethnobotanical samples containing wood charcoal and other arboreal remains came from throughout the archaeological site (Households 1, 2, 4, and Operations F, L, M, P, R-V, X, Y, Z, AA, AD, AE-AK, AN), see Fig. 1). Cultural contexts where arboreal remains were recovered included floors of domestic structures, roof fall of those structures, within ceramic vessels (Farahani et al., 2017; Lentz et al., 1996a; Lentz and Ramirez-Sosa, 2002), midden deposits (Hood, 2012), milpa agricultural fields, an earthen sacbe (causeway), canals adjacent to the sacbe, as well as cleared areas void of features (Slotten, 2015).

All macrobotanical samples were sorted at the Paleoethnobotany Laboratory at the University of Cincinnati using a Wild Herbrugg M5 light microscope (6x-50x). Wood charcoal remains were initially sorted into broad taxonomic categories such as hardwood, pine, or palm and then stored in a Sanpla Drykeeper Desiccator to remove all moisture before examination of anatomical features. Wood charcoal fragments greater than 2.0 mm in size were fractured to observe anatomical features in the transverse, tangential, and radial views when possible. Wood specimens were first coated with a thin layer of gold applied by a Denton Vacuum Sputter Coater and then examined using a Philips FEI XL-30 Environmental Scanning Electron Microscope (ESEM) maintained at the University of Cincinnati Advanced Materials Characterization Center. Micrographs were recorded for each specimen at magnifications of 50× and 100×, with further magnifications used if necessary. The Neotropical wood reference collection in the Paleoethnobotanical Laboratory and a number of reference sources on Neotropical wood were used in the identification process (Chichignoud et al., 1990; Hoadley, 1990; Insidewood [insidewood.lib.ncsu.edu]; Kribs, 1959; Uribe 1988). Anatomical features used to identify the wood charcoal include the size, arrangement, and quantity of vessel elements, the arrangement of axial parenchyma, the presence of tyloses, size, the quantity, and arrangement of rays, and presence of resin canals. While fragment counts are less likely to distort the frequencies of taxa compared to fragment weights (Asouti and Austin, 2005), Kabukcu and Chabal demonstrate that both counting and weighing wood charcoal are two equally valid methodologies in anthracology "due to the distributions being affected by symmetrical rare events" (2020: 6). At Cerén fragment counts of wood charcoal were recorded for only some of the field seasons. However, fragment weights of anthracological remains were recorded consistently throughout the years of paleoethnobotanical analysis at the site and as an effort to review all anthracological material at the site collectively, weight is thus the method presented in Table 1, along with context information and ubiquity. Ubiquity refers to the percentage of individual contexts where a species occurs compared to the total number of samples collected.

4. Location and accession of archaeological materials

The plant remains discussed in this study are on loan from the Museo Nacional de Antropología Dr. David J. Guzmán in San Salvador, El Salvador, and are currently housed in the Paleoethnobotanical Laboratory of the University of Cincinnati. All of the samples discussed in this paper with their accession numbers and operation numbers are listed in TableSM1 of the Supplementary Online Material Section.

5. Results and discussion

5.1. Village center

A series of household complexes have been partially excavated and identified at Cerén (Fig. 1), and the unique preservation at this site has revealed that each of the households were surrounded by productive house-lot gardens and fruit trees at the time of the Loma Caldera volcanic eruption. The plants that were growing in the areas surrounding the homes provided food, medicine, tools, and other resources to the village. The content and variety of these vegetative spaces reflect the traditional ecological knowledge (Berkes et al., 2000) of the village inhabitants and how they successfully diversified their diet to go beyond the staple crops growing in their nearby agricultural fields. A combination of plaster cast and carbonized macrobotanical remains demonstrate that there were numerous fruit trees surrounding the residential structures. These trees certainly supplied foodstuffs for each household while also providing shaded areas where outdoor activities and social gatherings could take place. Not surprisingly, the most ubiquitous trees and shrubs identified through anthracological remains (Fig. 2, Table 1) were all present within the village center, although often in other forms of preservation (such as the plaster mold casts).

Household 1 (Fig. 3), the first of the residential structure complexes to be excavated at the archaeological site, is the eastern most household uncovered thus far and is comprised of four structures including a

Table 1
Arboreal taxa recovered at Joya de Cerén (Hood, 2012; Lentz and Ramirez-Sosa, 2002; Slotten, 2015). Total weight of charcoal is provided rather than fragment counts because this is the only common form of data recorded among all field seasons. Ubiquity refers to the overall presence of material within the 62 contexts considered in this study. Non-charcoal arboreal remains are included to provide ubiquity and context information. Weights for non-charcoal remains are not included due to the most common form of preservation, plaster casts, making this data irrelevant and not comparable to wood charcoal remains. [e]indicates taxa that produce edible plant parts. [m]indicates that the taxa has known medicinal applications.

Taxon	Common Name	Plant Part	Total Weight (g)	Ubiquity	Context	Feature							
						Structure Floor	Roof Fall	Ceramic	Cleared Area	Milpa	Sacbe	Canal	Midden
Anacardiaceae													
Astronium graveolens	glassywood	charcoal	0.11	1.61%	Op. AE				•				
Metopium brownei[m]	posionwood, chechem	charcoal	1.24	8.06%	Op. AE, AH, AI					•		•	
Spondias sp.[e,m]	jocote, hogplum	charcoal	0.07	4.84%	Str. 1, HH1, 2		•		•				
		pits			HH2, Op. P		•						•
Annonaceae													
Annona sp.[e,m]	custard apple	charcoal	0.36	1.61%	Op. AA				•				
Apocynaceae													
Aspidosperma sp.[m]	white malady	charcoal	28.45	9.68%	Str. 4, HH 2, 4, Op. AA	•	•		•				
Cameraria latifolia[m]	white poisonwood	charcoal	0.58	3.23%	Op. AE, AH						•		
Tabernaemontana sp.	milkwood	charcoal	0.27	1.61%	Op. AH							•	
Bignoniaceae													
Crescentia alata[e,m]	calabash, jicaro	charcoal	0.03	12.90%	Op. AI					•			
		gourds, rinds, stems			Str. 6, 10, 11, HH1, 2, 4, Op. P	•							•
Jacaranda sp.[m]	jacaranda	charcoal	0.38	1.61%	Op. AI			•		•			
Bixaceae													
Bixa orellana[e,m]	achiote, annatto	seeds		1.61%	Str. 10			•					
Bombacaceae		charcoal	0.13	1.61%	Op. P								•
Boraginaceae													
Ehretia tinifolia[m]	bastard cherry	charcoal	0.06	3.23%	Op. AE, AF					•	•		
Burseraceae													
Protium copal[m]	copal	charcoal	0.14	1.61%	Op. P								•
Cannabaceae													
Celtis sp.[e,m]	hackberry, cagalero	pits	0.19	3.23%	HH1, OP. AE	•					•		
Capparaceae		charcoal	0.04	1.61%	Op. AE						•		
Clusiaceae													
Clusia sp.	matapalo	charcoal	461.24*	3.23%	Op. AD, AE					•	•		
		*460.74 g from a large branch within milpa (Op. AD)											
Combretaceae													
Terminalia buceras[m]	black-olive, bullet tree	charcoal	37.18*	3.23%	Op. Y, AA				•	•			
		*36.52 g from a large branch within milpa (Op. Y)											
Leguminosae													
Haematotoxylum campechianum[m]	logwood	charcoal	3.54	18.75%	Op. P, U, AH, AI, AK					•	•	•	•
Hymenaea courbaril[e,m]	guapinol	charcoal	0.05	1.61%	Op. P								•
Dalbergia sp.	rosewood	charcoal	0.3	3.23%	Op. P, R					•			•
Platymiscium sp.	granadillo	charcoal	115.26*	4.84%	Op. U, AA				•	•			
		*106.9 g from a structural beam (Op. AA)											
Pterocarpus sp.[m]	bloodwood	charcoal	3.6	1.61%	HH4			•					
Lauraceae													
Nectandra sp.[m]	timber sweet	charcoal	2.68	9.68%	Str. 1, 4, Op. AE		•				•		
Persea americana[e,m]	avocado, aguacate	charcoal	0.6	12.90%	Op. AI						•		
		pits			HH1, 2, 4, Op. P, AE, AH		•	•			•		

