Journal of Anthropological Archaeology 59 (2020) 101191

Contents lists available at ScienceDirect

Journal of Anthropological Archaeology

journal homepage: www.elsevier.com/locate/jaa

Landscape management and polyculture in the ancient gardens and fields at Joya de Cerén, El Salvador

Venicia Slotten[a,*], David Lentz[b], Payson Sheets[c]

[a] Department of Anthropology, University of California, Berkeley, Berkeley, CA 94720, USA
[b] Department of Biological Sciences, University of Cincinnati, Cincinnati, OH 45221, USA
[c] Department of Anthropology, University of Colorado, Boulder, 80309, USA

ARTICLE INFO

Keywords:
Household archaeology
Kitchen gardens
Agriculture
Milpas
Paleoethnobotany
Anthracology
Mesoamerica
El Salvador
Maya
Weedy plants

ABSTRACT

The Late Classic Maya village of Joya de Cerén's extraordinary preservation by the Loma Caldera eruption circa 660 CE allows for a unique opportunity to study ancient Mesoamerican landscape management and agricultural practices. Various fruit trees, annual and root crops, fiber producers and other useful plants were cultivated within the village center, creating productive house-lot gardens. Extensive agricultural outfields of maize, manioc, squash, common beans, and numerous weedy species also have been documented through intensive paleoethnobotanical recovery methods and demonstrate the practice of multi-cropped or polyculture farming during Prehispanic times. The assorted array of economically useful species reveals the diversity of foodstuffs readily accessible to the inhabitants on a daily basis that were not simply the annual crops planted within the outfields. The long history of paleoethnobotanical research at this exceptionally preserved site provides the opportunity to not only understand what plant species the ancient inhabitants of this village utilized in their daily lives but also how the villagers perceived, managed, and manipulated their landscape in order to ensure a diverse and nutritional diet.

1. Introduction

Joya de Cerén offers a unique and exciting opportunity to study the daily lives of Mesoamerican rural residents (commoners) and their household contexts during the Late Classic period in what is now El Salvador. The village was rapidly abandoned and experienced a sudden burial below several meters of fine volcanic ash and coarse cinders deposited from the eruption of Loma Caldera circa 592–660 CE (2 Std dev from AA105791, Slotten, 2015:72). This eruption was relatively small in that its ash deposits only covered a few square kilometers (Sheets, 2002: 15). The ancient village of Cerén was unlucky enough to be located only 600 m southeast of Loma Caldera, falling victim to several hours of tephra falls and lava bombs that buried the settlement. Along with the rapid burial from tephra deposits, thatch roofs of the domestic structures caught on fire, subsequently preserving much of the village even further. The conditions that resulted from this eruption led to exceptional archaeological preservation and allows for the recovery of earthen architecture as well as materials left in situ that related to daily activities such as intact ceramic vessels, finely crafted lithic tools, and organic material that was utilized in a wide range of ways. Such extraordinary preservation provides an opportunity to not only understand what plant species the ancient inhabitants of this village utilized in their daily lives, but also how the villagers perceived and managed their landscape (Farahani et al., 2017a).

The preservation from the rapid deposition of volcanic ash results in the archaeological visibility of flora that were either growing at the time of the eruption or were collected, stored, and utilized in some manner by the ancient inhabitants. Thus far, plant material has been recovered at this site in two main forms: carbonized macrobotanical remains and plaster casts taken when archaeologists encountered voids within the volcanic ash during excavations. Using paleoethnobotany as a methodological tool at Cerén reveals significant plant-human interactions of ancient Mesoamericans that add to other studies of less well-preserved domestic settings, where investigations have typically focused on architecture and artifacts (Robin, 2003), creating a stronger and more in-depth interpretation of ancient household life in ancient Mesoamerica.

The paleoethnobotanical collection efforts at Cerén have been highly productive, revealing foodstuffs within homes, kitchens, and storage facilities as well as exterior spaces such as small household garden plots, clusters of fruit trees surrounding each structure, and extensive infields and outfields of maize, manioc, and wild and weedy

* Corresponding author.
E-mail addresses: venicia_slotten@berkeley.edu (V. Slotten), david.lentz@uc.edu (D. Lentz), payson.sheets@colorado.edu (P. Sheets).

https://doi.org/10.1016/j.jaa.2020.101191
Received 29 September 2019; Received in revised form 18 May 2020

plant species. The assorted array of culturally and economically useful species reveals a detailed variety of foodstuffs readily accessible to the inhabitants on a daily basis that would have been incorporated into meals and contributed towards daily life as medicine, tools, construction material, fuel, and more. Typically, the recovery of ancient plant remains in Mesoamerica is challenging due to the generally poor preservation of organic materials in the tropical environment, with carbonization leading to the best preservation conditions (Miksicek, 1987:219). The long history of paleoethnobotanical research at Cerén (Hood, 2012; Lentz et al., 1996a; Lentz and Ramírez-Sosa, 2002; Slotten, 2015) allows for a deeper study of the social meanings behind Mesoamerican agriculture and home gardens with an intimate view of how these ancient people interacted with and viewed their environment in the past.

Joya de Cerén serves as a valuable case study in household archaeology because of the detail that can be obtained concerning prehispanic Mesoamerican residential and rural lifeways (Sheets, 2006). For example, the exceptional preservation establishes consistent characteristics and components of an average household in Mesoamerica. The structures at Cerén had an average of 70 ceramic vessels within them, many decorated with intricate painted designs and hieroglyphic depictions. Many of the structures held finely crafted obsidian blades tucked away within the thatch roofs, a safe and secure space for sharp and dangerous tools. The obsidian blades and fine ceramic in situ assemblages illustrate that these rural villagers were able to obtain materials necessary to complete daily tasks of life. Over all, the inhabitants of Cerén were doing quite well for themselves while occupying a rural segment of society. Households took care to surround themselves with many of their daily resource needs with thriving kitchen gardens and clusters of fruit trees. Recent paleoethnobotanical data from flotation samples collected from the agricultural infields (Slotten, 2015) reveal that these spaces not only supplied staple crops, but also an abundance of herbs and spices that could have flavored their meals and provided additional nutritional and medicinal benefits. Archaeological investigations at Cerén provide a unique perspective of household life in Mesoamerica and help archaeologists working in other areas to further imagine activities and behaviors in the past.