(*continued on next page*)

Table 1 (*continued*)

Taxon	Common Name	Plant Part	Total Weight (g)	Ubiquity	Context	Feature							
						Structure Floor	Roof Fall	Ceramic	Cleared Area	Milpa	Sacbe	Canal	Midden
Malpighaceae													
Heteropterys sp.	redwing	charcoal	0.01	1.61%	Op. AG						•		
Byrsonima crassifolia[e,m]	nance	pits, fruits		3.23%	Op. 6, P				•				•
Malvaceae													
Theobroma cacao[e,m]	cacao	pods, seeds		11.29%	Str. 6, 4, 7, HH 2, 4	•		•	•				
Meliaceae													
Cedrela odorata[m]	spanish cedar, cedro	charcoal	11.8	1.61%	Str. 6	•	•						
Moraceae													
Ficus sp.[e,m]	fig, amate	charcoal	1.65	9.68%	Str. 1, 6, HH1, Op. AA, AH, AI	•	•	•	•	•	•		
Muntingiaceae													
Muntingia calabura[e,m]	capulín	seeds		3.23%	Str. 1, 6	•							
Myrtaceae													
Psidium guajava[e]	guava, guayaba	fruits, stems, mesocarp	0.09	8.06%	Str. 4, HH1, 4, Op. AK	•			•			•	
Pinaceae													
Pinus sp.[e,m]	pine, ocote	charcoal	4.10	19.35%	Str. 4, Op. P, S, AA, AE, AH, AI, AJ, AK	•	•		•	•	•	•	•
Rhamnaceae													
Colubrina aborescens[e,m]	greenheart	charcoal	0.09	1.61%	Op. AH					•			
Rosaceae													
Prunus cf. *brachybotrya*	escobo	charcoal	3.77	1.61%	Str. 4	•							
Rubiaceae													
cf. Hamelia patens[m]	coloradillo	cast		1.61%	HH4				•				
Exostema caribaeum[m]	princewood	charcoal	0.03	1.61%	Op. AI						•		
Salicaceae													
Casearia sp.	café de monte, canjuro, iximche	charcoal	0.68	4.84%	Str. 4, Op. AE, AH	•	•			•			
Sapindaceae													
Allophylus sp.[m]	chal-chal	charcoal	0.03	1.61%	Op. AH					•			
Cupania dentata	grande betty, pava	charcoal	1.11	1.61%	HH4		•						
Exothea paniculata	inkwood	charcoal	0.13	1.61%	Op. AH					•			
Matayba sp.	white copal	charcoal	0.05	1.61%	Op. AK							•	
Sapotaceae		charcoal	2.00	3.23%	Op. P								•
Manilkara sp.[e]	sapodilla	charcoal	0.11	1.61%	Op. P								•
Solanaceae													
Acnistus aborescens	hollowheart	charcoal	0.26	1.61%	Op. AK							•	
Symplocaceae													
Symplocos sp.	sweetleaf	charcoal	2.57	1.61%	Op. AA				•				
Ulmaceae													
Ampelocera hottlei	tisón, bullhoof	charcoal	0.72	3.23%	Op. AK					•	•		
Verbenaceae													
Vitex gaumeri	verbena	charcoal	1.71	1.61%	Op. AA				•				
Dicot		charcoal	29.79	50.00%	HH1, 4, Op. L, P, Q, R, S, T, U, V, AA, AE, AF, AG, AH, AI, AJ, AK, AN	•			•	•	•	•	•

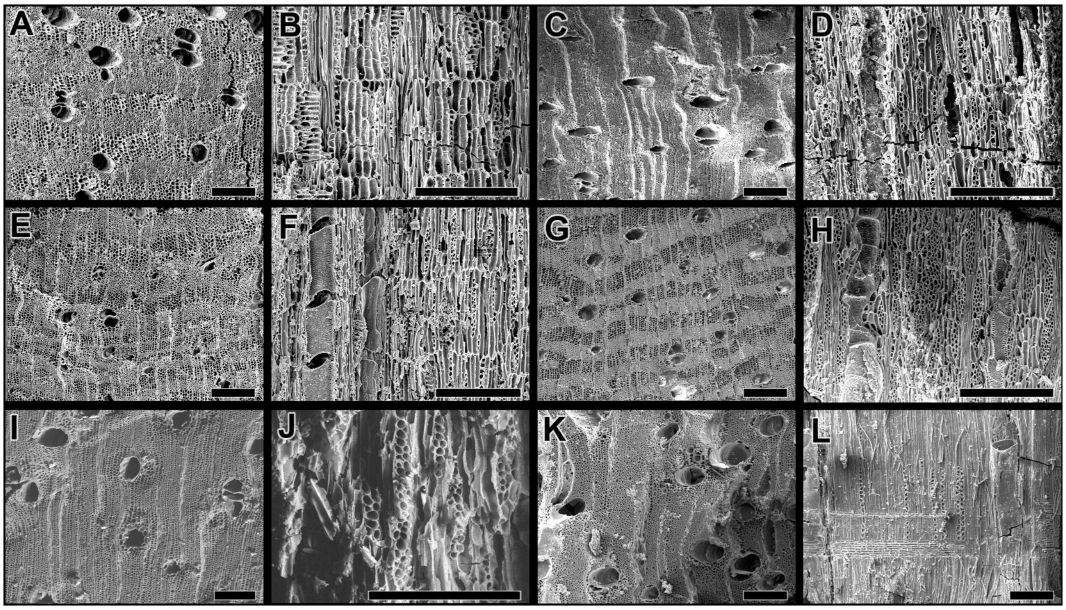

Fig. 2. Scanning electron micrographs of the top six most ubiquitous hardwoods recovered in the form of wood charcoal. A) *Haematoxylum campecianum* transverse section, B) *H. campecianum* tangential section, C) *Persea americana* transverse section, D) *P. americana* tangential section, E) *Crescentia alata* transverse section, F) *C. alata* trangential section, G) *Ficus* sp. transverse section, H) *Ficus* sp. tangential section, I) *Nectandra* sp. transverse section, J) *Nectandra* sp. tangential section, K) *Aspidosperma* sp. transverse section, L) *Aspidosperma* sp. radial section. All scale bars are 200 μm.