2. Environmental setting

The village of Joya de Cerén formed sometime after the eruption of Ilopango (c. 539 CE), a volcano located in the central area of El Salvador that would have created an uninhabitable environment for flora and fauna within 1000 km for perhaps a century (Sheets, 2002: 2). The ancient agriculturalists of Cerén were almost certainly pioneers onto this recently transformed landscape with its rich, fertile volcanic soils of the Zapotitán Valley that they chose to reside within, located in central El Salvador (Fig. 1). After weathering, ash deposited from volcanic eruptions is typically full of nutrients, so that eventually it can lay the foundation for vibrant ecosystems. A soil survey conducted in 1983 found that Cerén's soils were in fact quite fertile in terms of the chemical and physical properties (Olson, 1983:56). The average pH of the soil within Cerén's maize fields was neutral, with high levels of phosphorous, potassium, iron, and copper yet low concentrations of inorganic material (Egan and Halmbacher, 2013:117).

Cerén is situated at 450 masl in a tropical monsoon climate with an average annual temperature of 24 °C (75 °F) (Sheets, 2002). The area receives 1700 ± 300 mm of precipitation per year, with the vast majority of rain falls occurring between May and October. The village is conveniently situated along the Rio Sucio, which provides a nearby water source. The Rio Sucio was clearly significant to the village, since the domestic, religious, and political structures at the site are all oriented 30° east of north, aligning the built environment with the riverbank (Sheets, 2006). Even the agricultural ridges within the kitchen gardens of Household 1 and the milpas (cultivated fields) are oriented parallel to the Rio Sucio. Since water is sacred to the Maya, it is not surprising that the community was oriented to the water source. Such an orientation also facilitated water drainage within the fields which prevented soil erosion.

Reconstructions of the Zapotitán Valley before it was colonized by the Spanish suggest that the area was 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). Today, much of the original flora of El Salvador has been cleared for agriculture and urban development, making modern comparisons challenging. Through years of archaeological research at Cerén, we have a sense for what the landscape was like at the time of the eruption that buried this small agricultural settlement. Phytolith evidence shows that the Cerén landscape was dominated primarily by grasslands; some phytoliths representing maize and squash were also present (Sheets et al., 2012: 277). Much of this grassland may have been dominated by *Trachypogon spicatus* (L.F.) Kuntze, the material used as thatch roofing on the earthen structures (Lentz et al., 1996b).

Forest products used as construction materials or as fuel have been identified via the abundant charcoal remains recovered through paleoethnobotanical investigations at the site. These data indicate that the surrounding environment was comprised of multiple ecosystems, including tropical deciduous forests, wetlands, savanna, and second-growth forests (Hood, 2012; Slotten, 2015). The wood charcoal assemblage indicates that these villagers traveled to or traded with people who lived in various ecosystems nearby; they made use of the expansive and diverse floral setting available to them. This shows that the residents of Cerén did not solely rely on the gardens surrounding their homes or the maize and manioc fields surrounding the village for their resource needs. The small patches of plants cultivated immediately surrounding the Cerén structures are not the only gardens at Cerén. The entire landscape surrounding the village may have been considered their garden that they visited, maintained, tended frequently, and formed meaningful relationships with beyond functional or economic aspects.

3. Methodology

Paleoethnobotanical investigations at Joya de Cerén have incorporated a variety of methodologies since excavations began in 1978. Early work collected floral remains that were preserved in a variety of ways. Foodstuffs were directly preserved within storage vessels inside of household buildings. Tree parts were preserved through carbonization and recovered when encountered during excavations. Additionally, plaster impressions were taken of cultigens from visibly noticeable voids within the ash. Recovery efforts soon began to include the use of mechanized water flotation strategies (Apple Creek and SMAP water flotation systems) with soil samples of 1 to 2 L in volume collected systematically from cultural contexts (Hood, 2012; Lentz and Ramírez-Sosa, 2002; Slotten, 2015). This study incorporates plant materials recovered as plaster casts or carbonized macrobotanical materials from the village as well as 80 flotation samples (2 L each, 0.2 mm mesh lining in flotation tank) collected in 2013 from the maize agricultural fields and an earthen sacbe (operations AE-AK, and AN) (see Fig. 1). '*Sacbe*' is the Maya term for a causeway or road feature. *Carbonized* macrobotanical remains (such as seeds, fruits, rinds, leaves, and wood charcoal) were analyzed and identified with the aid of comparative reference collections at the University of Cincinnati Paleoethnobotany Laboratory. Identification and imaging of botanical remains were accomplished using low-powered stereomicroscopes (6-50x), a Keyence VHX 1000E digital microscope, and a Philips FEI XL-30 Environmental Scanning Electron Microscope.