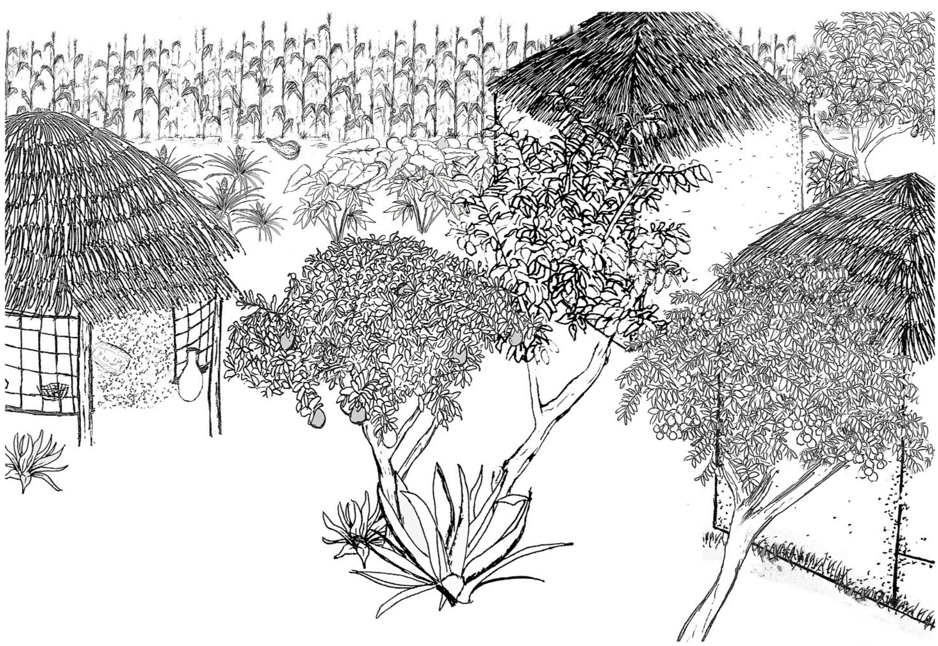

Fig. 3. Household 1 at Cerén illustrated with the trees that were surrounding the structures and the garden plot: (Left to right) *Crescentia alata, Psidium guajava, Spondias* sp. and *Persea americana.*

domicile (Str. 1), a kitchen (Str. 11), a storehouse (Str. 6), and a workshop (Str. 5). Southwest of the Household 1 structures were rows of agricultural ridges with piñuela (*Bromelia balansae* Mez.), malanga (*Xanthosoma sagittifolium* [L.] Schott), and manioc (*Manihot esculenta* Crantz.) as evidenced by plaster cast molds (Lentz and Ramirez-Sosa, 2002). In the courtyard connecting these earthen structures were a series of trees and shrubs. In between the kitchen and the storehouse were a series of trees likely growing at the time the site was buried, including guava (*Psidium guajava* L.) as evidenced by numerous leaf impressions and also calabash (*Crescentia alata* Kunth.) which was recovered in the form of a concentration of branches, gourds and rinds.

Guava is a small evergreen tree or shrub that produces edible fruits eaten fresh and the plant has been used in traditional medicine throughout Central America to treat inflammation, pain relief, fevers and is applied to insect bites and skin fungus (Atran et al., 2004:118; Gutierrez et al., 2008). Calabash is a small, evergreen tree with gourd-like fruits and has been featured in the Maya myth of Popol Vuh where the hero twin's heads are hung by the tree's branches (Goetz and Morley, 2003). Calabash seeds are edible, and today are often ground and mixed with other ingredients for beverages such as *horchata* (Lentz and Dickau, 2005). The pulp has been used as a fertilizer by the Peten Itza' Maya (Atran et al., 2004:94). The gourds have a woody exterior, making them excellent storage containers. Calabash gourds were recovered within six different structures in the Cerén village and were likely used as food service containers or as utensils for dipping water. Paint fragments consisting of mineral pigments such as kaolinite, hematite, cinnabar, goethite, and ferropyrosmalite were also found at the site and are interpreted as remnants of a painted calabash gourds (Beaubien, 1993). Wood fragments identified to be from an avocado (*Persea americana* Mill.) tree also were recovered from the Household 1 complex, suggesting that this medium-sized evergreen tree was growing nearby.

Many wood charcoal fragments were also recovered from the Household 1 complex (Lentz et al., 1996a). Achiote (*Bixa orellana* L.) seeds were discovered within a ceramic vessel in Household 1. Hackberry or *cagalero* pits (*Celtis iguanaea* [Jacq.] Sarg.) were also found in Structure 1, which would have come from this shrub that is commonly found in the Pacific lowlands (Standley and Steyermark, 1946). *Jocote* (*Spondias* sp.) charcoal was encountered just south of the domicile structure, possibly indicating the presence of the tree growing in this convenient location in the past. Jocote are small, deciduous trees typical of dry tropical forests and produce sweet yet acidic fruits that are often described as plum-like (Miller and Schaal, 2005). The fruits can be eaten fresh or made into jams and beverages (Baraona Cockrell, 2000).

Timber sweet (*Nectandra* sp.) and *amate* (*Ficus* sp.) charcoal fragments were found within structure 1, a domicile. Timber sweet are medium-sized trees found within moist tropical forests that produce black fruit in the form of drupes, with many species within the genus widely used as a source of timber today (Bohn et al., 2014). *Amate* are trees that grow into the upper canopy of tropical deciduous forests and in riparian zones along the river. Some, known as strangler figs, germinate on host trees and then parasitize them through the use of aerial roots (Standley and Steyermark, 1946: 39). Since both of the timber sweet and *amate* species were identified through charcoal remains within the domicile structure, it is likely that they had been utilized as sources of fuel by the villagers in Household 1. Also on the floor surface of this domicile structure were common beans (*Phaseolus vulgaris* L.), chili pepper (*Capsicum annuum* L.), and *cagalero* pits. *Cagalero* is a pioneer tree species typical of riparian forests that has been documented for its use in Latin America to treat urinary infections (Pereira de Silva and Proenca, 2008).

Structure 6, the storehouse, revealed charcoal likely originating as a fuel from both Spanish cedar (*Cedrela odorata* L.) and *amate* (*Ficus* sp.) trees as well as some concretions identified to be from *cacao* (*Theobroma cacao* L.) pods. Spanish cedar is a medium-sized semi-deciduous tree that prefers well drained soils but is considered a climatic generalist in that it can thrive in a variety of forest environments (Burns and Honkala, 1990). Today, Spanish cedar is highly valued commercially for its wood which is aromatic, lightweight, and resistant to termites and rotting. Some studies suggest that *C. odorata* grows best in soil that has been enriched with the burnt remains of secondary forests (Vega, 1974). Also, within Structure 6 were *capulín* (*Muntingia calabura* L.) seeds on the floor surface in the southwest corner. Capulín is a small tree with juicy red edible berries that is common in disturbed habitats. Traditional uses of this plant within Central America include the treatment of measles, stomachaches, headaches, and to reduce swelling (Mahmood et al., 2014).