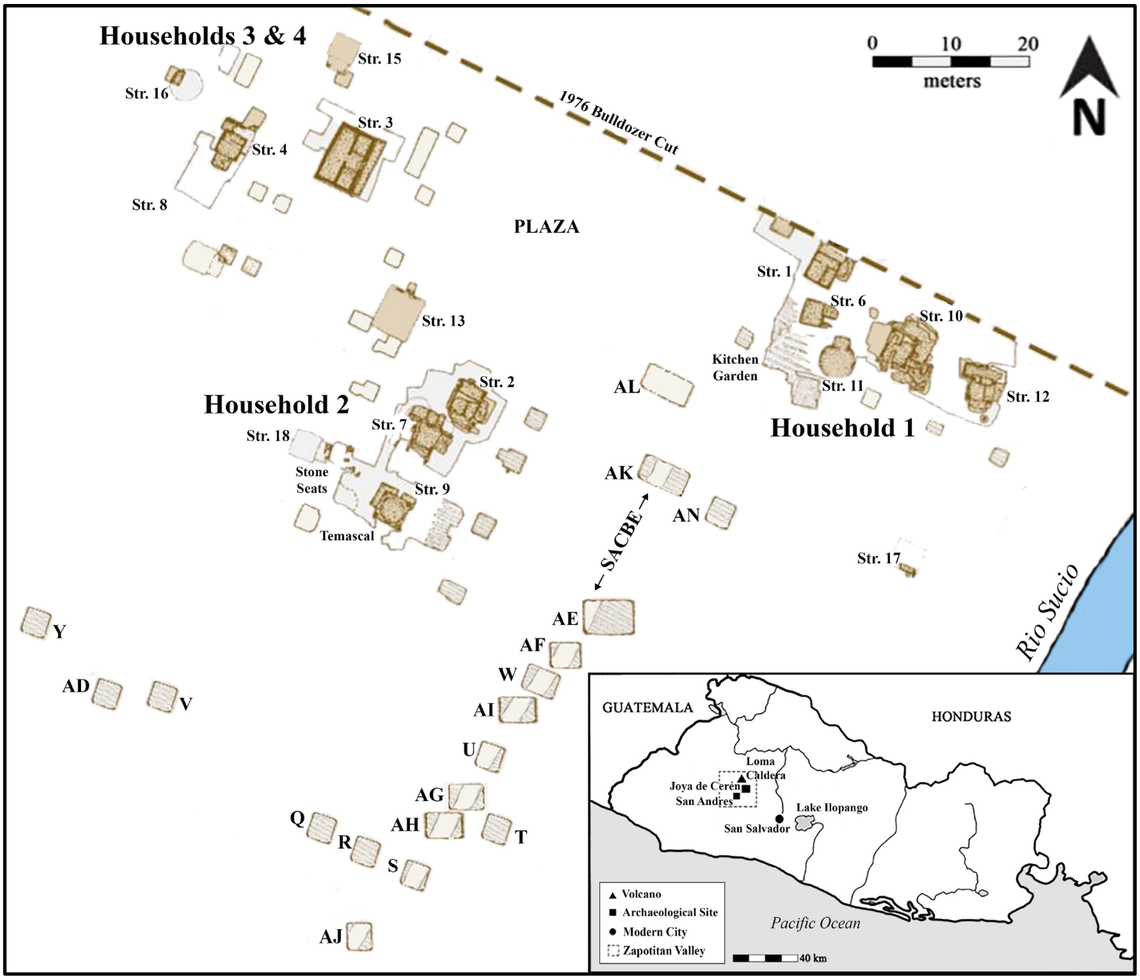

Fig. 1. Map of the Cerén village including excavations of the earthen sacbe and agricultural fields excavated in 2011 and 2013.

4. The managed landscape at Joya de Cerén

4.1. Household gardens

Within the immediate vicinity of the four separate households identified at the settlement are kitchen gardens adjacent to the structures containing various plants that were growing at the time of the volcanic eruption. These kitchen gardens provided a small amount of produce using a large diversity of plant species to supplement the staple crops growing in the larger fields (Sheets and Woodward, 2002). These plants provided food, medicine, tools, and other resources to the village as well as aiding in spiritual and cultural activities. Cerén's kitchen gardens demonstrate that these spaces were not just locations for decorative/shade plants, they reflect the traditional ecological knowledge of the village inhabitants and diversified their diet to go beyond the staple crops while also supporting other household needs (Berkes, Colding, and Folke, 2000).

There were numerous fruit trees surrounding the structures including avocado (*Persea americana* Mill.), guava (*Psidium guajava* L.), calabash (*Crescentia alata* Kunth), cacao (*Theobroma cacao* L.), and nance (*Byrsonima crassifolia* (L.) DC.) (Farahani et al., 2017a; Lentz and Ramírez-Sosa, 2002). Lamb (2011) argues that a house-lot garden should be considered a living and a social space as it can provide an area for social gatherings and other communal activities. This perspective can be envisioned within the ancient village at Cerén since the fruit trees surrounding the homes would have created desirable outdoor activity spaces in such a hot tropical climate by supplying shaded, comfortable areas, in addition to producing nutritious fruits for consumption. The distribution of these trees at Cerén demonstrate that the villagers included trees into their perception of household spaces, rather than limiting such a space to include just herbs and major cultigens.

Adjacent to Household 1 were rows of agricultural ridges with piñuela (*Bromelia balansae* Mez.), malanga (*Xanthosoma sagittifolium* (L.) Schott), and manioc (*Manihot esculenta* Crantz.) (Fig. 2) (Lentz and Ramírez-Sosa, 2002). Charcoal fragments from jocote (*Spondias* spp.) may be indicative of a tree between structures 1 and 6, whereas plaster casts document guava, calabash, and piñuela were growing just outside the kitchen (structure 11). Household 2 had patches of maize (*Zea mays* L.) milpa within just a few feet of the structures and had large concentrations of seeds and branches indicating nearby cacao, avocado, and calabash trees. The small milpa plots adjacent to the households were more carefully maintained compared to those farther away from any structure in that they exhibited more formalized ridges, suggesting that the aesthetic appearance of the homes gardens was of importance to the ancient inhabitants (Lamb 2011). The small maize plots were managed using a ridge and furrow technique with the soil being tilled between rows (Zier 1992). Household 4 was surrounded by a garden plot including rows of agave (*Agave* cf. *americana* L.), some chile plants, cacao and avocado trees, and a guava tree, producing an abundant assemblage of fruits. To the west of the structure manioc and piñuela plants were growing as well.

It is likely that additional plants were thriving within the house-lot gardens at Cerén besides what was encountered using plaster cast recovery methods and large carbonized branches, but water flotation collection strategies were not yet implemented at the time of these

Fig. 2. Household 1 with kitchen in foreground (structure 11), bodega in middle ground (structure 6), and the domicile in the distance (structure 1). Adjacent to the kitchen is the kitchen garden and to the left of the bodega is a maize field.

investigations. It is common for volunteer plants (plants that are not deliberately planted by a gardener) to develop surrounding home gardens that may be tolerated and cared for by residents. As discussed further below, the more extensive agricultural fields in this ancient village exhibited many plants that may have been volunteers in disturbed environments and were subsequently tolerated and perhaps even encouraged. Further excavations could confirm the same cultivation strategies within the house-lot gardens as well, revealing wild species that could contribute towards nutritional, medicinal, and ornamental needs of the village occupants.

These house-lot gardens were likely conceptualized and managed at the scale of the household, in comparison to the more expansive agricultural fields which could have been incorporated into larger state-level organization (Moran, 2016:10). Each house-lot garden space at Cerén is organized differently and composed of its own set of plant species, suggesting that each household managed such spaces. The agriculturalists at Cerén chose to surround their homes with a variety of important plant species so that their daily needs could be fulfilled by simply stepping outside of their doorway, as can be seen with the variety of food products noted above that encompassed the village center. The soil within these village gardens would have been easily fertilized and replenished through household refuse along with human and animal waste (Hutson et al., 2007:453). Additionally, the array of fruit trees could have provided shade for the house compounds and ample space for daily activities.

Rural commoners, such as those living at Cerén, could have enjoyed practices that were usually associated with the elite through their gardens by growing desired plants within their own land. For example, *Theobroma cacao* seeds, rinds, branches, and other plant parts were identified in areas surrounding both Households 2 and 4 and ceramic vessels were recovered that contained cacao residue. Cacao was a prized plant in Mesoamerica, with its value translating into both beverages and as a form of currency (McNeil, 2006). Cacao resources are typically associated with ceremonial activities, which are generally believed to have been practiced mainly by elite individuals (Morehart et al., 2005). Yet, Cerén demonstrates that rural households in Mesoamerica had access to valued and prized plant resources.

The above depictions of Cerén allows one to envision the small village as a comfortable place to reside. Privacy was not a priority in that walls or barriers were not created to block visibility of households and human activities within them. The visibility and openness of the Cerén household gardens is apparent through visual recreations of the settlement (Farahani et al., 2017a). This is not to say that the ancient inhabitants were open with all aspects of their lives. Sharp tools like obsidian blades were consistently stored up high in the thatch roofing, out of reach from children who could easily injure or cut themselves. Food that was stored within ceramic vessels was almost entirely found within structures and was neatly organized into various jars containing maize, manioc, beans, cotton, and squash (Farahani et al., 2017b), demonstrating that collected food items were hidden in that they were not readily visible to a passerby. The Cerén people certainly kept many of their belongings in specific locations so that they would not be visible to just anyone—but their gardens were evidently not hidden or demarcated with proprietary intentions.

Gleason (1994:2) defines gardens and fields as spaces that are cultivated and bounded. However, no evidence has been found for fences surrounding house gardens or even fields at Cerén. Clear boundaries between households were not necessarily marked with physical materials or through strategic placement of cultivated flora. The closest evidence for any physical boundaries are the rows of agave outside Household 4, but the spatial location of these suggest more of a garden patch, which provided a source of fiber rather than a natural fence.

Fencing is often utilized to keep animals out of cultivated spaces. Identified zooarchaeological remains recovered from the site suggest that the residents of Cerén did consume white-tailed deer (*Odocoileus virginianus*), domesticated dog (*Canis familiaris*), peccary (*Tayassu* sp.), and duck (Antidae). Household 1 exhibited the largest concentration of unmodified animal remains as well as obsidian blades which tested positive for nonhuman animal protein, suggesting that this household processed more meat that the others excavated thus far (Brown, 2002:154). All of these animals were certainly capable of disturbing cultivated spaces, yet this must not have been of great concern to the ancient residents since no regular barriers were put in place surrounding the gardens or fields.

Besides the fruit trees surrounding the homes, which would have concealed a bit of the space around each dwelling, the Cerénians did not bother to hide their wealth in terms of the foodstuffs growing in their immediate surroundings. Since the Cerén households were able to

Fig. 3. Operation AE with sacbe in foreground and milpa. All cultigens, including maize and squash, were preserved as hollow spaces, filled with dental plaster.

see other neighboring gardens and fields, this suggests something about the intimate relationships these inhabitants had with each other (Gleason, 1994). Large quantities of beneficial wild and domesticated plants encompassed their entire village, just waiting to be transformed into collected food, goods, and tools that could be stored to ensure a prosperous future, supporting a sense of regular landscape management. There has been no indication that the gardens within the village were blocked off, with access denied to neighboring households or even views blocked. If we view the household gardens as a form of wealth at Cerén, each household's potential was readily visible, and each villager would have had a basic knowledge of everyone's relative wealth in terms of plant goods.

This becomes more significant when we consider that each household likely had a surplus of certain plant products. For example, Household 4 had a courtyard garden consisting of rows of agave plants, whose fiber was transformed into rope and clothing material. It was probably well known among the inhabitants that this domestic unit provided the main fiber resources for the village (Sheets, 2000). Such important aspects of their livelihoods were not kept secret, with the knowledge of each households' belongings visible yet controlled with the use of storehouses. Each household at Cerén produced surplus goods that could be exchanged within the community and perhaps at nearby marketplaces. The kitchen gardens demonstrate that each household also produced their own basic commodities for the household's consumption, thus creating a dual role for the kitchen gardens as both subsistence and market production (Toledo et al., 2003).

Even if we consider the perspective that collected food was stored almost entirely inside the structures, away from the public eye, recent spatial distribution studies by Farahani et al. (2017b) show that food was stored throughout the village in domiciles, bodegas, and kitchens. Most structures contained ceramic vessels that would have been used to hold foodstuffs, so these materials were not necessarily hidden or private.

It is important to note that preservation is not perfect at Cerén, leaving much to be imagined by archaeologists. Granted, foodstuffs that were in ceramic vessels were preserved well when the thatch roofs collapsed during emplacement of Unit 3 tephra. However, foods stored in organic containers such as gourds and baskets did not preserve, and those containers themselves did not preserve except for the painted surface of a single gourd under the bench in Structure 2 (Beaubien, 2013). Gourds, for example, could have been good storage containers for manioc or malanga flour as it could be kept dry under the roofs. While the archaeological preservation only allows a glimpse of the most durable storage containers, it is still clear that subsistence and diet were not hidden aspects among the social lives of Cerén inhabitants; they were very prevalent in their day to day routine and view of neighboring households through the presence of productive garden plots.

4.2. Agricultural fields

Since 2007, excavations at Cerén have focused on the agricultural contexts south of the village, beyond the immediate vicinity of the structures excavated thus far and reveal extensive fields of staple crops that serve as an extension of the fields found adjacent to the household gardens. Infields of maize were situated close to the village. The maize, belonging to the Chapalote-Nal-Tel race, has been identified within the milpa through plaster casts of entire stalks, as well as carbonized kernels, cupules, and larger cob fragments (Lentz and Ramírez-Sosa, 2002). Farther south of the main village center, just past the maize agricultural fields were outfields of manioc. All of the agricultural fields were cultivated in a series of ridges oriented parallel to the ground slope to help with moisture removal and drainage, just as the kitchen gardens were within the village. The mean precipitation in the Cerén area is at the maximum ideal range for manioc, so drainage was necessary for productive manioc yields. Excavations of the extensive manioc fields strongly suggest that this root crop likely comprised a significant portion of the diet in this region during the Late Classic period, suggesting that this food regime could have been widespread throughout Mesoamerica (Sheets et al., 2011). The unique preservation of agricultural fields at Cerén allows us to view *both* maize and manioc as staple crops that greatly contributed towards the diet of these Late Classic inhabitants in Mesoamerica.

The inter-ridges of the maize fields—i.e. the smaller ridges that did not contain plaster casts of maize stalks—showed evidence of squash and common beans (Fig. 3). This conclusion was determined through paleoethnobotanical recovery efforts that utilized both plaster cast techniques and water flotation of soil samples. These inter-ridges were not as large as the maize ridges, but were nevertheless distinct ridges and were located in an alternating manner in between the larger maize ridges. A plaster cast of a squash gourd (*Cucurbita pepo* L.) was recovered in between the maize ridges in an inter-ridge within the milpa of Operation AE, along with multiple bean cotyledons that were identified from soil samples originating from other inter-ridges (Fig. 4). Multiple common bean (*Phaseolus vulgaris* L.) populations have been found throughout Cerén, appearing in storage containers, middens, and floor surfaces (Kaplan et al., 2015). Squash seeds and rinds have also been identified previously at the site, within ceramic vessels, a basket, and even atop a metate inside the kitchen structure (Lentz et al., 1996a:254).