Household 2, just southwest of Household 1, had patches of maize (*Zea mays* L.) milpa within just a few feet to the east of the structures and had large concentrations of seeds, branches, and fruit parts indicating nearby cacao, avocado, and calabash trees.

Household 4 had a garden plot just south of the structure with abundant rows of agave (*Agave* cf. *americana* L.). To the west of the structure, manioc and *piñuela* plants (*B. pinguin*) were growing as well. South of the agave plot were numerous woody branches identified to be from cacao, calabash, and avocado trees, as well as a guava tree producing an abundant assemblage of fruits. An abundance of wood charcoal likely used as fuel were recovered and identified from Household 4 as well, including species such as palms (Arecaceae family), white malady (*Aspidosperma* sp.), *café de monte* (*Casearia* sp.), grande betty (*Cupania dentata* Moc. & Sessé.), pine (*Pinus* sp.), timber sweet, bloodwood (*Pterocarpus* sp.), and other unidentifiable hardwoods. North of structure 4, eight plaster molds of fruits from nance (*Byrsonima crassifolia* [L.] Kunth) were recovered suggesting that the tree once stood nearby. Nance is a slow growing medium-sized tree with small, sweet yellow fruit which has been traditionally fermented in sugar to produce a liquor and is thought to help with stomach ailments or skin irritants (Atran et al., 2004:113). Within Structure 4, wood charcoal discovered within a ceramic vessel was identified to be from bloodwood (*Pterocarpus* sp.).

Considerable evidence for cacao has been recovered from the site, strongly demonstrating that the tree was growing within the village. *T. cacao* is a spindly understory tree that is most well-known for the chocolate produced from its seeds. The tree requires quite specific growing conditions: damp, shaded understory areas abundant with their sole pollinators of small flies or midges and temperatures above 60 °F (Bletter and Daly, 2006; Coe and Coe, 2013:19). Once pollinated, the flower results in a large pod that contains around 40 seeds that are surrounded by a sweet, white aril or pulp. The seeds cannot survive low temperatures or low humidity and have a short dormancy period (Ogata et al., 2006: 70), which is significant because the seeds are the most highly valued part of the plant. Four different vessels within structure 4 of Household 4 contained cacao seeds and peduncles (Lentz et al., 1996a). Casts of the fruit pods were found in both Operations 2 and 4. Recovering the seeds and casts of cacao pods is significant because neither of these plant parts travel well or for long distances, suggesting that the plant must have grown nearby. In fact, a plaster cast of a cacao tree with a cauliflorous inflorescence still attached to its trunk was found near Structure 4, further solidifying the evidence that these ancient rural farmers were cultivating this valuable Mesoamerican tree. Cacao seeds have been documented in historic accounts as a form of currency (Millon, 1955) and were also used for making fermented beverages (McNeil, 2006). Cylindrical vases that are associated with cacao beverage consumption (Hall et al., 1990; Reents-Budet, 1994) were also recovered within Structure 4. Cacao is intricately linked with political, social, and economic worldviews of ancient Mesoamerica.

5.2. Construction beams

There have been multiple encounters with large carbonized sections of wood material during archaeological excavations representing the remains from construction beams that were preserved from the volcanic eruption (Lentz et al., 1996a). Such finds allowed for more detailed interpretations regarding the use and state of the wood material by the village residents in the past. In 2011, multiple segments of wood beams were recovered within the southwest corner of Operation AA from the edge of a storage or domicile facility (Sheets and Dixon, 2011), a context located about 200 m south of the main village area. Only the carbonized beam fragments were collected, and the structure has not been excavated further. This presented an exciting opportunity to determine what species of wood were used to build their household structures. This particular wooden beam was identified to be from a granadillo tree (*Platymiscium* sp.) (Fig. 4), which is a slow-growing leguminous tree that is typically found in dry forests and woodlands. It is commonly used for construction purposes by indigenous populations even today (Atran et al., 2004; Moya et al., 2013), just as it was at this Late Classic Maya village. Its heavy use in construction today has led the tree to be classified as “critically endangered” and a threatened species due to over exploitation for timber products (Klitgaard, 2005). As has been previously reported by Lentz et al. (1996a), multiple tree species identified through wood charcoal remains recovered within the main village center represent portions of roofing material that had collapsed at the time of the volcanic eruption, including malady (*Aspidosperma* sp.), cedro (*Cedrela* sp.), amate (*Ficus* sp.), ocote (*Pinus oocarpa*), jocote

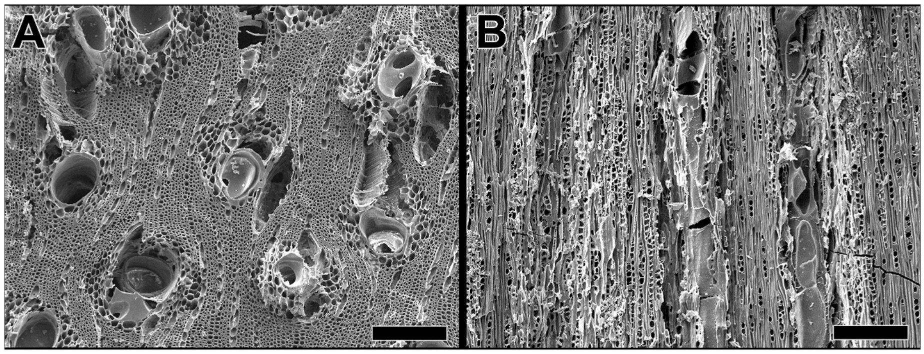

Fig. 4. Scanning electron micrographs of *Platymiscium* sp. (granadillo) that was recovered as a construction beam in Operation AA. A) transverse section at 100x, B) tangential section at 100x. All scale bars are 200 μm.

(*Spondias* sp.), timber sweet (*Nectandra* sp.), café de monte (*Casearia* sp.), and *pava* (*C. dentata*). Today, wood from all of these trees continue to be valued as important sources of timber throughout Central America.

The variety of tree species used to support structures at Cerén is strikingly different than analysis of ancient Mesoamerican construction beams at Tikal which demonstrates a more selective preference for construction wood (Lentz and Hockaday, 2009). Just two wood species were identified from beams used in temples and palaces at Tikal, *Manilkara zapota* (L.) P. Royen (sapodilla) and *Haematoxylum campechianum* L. (logwood or inkwood). Admittedly, the beams and lintels identified from Late Classic elite structures at Tikal represent a larger scale of construction compared to that of a rural village like Cerén and required hardy, durable wood that could withstand tremendous strain and support the weight of large structures (Lentz and Hockaday, 2009:1348). When compared to the assemblage of arboreal species used as wooden posts at Payne's Creek (Robinson and McKillop, 2013), both archaeological sites exhibit a greater variety in construction material than Tikal. Two of the species identified at the salt production workshops at Chan B'i and Atz'aam Na (*Ficus* sp. and *Casearia* sp.) were also identified in the roof fall of Cerén's domiciles. Both of these studies show less pressure to overexploit and exhaust timber resources of certain species compared to large population centers such as Tikal. Rather, Cerén villagers likely practiced a low intensity management of their forests for their construction needs.