For the first time the presence of both beans and squash is now verified within the milpas and shows that farmers at Cerén practiced inter-planting within their agricultural fields (Slotten, 2015). The eruption apparently occurred in August when maize was mature, yet common practices today in El Salvador suggest that squash and beans would not have been planted yet. The paleoethnobotanical remains propose that in the past these three annual plants were cultivated simultaneously at Cerén, especially considering that all three were recovered in a mature form. Inter-cropping maize, beans, and squash is advantageous in that it aids in an efficient and prosperous harvest; crop yields are prolonged into subsequent growing seasons, which is a common feature of many agricultural systems in the tropics. For example, the Kekchi Maya incorporate various plants in their milpas immediately after maize begins to sprout (Wilk, 1997:94). The leguminous beans would have replenished the soil with nitrogen that had been depleted from maize, while the maize created a sturdy structure for the *Phaseolus* to climb upon and be supported. The squash likely served as a cover crop, helping to retain soil moisture by reducing the total surface exposed to sunlight and also helping to prevent soil erosion. Squash residues incorporated into soil also aids in the prevention of seed germination for many weed species (Qasem and Issa, 2005). These ancient villagers were successfully maintaining an agroecological system that today we would describe as resilient and sustainable.

4.3. Wild and weedy species

Flotation samples taken directly and regularly from the interior of these agricultural ridges show that a great variety of plants were growing and thriving in the infields, not just the domesticates recovered and discussed above. These milpas are not just simple agricultural fields dominated by a single crop, they incorporate a variety of plants that could serve as food, medicine, and pesticides (Ford and Nigh, 2015; Sharer, 2009). The maize fields at Cerén had over a dozen weedy species growing in or around the well-maintained maize agricultural ridges, amounting to over 140,000 seeds and achenes (Fig. 5). The varied floral assemblage within the infields reflects the effort that the Cerén residents made to diversify their agricultural production, a continuation from what can be seen in the household gardens.

It was previously hypothesized that the Cerén residents had well-maintained agricultural fields, with few intrusive plants growing among the domesticated crops. The intensification of paleoethnobotanical recovery has made the overwhelming abundance of weedy species visible archaeologically. The majority of the weedy species recovered from the agricultural fields have seeds with an average width of less than a millimeter, which makes water flotation an essential collection strategy to broaden the understanding of this complex agricultural system.

Weeds are generally referred to as unwanted pests in agricultural fields (Hilje et al., 2003) and are defined as plants that grow predominantly in disturbed areas and are fast growing (Zimdahl, 1992). This view regards weeds as problematic due to the competition for nutrients and moisture from soil within a field that weeds take part in, often contributing to a decline in yields, soil fertility, and an increase in other pests such as insects (Cowgill, 1962). However, many ethnobotanical studies that report weeds as a problem dealt with invasive species introduced from the Old World post-conquest, which would not have been a concern at the ancient village of Cerén. If competition for resources between weeds and food crops were a major factor, this obstacle could have been eradicated through laborious weeding. While it is possible that the farmers worked to remove weedy plants, the overwhelming abundance of weedy seeds and achenes suggests that the weeding process was not intensive. Perhaps the households at Cerén did not have an abundance of labor to devote to weed removal, which would have been done through manual labor at this ancient village with

Fig. 4. Staple crops recovered from the milpas at Cerén include: (a) maize (*Zea mays* L.); (b) common beans (*Phaseolus vulgaris* L.); and (c) squash (*Cucurbita pepo* L.) (Sheets and Dixon 2013:96; Slotten 2015).

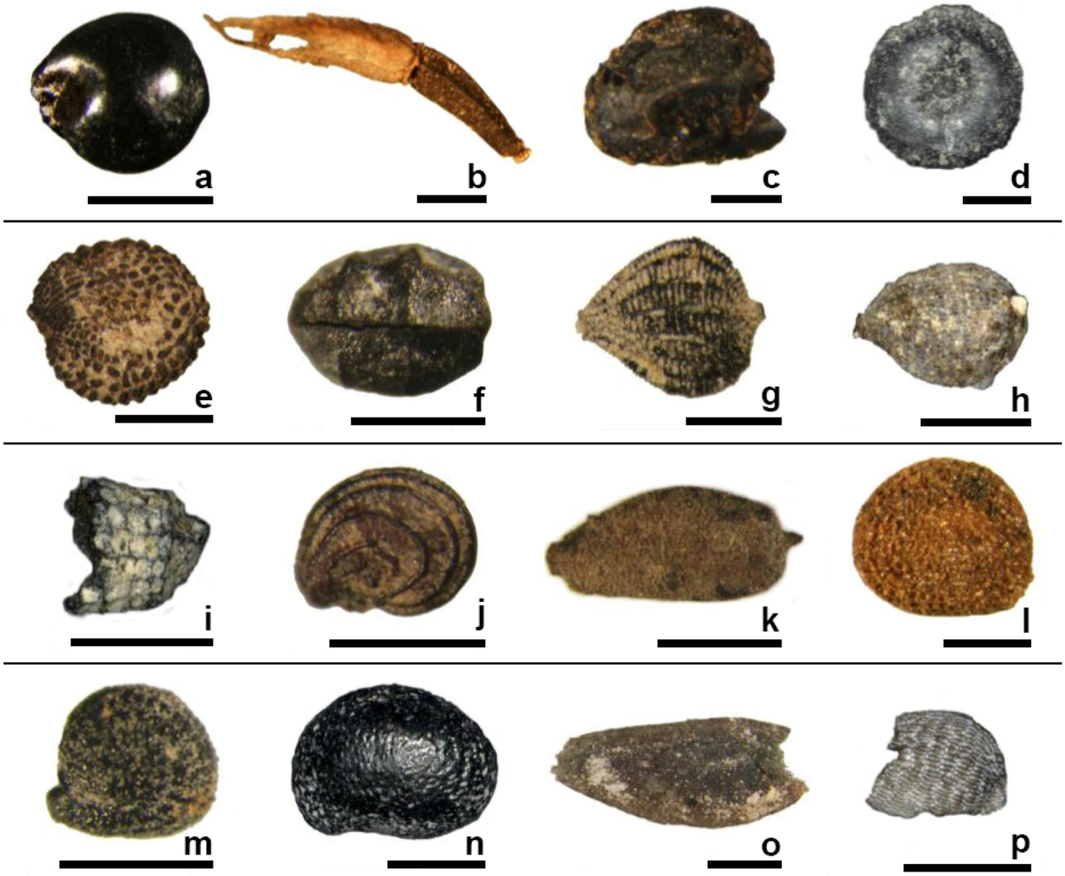

Fig. 5. Weedy seeds and achenes recovered from the milpas at Cerén: (a) *Amaranthus* sp.; (b) Asteraceae; (c) *Crotalaria* cf. *sagittalis* L.; (d) cf. *Cycloloma atriplicifolium*; (e) *Drymaria cordata* (L) Willd. Ex Schult.; (f) *Euphorbia graminea* Jacq.; (g) *Fimbristylis dichotoma* (L.) Vahl.; (h) *Fimbristylis* cf. *ferruginea* (L.) Vahl.; (i) cf. *Marina nutans* (Cav.) Barneby; (j) *Mollugo verticillata* L.; (k) *Panicum* sp.; (l) *Physalis angulata* L.; (m) *Portulaca oleracea* L.; (n) *Solanum* sp.; (o) *Spilanthes acmella* (L.) Murray; (p) cf. *Talinum fruticosum* (L.) Juss. All scale bars = 0.5 mm.