5.3. Agricultural fields

Beyond the immediate vicinity of the structures excavated thus far were extensive fields of maize and manioc. Flotation samples taken directly from these agricultural fields revealed that a great variety of plants were growing and thriving in the fields, not just the domesticates recovered as plaster casts (Slotten et al., 2020). Within the inter-ridges of the maize fields, the Cerén farmers were growing squash (*Cucurbita* sp.) and common beans, evidence that the farmers practiced inter-planting in order to collect an efficient and prosperous harvest. The Cerén farmers also allowed and possibly even encouraged the growth of wild and weedy plants within their maize fields, as evidenced by over a dozen weedy species growing in the maintained agricultural ridges; all of which have known uses nutritionally, medicinally, or for other purposes. The overwhelming amount of these wild and weedy seeds and achenes recovered from the agricultural fields may indicate the herbs or spices that the ancient villagers could have used to flavor their daily meals such as amaranth (*Amaranthus* sp.), paracress (*Spilanthes acmella* [L.]L.), purslane (*Portulaca oleracea* L.), *tomatillo* (*Physalis angulata* L.), rattlebox (*Crotalaria* cf. *sagittalis* L.), and various sedges.

While the composition of the maize agricultural fields, or milpas, preserved at Cerén is not the focus of this article, this context contained the greatest amount of woody species overall at the site (17 taxa, see Table 1). The wood charcoal could be the result of trees within such areas that were burned during the Loma Caldera eruption, or alternatively leftover fragments from fuel that were deposited in the agricultural fields as a soil amendment that can significantly increase plant growth and nutrition (Lehmann et al., 2002), as seen at other Mesoamerican sites (Morehart, 2010; Wyatt, 2012). Additionally, some of the wood charcoal fragments recovered within the fields were likely originally deposited in midden contexts which were recycled and incorporated into various features within the milpa such as the agricultural ridges and the earthen causeway that ran through the fields south from the village center (Slotten, 2015). Trash from households are typically full of organic residue and charred macroremains such as burnt seeds and wood, and therefore would be a convenient source of fertilizer (Miller and Gleason, 1994). Within Op. AI, wood charcoal from both jacaranda and amate were uncovered against the wall of a ceramic sherd within a surco in the milpa on the eastern side of the earthen sacbe. Additionally, numerous arboreal taxa were identified from wood charcoal from the interior of the causeway (*Cameraria latifolia* L., *Clusia* sp., *Ehretia tinifolia* L., *Ficus* sp. *Nectandra* sp., *Pinus* sp.) along with charred food remains (*Phaseolus* sp., beans, and *Z. mays* cupules and kernels).

Large carbonized wood fragments also were recovered during excavations of the maize fields (Slotten et al., 2020), indicating the presence of large branches, likely from trees that used to stand among the maize stalks. This shows that the Maya did not necessarily clear their land of all existing plants in order to grow their crops. We see at least two examples of large branches found within the agricultural fields, suggesting the presence of full trees close by: *Terminalia buceras* [L.] C. Wright, better known as the bullet tree and *Clusia* sp., or what is known as *matapalo* (or *chunup* in Maya) (Atran, 1999; Slotten et al., 2020). The charcoal from the bullet tree was located within Operation Y, located among the agricultural fields at Cerén. This particular operation had what the excavators identified as a possible boundary marker between two maize fields. This marker was an eroded *surco* that was not cultivated. This tree could have possibly separated a northern from a southern section of the agricultural fields or it is simply an extension of the riparian zone located along the Rio Sucio that borders eastern edge of the site. The matapalo branches were recovered from Op. AD, again an agricultural context, and it lies just east of where the tree branch fragments were found. The charred remains were recovered in a stratum of ash that would have been deposited after the Cerén inhabitants evacuated the village (Unit 4). Because of this we know that these charred remains are parts of a tree that remained standing until the very hot tephra composing Unit 4 fell. This species is known to have been used by Mesoamericans medicinally with the latex used to treat toothaches (Atran et al., 2004:100). The wood also has been used in construction or as fuel. In fact, we have evidence for the wood being utilized as fuel at Cerén village, where the charcoal fragments were present in midden deposits.

5.4. Environmental indicators

The wood charcoal fragments recovered from the site primarily through flotation samples reveal that an array of ecosystems was represented in the village's wood assemblage including tropical forests, wetlands, marshes, dry savannas, and mountainous areas (Fig. 5). Identification of these wooden resources demonstrates that the villagers traveled to and exploited multiple nearby ecosystems in order to gather their resources and that they had a diverse floral setting readily available for their needs. The residents did not rely solely on the gardens surrounding their homes or the maize and manioc fields surrounding the village for their resource needs. The entire landscape surrounding the village may have been visited, maintained, tended to frequently, and the villagers would have formed meaningful relationships with these spaces beyond functional or economic aspects.

The majority of the woody taxa recovered (70%) represent typical flora of tropical and subtropical moist forests or humid lowland forests. Such forests are characteristic of Central America and are typically comprised of thousands of species, which is why tropical moist forests have the highest level of species diversity among major terrestrial habitat types. Thus, the trees identified among archaeological samples at Cerén are just a hint of the composition of the Late Classic period forested landscape in the Zapotitán Valley. This charcoal assemblage largely represents wood resources that would have been collected and used as fuel by the local residents or resulted from prior cultural burns. Fire aids in the enhancement of soil fertility after intensive cycles of cultivation through the formation and addition of black carbon into the soil profile (Sombroek et al., 2003). Black carbon positively alters soil fertility by increasing phosphorus levels, cation exchange capacity, and provides surface area for microbial activity and the fixation of nutrients (Glaser et al., 2002). Studies that have been conducted at Cerén concluded the soil to be fertile in terms of the chemical and physical properties with a neutral pH within the agricultural fields and high levels of phosphorus, potassium, iron, and copper yet low concentrations of inorganic material (Egan and Halmbacher, 2013:117; Olson, 1983:56). The low-temperature burns would have produced an abundance of charred plant material, subsequently spreading charcoal throughout the field (Nigh, 2008).

5.4.1. Pioneer species

The trees and shrubs identified from the wood charcoal demonstrate a multifunctional and multistory floral setting, suggesting that at least some time had passed to create canopied spaces as well as understory. Six of the trees identified from the wood charcoal assemblage represent species that are typical of primary forests (*Ampelocera hottlei* (Standl.) Standl., *Astronium graveolens* Jacq., *C. odorata*, *Protium copal* (Schltdl. & Cham.) Engl., *Pterocarpus* sp., and *Spondias* sp.). In particular, *C. odorata*

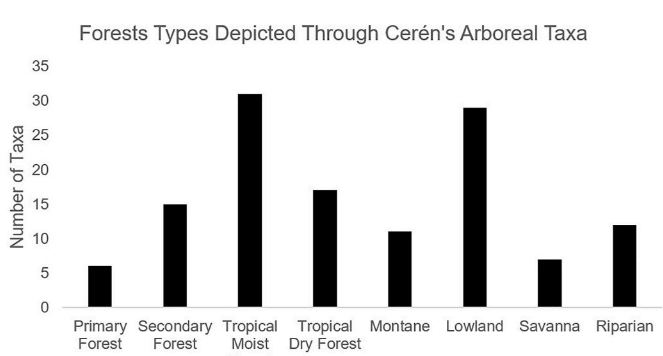

Fig. 5. An array of forested spaces are depicted through the arboreal taxa identified from paleoethnobotanical remains at Cerén. Individual species can grow in multiple types of forests and therefore may be present in more than one of the categories below.

has been documented among indigenous groups today to be extremely useful for forest system restoration (Diemont et al., 2011). In comparison, there are numerous species present in the assemblage that represent secondary forests (*Acnistus aborescens* (L.) Schltdl., *Allophylus* sp., *Casearia* sp., *Exostema caribaeum* (Jacq.) Schult., *Matayba* sp., *M. calabura*, *Nectandra* sp., *Platymiscium* sp., *P. guajava*, *Tabernaemontana* sp., and *Vitex guameri* Greenm.). It is not surprising to find so many pioneer species within the wood charcoal assemblage given the volcanic history of this setting. These species represent the trees and shrubs that would have been the first to colonize the Zapotitán Valley after it was buried by the eruption of Ilopango (Fig. 6), which occurred roughly a century before the Loma Caldera eruption that left the ancient Cerén village in the state that it is preserved today (Sheets, 2002). These early colonizers reestablished a forest system after a catastrophic volcanic disturbance and contributed to the landscape with crucial roles of maintaining soil fertility, increasing water retention, water percolation, biodiversity, ecosystem health and resiliency (Elevitch et al., 2018). Recent research on the Holocene vegetation history of El Salvador suggests that secondary vegetation types are the more characteristic formations of the region, due to the regularity of disturbances such as volcanic eruptions, earthquakes, mass movements, fires, hurricanes, tsunamis, and floods (Dull, 2001; Hecht et al., 2006). The woody vegetation present at the site reflects frequent environmental perturbation.

Plant growth within tropical moist forests is incredibly productive, wherein trees can grow several meters in height in the time span of just a few years. The majority of the wood charcoal specimens exhibit parallel rays when viewed by the transversal cross-section. This characteristic suggests that the wood gathered for fuel use was not especially young or from small branches; these trees had been able to grow considerably following the previous volcanic disturbance episode. This finding is surprising when the volcanic setting is considered. Since it had only been roughly one single century since a major disturbance to the landscape had occurred, it is unlikely that the forest had reached full maturity in terms of its proportion of animal-dispersed species, non-pioneer species, and understory species (Liebsch et al., 2008). This process requires about one to three hundred years, leaving the establishment of the Cerén village on the lower, younger end of that transformation. It is possible that some specimens were gathered from regions unaffected by the Loma Caldera eruption as well, thus explaining their relatively older age in terms of growth. The strong prevalence of the pioneer species in the wood assemblage intensifies this interpretation.

5.4.2. Riparian species

It is likely that the riparian species recovered in the wood charcoal assemblage were found along the meandering Rio Sucio that runs alongside the ancient village. Several tree species in the macrobotanical assemblage are known to thrive in wetland ecosystems such as swamps, marshes or along riverbanks, creeks, and streams (Fig. 7). This includes malady (*Aspidosperma* sp.,), hackberry (*Celtis* sp.), pava (*C. dentata),* logwood (*H. campechianum*), amate (*Ficus* sp.), guapinol (*Hymenaea courbaril* L.*)*, redwing (*Heteropterys* sp.), jacaranda (*Jacaranda* sp.), white copal (*Matayba* sp.), guava (*Psidium guajava*), bloodwood (*Pterocarpus* sp.), and black olive (*T. buceras*). These wood charcoal specimens could have originated from trees growing along the riverbank of the Rio Sucio, which was just meters away to the east from the Household 1 complex of the village, but of much lower elevation. These trees and shrubs are certainly not a complete depiction of the flora along the river, but they represent taxa which were deemed useful fuel resources by the villagers and could have been easily collected without arduous travel to other environments. Many of these trees produce edible fruits and spices, which could have contributed to the village diet. Logwood is a ubiquitous tree found at the site, but is interestingly not documented in either modern or historic forests of El Salvador (Carlson, 1948; Daugherty, 1969; Komar, 2003; Standley and Calderon, 1925). Since the 17th

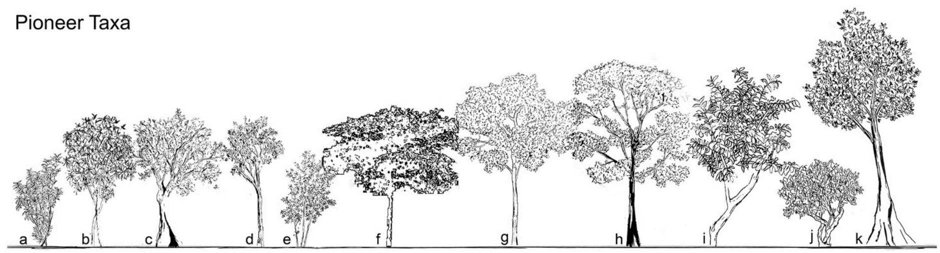

Fig. 6. Arboreal taxa recovered via wood charcoal remains that are indicative of pioneer species that are known to comprise regenerative forests. a) *Acnistus aborescens,* b) *Allophylus* sp., c) *Casearia* sp., d) *Exostema caribaeum*, e) *Matayba* sp., f) *Muntingia calabura*, g) *Nectandra* cf. *globosa*, h) *Platymiscium sp.*, i) *Psidium guajava* j) *Tabernaemontana* sp., k) *Vitex gaumeri.*

Fig. 7. Taxa recovered via wood charcoal remains that are riparian trees and shrubs known to grown along riverbanks, marshes, and in wetland areas. Scanning electron micrographs are of the transverse view of each specimen. a) *Aspidosperma* sp., b) *Celtis* sp., c) *Cupania dentata,* d) *Ficus* sp., e) *Haematoxylum campechianum,* f) *Heteropterys* sp., g) *Hymenaea courbaril*, h) *Jacaranda* sp., i) *Matayba* sp., j) *Psidium guajava*, k) *Pterocarpus* sp., l) *Terminalia buceras*.

century, logwood has been heavily exploited in parts of Mexico and Central America by Europeans as a source of purple or black dye for textiles and leather (McJunkin, 1991), so its absence today is likely a result of extensive deforestation throughout the region. Logwood grows abundantly in wetland areas and was highly valued by ancient Mesoamericans for its durable wood (Lentz and Hockaday, 2009). Redwing, gaupinol, and white copal are all commonly used for construction purposes by indigenous groups in the region (Atran et al., 2004; Balick et al., 2000; Robinson and McKillop, 2013), and so it can be imagined that these charcoal fragments were leftover pieces from such endeavors. The abundance of tree species that inhabit wetland environments in this charcoal assemblage further emphasizes the importance of waterways and wetland habitats to these agriculturalists and validates their decision to establish a settlement near the Rio Sucio.