the use of stone and wooden tools which limit the ability to control the growth of unwanted plants (Sanders, 1973:333). Removing weeds from a field is a laborious task even with modern technology. Alternatively, the residents of Cerén may have been knowledgeable of the multitude of applications for these ‘weedy’ plants, especially as nutritious herbs, given their strong presence among other food crops. Jones and Halstead (1994) demonstrate this same concept with maslins (deliberate grain mixtures) in Europe, where minor contaminants such as wild herbaceous species are difficult to remove and also tend to be tolerated within agricultural fields.

When the life forms of the weedy species identified within Cerén milpas are taken into consideration, it becomes apparent that the majority of these weeds would have been manageable if desired. The majority of weedy seeds and achenes recovered from the maize agricultural fields at Cerén come from annual plants (Table 1), which would have been relatively easy to control by farmers. Annuals that only live for a single season and generally have more shallow root systems can be removed much more effectively than perennial weeds (Roumet et al., 2006). Annual weeds do grow much more rapidly than perennials (Garnier, 1992), but the deeper root system of perennials make them considerably more difficult to control. Perennial weeds have a minimal presence within the fields at Cerén, both in terms of quantity and ubiquity.

5. Were the wild and weedy species deliberately encouraged?

The utility and the abundance of the weedy species found within these agricultural fields raise speculations concerning whether or not these species were deliberately cultivated here or were tolerated. The dichotomy between wild and cultivated food plants does not have a clear distinction; many wild species are thought to actually fall along a continuum where various levels of intervention and human management take place during growth cycles (Bharucha and Pretty, 2010). Cerén farmers clearly managed the landscape in a manner that would have allowed for harvest from both agricultural and non-agricultural species simultaneously.

Ethnographic work in Mesoamerica has suggested that the main goal of agriculture for the Maya is to “use the land constantly and keep it covered, as far as possible, with useful plants” (Steggerda, 1941: 99). Farmers aim to design agricultural systems that yield the greatest return. Perhaps these ancient agriculturalists conceptualized weedy plants in a much different way than modern views on such plants. The Cerén farmers tolerated and possibly even encouraged the growth of wild and weedy species within their maize fields. All of the weedy species recovered from these fields have known uses nutritionally, medicinally, or for other purposes where they were incorporated into ceremonial activities or valued as a decoration (Table 1). *Amaranthus*, *Crotalaria*, and *Portulaca* are all significant contributors towards Mesoamerican diets today and are often intentionally integrated into milpa agroecosystems (Mapes et al., 1997; Messer, 1972).

Kekchi villagers in Belize only remove weeds if a particularly dangerous variety has encroached, such as those with thorns or spines (Wilk, 1997: 95). The Kekchi Maya do not view weeds as a threat to their crops and consider their constant removal to be futile. Weeds can be useful additions whether fertilizing the soil, increasing moisture, or serving as a foodstuff. In fact, milpa agricultural systems in

Table 1
Weedy species recovered from the milpas at Cerén, showing ubiquity, lifeform ([a] annual, [p] perennial), and known applications ethnographically (Atran et al. 2004; Balick et al. 2000; Lentz and Dickau 2005; Standley and Calderon 1925; Standley and Steyermark, 1946; Williams 1981). Ubiquity refers to the percentage of samples within which evidence for a species was present.

Taxon	Common Name	Ubiquity	Known Applications
Amaranthus sp.[a]	Amaranth	20.21%	Herb, medicinal applications, ceremonial uses
Crotalaria cf. *sagittalis* [a]	Rattlebox	12.77%	Food, beverage, fertilizer, medicinal applications
cf. *Cycloloma atriplicifolium* [a]	Winged pigweed	1.06%	Herb, food
Drymaria cordata [a]	Chickweed	1.06%	Herb, ornamental, medicinal applications
Euphorbia graminea [p]	Grassleaf spurge	3.19%	Ornamental, antibacterial
Fimbristylis spp. [a,p]	Forked fimbry	2.13%	Herb
cf. *Marina nutans* [p]	Prairie clover	2.13%	Dye, brooms/brushes
Mollugo verticillata [a]	Carpetweed	14.89%	Herb, poultice
Panicum sp. [p]	Grass	4.26%	Thatch, ornamental, fodder
Physalis angulata [p]	Tomatillo	2.13%	Herb, spice, poison, medicinal applications
Portulca oleracea [a]	Purslane	4.26%	Herb, medicinal applications
Solanum sp. [a]	Nighshade	1.06%	Food, medicinal applications
Spilanthes cf. *acmella* [a]	Paracress	89.60%	Herb, spice, anesthetic
cf. *Talinum fruticosum* [p]	Waterleaf	1.06%	Herb, ornamental

Mesoamerica commonly incorporate weedy species that are considered nutritious and edible, what is called *quelites* (Bandiera et al., 2002; Bye, 1981).

Ethnobotanical records show that the majority of species procured for medicinal purposes are collected from disturbed habitats, such as agricultural fields, where weeds are predominant (Alcorn, 1984; Frei et al., 2000; Stepp and Moerman, 2001). Nine of the wild and weedy species within the Cerén fields have known medicinal applications to present day Mesoamerican groups (Table 1). Eleven of them are edible and are incorporated into meals as herbs. Amaranth was the second most ubiquitous herb within the fields, occurring in all operations excavated except for Op. AN, and is an important edible green and grain throughout Mesoamerica (Table 1, Fig. 7) (Espitia-Rangel et al., 2010; Mapes et al., 1997; Sauer 1967). The overwhelming amount of *Spilanthes acmella* achenes recovered could have been used as an herb or spice to flavor daily meals. The *S. acmella* achenes were so abundant that their distribution within agricultural contexts can reveal how the herb is significantly more prevalent within the fields closest to the households (Fig. 6), suggesting that the farmers encouraged its growth. This follows Killion's (1992) assessment that mono-cropped agricultural fields may have been farther from domestic structures, whereas multi-cropped or polyculture fields would have been located closer to where people lived.