5.4.3. Savanna species

Archaeobotanical remains from Cerén reveal that grasslands and savannas were common in the landscape that included arboreal elements as well as native grasses such as *Trachypogon plumosus* (Lentz et al., 1996b). Typically grasslands support few woody plants, yet several trees and shrubs that inhabit dry sandy areas or open savannas such as princewood (*E. caribaeum),* milkwood (*Tabernaemontana* sp.), café de monte (*Casearia* sp.), white poisonwood (*Cameraria latifolia* L.), nance (*B. crassifolia*), and granadillo (*Platymiscium* sp.) were identified

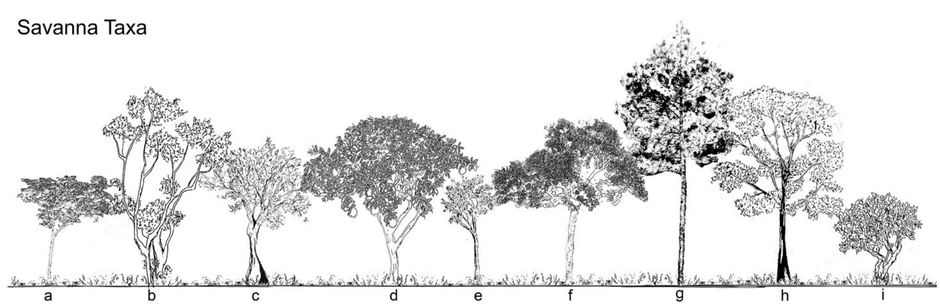

Fig. 8. Taxa recovered via wood charcoal remains that are common trees and shrubs in dry, savanna ecosystems. Scanning electron micrographs are of the transverse view of each specimen. All scale bars are 200 μm. a) Byrsonima crassifolia, b) *Cameraria latifolia,* c) *Casearia* sp., d) *Crescentia alata,* e) *Exostema caribaeum*, f) *Jacaranda* sp., g) *Pinus* sp., h) *Platymiscium* sp., i) *Tabernaemontana* sp.

in the assemblage that were likely collected for fuel resources (Fig. 8). Princewood, milkwood, and café de monte all have known medicinal applications from ethnographic studies elsewhere in Mesoamerica. Bark from princewood is used to treat malaria, snakebites, anemia, hemorrhoids, stomach aches, whereas milkwood is used to relieve inflammations and insect bites (Atran et al., 2004; Deciga-Campos, 2006). Café de monte is used as a source of construction material, medicine, and food (Balick et al., 2000) and has been identified from multiple areas of the Cerén site including agricultural ridges and within a ceramic vessel that contained roof-fall from the burning storehouse in Household 4 (Lentz et al., 1996a; Slotten, 2015).

It is interesting that species recovered via wood charcoal remains that depict a dry, grassland ecosystem do not dominate the assemblage because microbotanical evidence from the site provides an indication of the area having been a savanna (Dull, 2007; Sheets et al., 2012: 277). Seventy percent of the arboreal species at Cerén represent a tropical moist forest, whereas just forty percent can be found growing in tropical dry forests. Tropical dry forests are more representative of the climax vegetation of central El Salvador and highland areas on the western side of the country (Dull, 2004; Osting 1956:271), yet Cerén is located in a lowland setting between these montane zones. Wood charcoal remains provide an additional line of evidence to depict past ecosystems, since major tropical forest species are underrepresented in pollen and phytolith records (Bush and Rivera, 2001; Ford and Nigh, 2015). Savannas, dominated primarily by grasses, develop in warm, hot climates where the annual rainfall is concentrated in several months of the year, which is typical of Central America. Savannas can be climatic, edaphic where they are resulting from soil conditions, or derived where they are the result of people clearing forested biomes for cultivation purposes (Furley, 2010). The ancient agriculturalists who lived at the village of Cerén certainly cleared expansive spaces of the land to cultivate maize and manioc crops, and so it is possible that such cultural practices expanded some grassland space in the Zapotitán Valley. However, as noted earlier, these farmers took care to leave trees growing within their agricultural fields and did not completely clear their plots of existing vegetation prior to planting their staple crops. Additionally, New World savannas typically experience less than 650 mm of precipitation each year (Furley, 2010; Walter, 1973:71) but as stated earlier, Joya de Cerén has significantly more rainfall in a year (1700 mm) that would make it unlikely the surrounding ecosystems were dominated by grassland and savanna ecosystems. Two woody species that tend to dominate arid and semi-arid areas, *Prosopis* and *Acacia* (Fagg and Stewart 1994; Walter, 1973), are not present in Cerén's paleoethnobotanical remains, further suggesting that the village was not necessarily surrounded by a savanna. Instead, these Late Classic villagers converted their landscape to an anthropogenic agricultural zone that preserved forest remnants for their woodland resource needs.

5.4.4. Montane species

The village was situated in a lowland setting (Fig. 1) at just 450 masl and the trees and shrubs recovered from the site overwhelmingly reflected forested spaces in lowland areas (29 of the 44 identified taxa). However, a significant group of taxa identified at Cerén represent trees and shrubs that can be found growing in pre-montane and montane forests (*Allophylus* sp., *Aspidosperma* sp., *B. orellana*, *C. odorata*, *Clusia* sp., *Dalbergia* sp., *E. tinifolia*, *H. courabaril*, *Manilkara*, *Pinus* sp., and *Prunus brachybotrya* Zucc.) (Fig. 9).

Pine was the most ubiquitous wood specimens among the Cerén archaeobotanical remains (Fig. 10); it was present within 19.35% of the contexts where arboreal remains were recovered. Pine charcoal was recovered from a range of features including the floor and roof fall of domestic structures (Lentz et al., 1996a; Lentz and Ramírez-Sosa, 2002), within the midden deposit (Hood, 2012), within the surcos of the agricultural fields (Slotten, 2015), inside of and on top of the earthen causeway, within the drainage canals on either side of the causeway, as well as the cleared areas void of features. Several species of pine, especially *Pinus oocarpa* Schiede, grow in montane woodlands of El

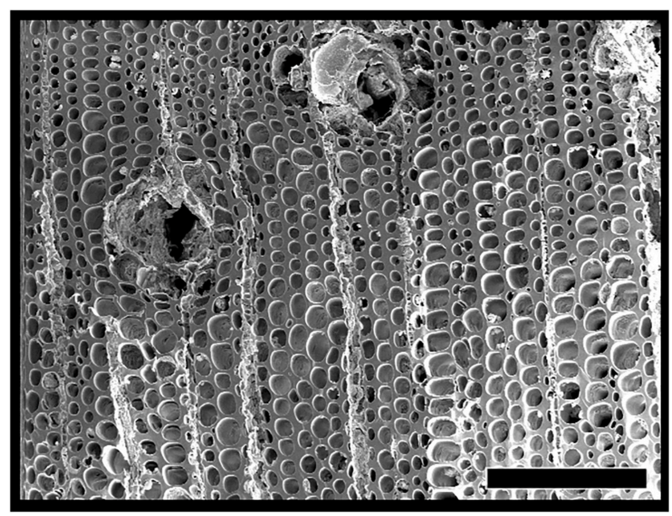

Fig. 10. Scanning electron micrograph of *Pinus* sp., the most ubiquitous woody taxa recovered at Cerén. Scale bar is 200 μm.

Fig. 9. Taxa recovered via wood charcoal remains common in mountainous areas. that are common trees and shrubs in dry, savanna ecosystems. Scanning electron micrographs are of the transverse view of each specimen. All scale bars are 200 μm. a) *Allophylus* sp., b) *Aspidosperma* sp., c) *Bixa orellana* d) *Cedrela odorata* e) *Clusia* sp., f) *Dalbergia* sp., g) *Ehretia tinifolia*, h) *Hymenaeae courabaril*, i) *Manilkara* sp., j) *Pinus* sp., k) *Prunus brachybotrya*.

Salvador, also referred to as montane forests or *tierra templada,* on the volcanic cones, e.g., Santa Ana, generally above 1500 m (Knapp, 1965; Greller, 2000). *P. oocarpa* can be found at a range of elevations (anywhere from 200 to 2500 masl), but primarily grows on well drained slopes above 1000 masl (Lentz et al., 1996a; Perry, 1991; Standley and Steyermark, 1946) making it unlikely that it was abundant near the village since the closest slopes of that elevation are greater than 10 km away. These montane forests around the Santa Ana complex likely would have been the source of the abundant pine resources obtained by the ancient occupants of Cerén. However, its strong presence as charcoal at the site suggests that there might have been pine trees growing within the village.

Pine was highly valued and used in religious ceremonies by the Late Classic Maya, likely because of the abundant smoke it produces which was deemed useful in invoking the gods. This connection between smoke and the deities was an important feature of Maya cosmology (Morehart et al., 2005). Because it was considered a valuable commodity, pine wood was a trade item that could be transported more easily when converted to charcoal (Lentz et al., 2005) and has been widely demonstrated as a resource that Mesoamericans traveled great distances to obtain (Miksicek, 1983, 1991; Morehart et al., 2005; Lentz et al., 2016). The ubiquity of pine charcoal at Cerén demonstrates that it was a significant resource for the residents and was a worthwhile resource even if it required long-distance transport. We don't know exactly how the pine remains arrived at the Cerén site, but it is clear that the occupants made extensive use of it. Many of the other montane taxa recovered at Cerén, such as *Clusia* sp., *Dalbergia,* and *Exostema*, are also denizens of the pine woodlands in El Salvador (Parker, 2008) whose charcoal is represented in the Cerén archaeological plant remains.

6. Conclusions

It is notable that the woody taxa identified in the main village that surrounded the domestic structures were primarily fruit-bearing trees that would have produced substantial food products to supplement the villager's diet beyond the staple crops growing in their agricultural fields. Undoubtedly these fruit trees provided shade that would have made life in this tropical village much more comfortable. Overall, only 15 of the 44 identified taxa (see Table 1) produce edible fruit or other plant parts that the ancient villagers may have collected. Those woody taxa identified as charcoal fragments throughout the other areas of the settlement (beyond the village center) have generally less food-related uses but rather more construction, fuel, or medicinal uses. By comparison, far more of the woody taxa (27 species) have known medicinal applications (e.g., Atran et al., 2004). However, whether or not the ancient villagers utilized these species for medicinal purposes is not evident given the contexts in which the material was recovered. This assemblage and distribution of archaeologically preserved arboreal taxa exemplifies the deliberate cultivation of fruit trees surrounding the households and a conscious effort to protect significant fruit trees that contribute towards their diet as a fuel resource. Although in the long run, once these trees stop producing fruit they would end up as fuel or structural material. Alternatively, the wood charcoal remains recovered from Cerén's agricultural fields could have resulted from prior cultural burns or possibly from an effort to amend the soil using hearth ash as practiced in other Maya communities. In terms of their total weight, the quantity of woody taxa that were utilized as fuel or structural material were not dominated by any particular species and exhibit a broad distribution of taxa. We hypothesize that forest resource management spared the removal of fruit trees, ensured their sustainability, and valued their presence. Arboreal elements at Cerén are intertwined with consumption practices, conceptualization of household garden plots, and daily life.

Descriptions of forest species for Prehispanic El Salvador (Daugherty, 1969; Dull, 2004) do not align well with the assemblage of trees and shrubs identified through macrobotanical remains at the Late Classic village of Cerén. Only two genera suggested by Daughtery (1969) were identified through charcoal remains (*Cedrela* and *Terminalia*), yet neither of these were very ubiquitous at Cerén. Dull (2004) describes the vegetation after the TBJ tephra horizon as dominated by pine, oak, and Urticales, yet focuses on a mountainous region to the west of the site. While oak was identified in the wood remains, pine was evident throughout the village. Urticales such as *Ampelocera*, *Ficus*, and *Celtis* were identified, with *Ficus* being the most prominent. Therefore, the wood charcoal remains do demonstrate that the Cerén villagers frequented the mountainous regions nearby. However, the charcoal assemblage does not indicate a strong dominance by any particular species. Whether it was for fuel, construction, or medicinal applications, Cerén villagers were venturing out into their surrounding ecosystems to support their everyday wood resource needs, including wetlands, savannas, and montane settings. All of the environments described herein were utilized by the Cerén residents; they clearly did not solely rely on the gardens surrounding their homes or the maize and manioc fields for their resource needs. The Cerén occupants traveled to various nearby ecosystems and perhaps managed them to sustain the variety of wood resources available.

Archaeobotanical research at Cerén shows that the villagers managed their landscape in such a way that integrated trees and forested spaces surrounding their homes with their agricultural fields, as the charcoal assemblage demonstrates. The Cerén village had only existed for a short time (3–4 generations) due to the previous eruption of the Ilopango volcano about a century prior, which dramatically impacted the flora and fauna in the entire region. The wood charcoal assemblage at Cerén suggests that the villagers were using land management strategies that took advantage of recently disturbed settings with recovering forests and fertile soil conditions. The Cerén residents took part in a resurgence of maize and manioc based horticultural activity onto this newly developed landscape (Dull, 2007). Moreover, they incorporated land management strategies that resulted in an array of landesque capital investments in the form of ridge and furrow agriculture and the distribution of woody taxa throughout their agricultural spaces. They effectively coped with an ever-changing landscape and opportunistically established their settlement in a biodiverse setting that had plentiful resources from a range of ecosystems available for their daily needs. These data demonstrate the usefulness of charcoal studies for palaeoecological reconstructions and stresses the importance of a systematic collection protocol for organic remains at archaeological sites.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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