Alternatively, farmers may be more tolerant of weeds during the final stage of a cultivation cycle, as the maize crop is ready to be harvested (Ford and Nigh 2010). Many of the maize stalks recovered here via plaster casts were bent over so that they can dry within the fields (Sheets, 2006), as if the agriculturalists were just about to collect that season's harvest. The bent stalks prevent moisture from entering the fruits since water can no longer be taken up through the stem and rain can no longer enter the cobs as easily either.

The apparent abundance of wild and weedy species within Cerén's milpas provides further evidence that these fields were at the end of their growing season and perhaps the weedy herbs were simply not an issue that required manual removal. Many milpa agroecosystems burn the entire field in order to prepare the landscape for the next planting cycle, thus managing any weed populations that had become overgrown. Relatedly, it has been documented that the Lakandon Maya take ashes from piles of collected weeds and leftover crop residue and spread them throughout their fields to provide organic matter as a fertilizer (Ford and Nigh, 2010: 186). Since the soil samples collected for flotation in this study were taken from the interior of the agricultural ridges, it is unlikely that these herbs were only present from burned organic matter spread throughout the area. If this was the case, the distribution of the weedy species would be more irregular, rather than the pattern of weedy seeds being more prevalent in fields closer to the village structures (Fig. 6). It is more probable that their existence in the flotation samples is due to their growth within the fields. These weeds' strong presence in the fields suggests that they could have held a positive relationship with the villagers and were part of a complex agricultural system; at the very least the weedy species were tolerated within the fields.

5.1. Management of the agricultural fields

Recent excavations at the site encountered a roadway feature, a sacbe, leading south out of the village, likely beginning near the village plaza (Fig. 1). '*Sacbe*' is the Maya term for a white road; *sacbeob* (the plural) were typically constructed using a white material such as plaster. In the case of Cerén, the causeway was covered with a layer of

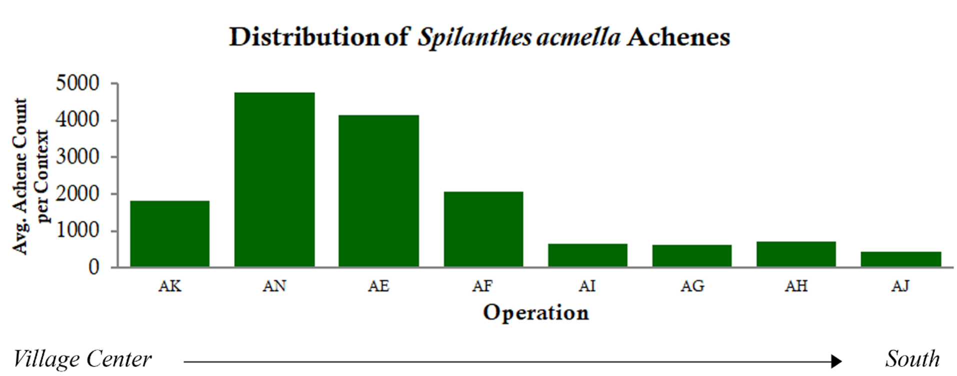

Fig. 6. Distribution of *Spilanthes acmella* achenes across the milpas excavated at Cerén during the 2013 field season. Operation AK was closest to the village center, whereas Operation AJ is located farther south and more distant from the village.

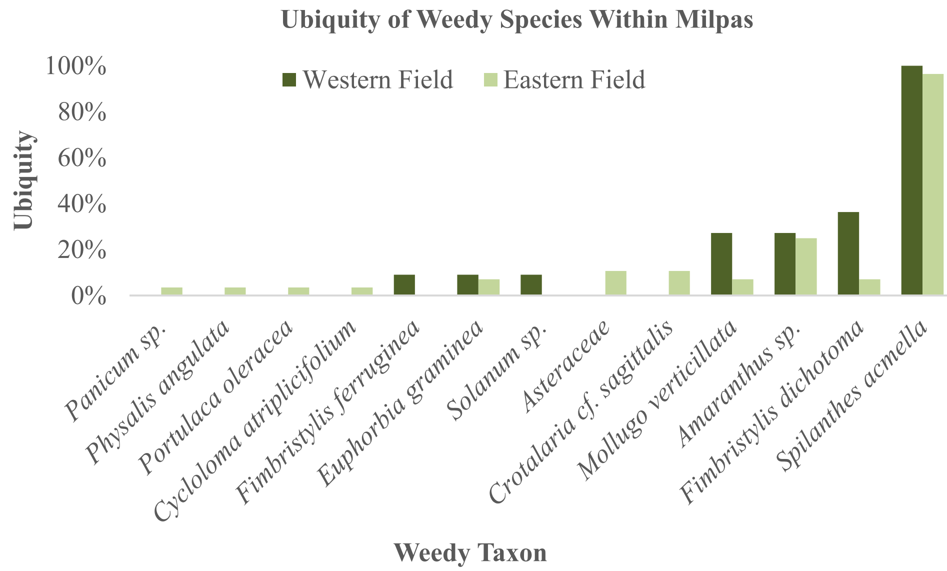

Fig. 7. Comparison of the presence of weedy species between the maize agricultural fields located to the west and east of the earthen sacbe that led south out of Cerén.

Tierra Blanca Joven, a white volcanic ash derived from Ilopango, and was about 2 m in width and elevated an average of 20 cm above the ground surface (Sheets and Dixon 2013: 19). The earthen sacbe found traveling through the maize agricultural fields could be interpreted as a boundary marker between agricultural plots. During the 2013 excavations, more than one maize field was often present within each operation, separated by the causeway (Fig. 1).

When the paleoethnobotanical remains recovered from the agricultural fields on either side of the causeway are compared, management practices differ between the western and eastern milpas. The western fields reveal a larger percentage of weedy species per sample than the eastern fields (Fig. 7). Yet, the eastern fields exhibit a more diverse assemblage of weedy species compared to the western fields. This distinction could indicate varying levels of attention to weed removal in terms of time and intensity. This variation suggests that different individuals or households practiced varying agricultural management strategies, perhaps even distinct timings for planting, and that the earthen sacbe served as a boundary marker within the fields.

Perhaps the varying presence of weedy species between the eastern and western fields is also indicative of varying perceptions of what a "weed" is to the different farmers tending these fields. Since the western fields exhibits a more limited set of weedy species, the agriculturalists tending this space may have had a more limited set of weedy species that they considered to be of value. The weedy species in the western fields are more limited to those that would have been used as nutritional herbs and foodstuffs, whereas the eastern fields' more diverse weed assemblage includes more species that have known medicinal applications. Sheets and Dixon (2013:5) characterize this milpa area as the intermediate agricultural zone at Cerén, which exhibits irregular fallowed areas and a great variability in cultivation strategies. Each household likely devoted varying amounts of time toward gardening and management of their fields, with weed removal taking place secondary to other tasks, if at all.

The distribution of the most abundant herbaceous species in the assemblage, *S. acmella* (Fig. 6), across the maize agricultural fields reveals a lower abundance of these achenes within the fields closer to the village center. Around roughly 40 m south of the village plaza (beginning with Op. AI), the maize agricultural fields begin to exhibit significantly lower counts of herbaceous species within the flotation samples. The species is still quite prevalent in this area, but only amounts to at most half of the quantity of achenes recovered from field contexts closest to the main village. This stark contrast could be indicative of a possible boundary within the milpa where different farmers were responsible for managing the fields to the north and south of Op. AI. Perhaps the farmer who managed the milpa closest to the plaza was more tolerant of wild and weedy plants compared to the one who managed the area farther away from the village.

Variation in management of agricultural fields is also visible within the manioc fields south of the village. While the composition of the manioc beds differs greatly from both the home gardens and the milpas in that it was apparently monocultural, each manioc field was managed by individual cultivators and families, as evidenced by land use lines encountered in 2009 excavations (Sheets et al. 2012). The land use lines were also aligned 30° east of north, just as the structures and milpas were. The community shares this dominant organizational scheme related to the importance of water coming from the river. Land was still subdivided into distinct plots with clear access by individual cultivators and households.

5.2. Arboreal remains

Also found within the agricultural field excavations were quite large carbonized wood fragments from fallen branches in the middle of the maize fields, identified through anthracological analysis. The ancient Maya did not necessarily clear their land of all existing plants in order to grow their crops (Ford and Nigh 2015), so the practice of leaving some trees still standing in the middle of the fields should not be a surprise. We see at least two examples of large branches found within the agricultural fields, *Castilla elastica* Cerv., better known as the rubber tree (or *k'ikche* in Maya) and *Clusia* sp., or what is known as matapalo (or *chunup* in Maya) (Atran 1999). These branches suggest that forest taxa were not completely eradicated in ancient Mesoamerican agricultural systems.

C. elastica is mostly known for its use in creating rubber, which is accomplished when its latex is mixed with juice from morning glory *(Ipomoea alba)*, but medicinal applications are also known such as using the leaves as a poultice on arthritic joints and sore kidneys (Atran et al. 2004:116). The wood charcoal from the rubber tree was located within Operation Y (Fig. 8), located among the agricultural fields at Cerén and adjacent to a possible boundary marker between two maize fields. This marker was an eroded furrow (*surco)* that was not cultivated. Small eroded furrows throughout the milpas suggest a delineation of farming duties between the various households. This eroded surco could have possibly separated a northern from a southern section of the maize

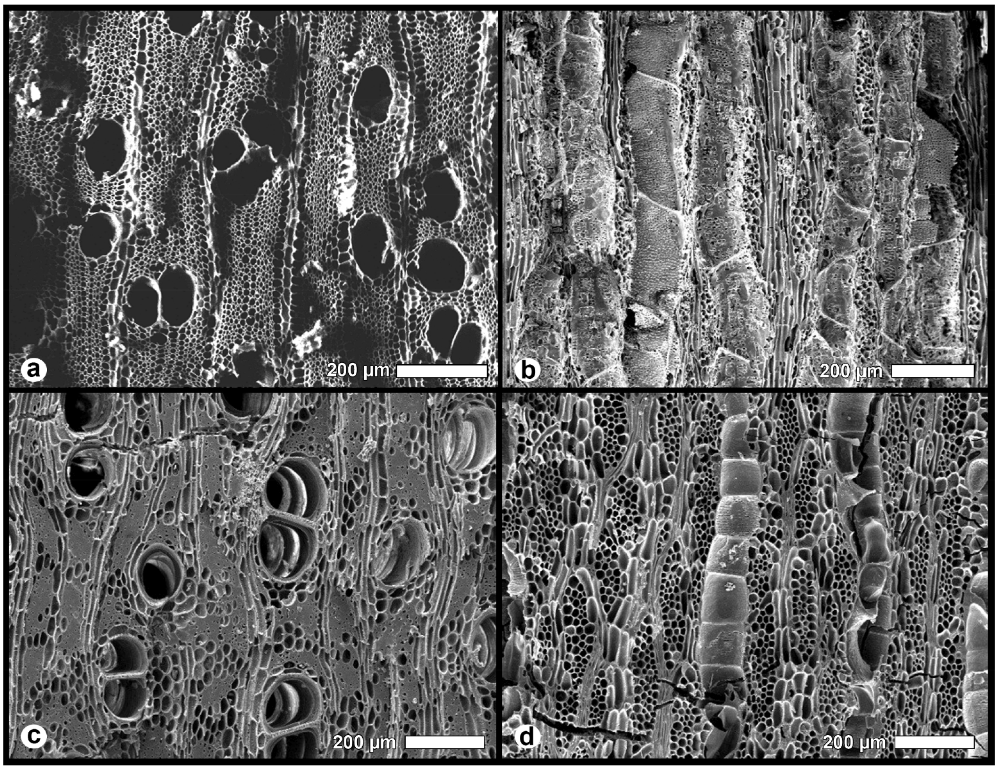

Fig. 8. Scanning electron micrographs of carbonized branches recovered within the Cerén milpas taken at 100x magnification. *Clusia* sp. (a) transverse view and (b) tangential view. *Castilla elastica* Cerv. (c) transverse view and (d) tangential view.

agricultural field. Since large quantities of *Castilla elastica* charcoal were recovered from this location, it is possible that the tree once stood near this location and could have also served as a boundary marker.

The matapalo branches were recovered from Operation AD, again an agricultural context, and it lies just east of where the rubber 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 part of a tree that remained standing until the very hot tephra [composing Unit 4] landed, with larger particles hotter than 575 °C (Sheets and Dixon, 2011). This species is known to have been used by Mesoamericans medicinally with the latex used to treat toothaches (Atran et al. 2004:100) and the wood also has been used for construction and as a fuel source.

The relationship between maize agricultural fields (milpas) and forest systems is critical. Forest ecosystems attract many pollinators, so incorporating them within close proximity to agriculture, perhaps on the margins, can be extremely beneficial. Additionally, the accumulation of plant litter on forest floors can serve as fertilizer for agricultural systems and tree root systems can help prevent erosion (Brubacher, Arnason, and Lambert 1989). Ethnographic work in the Sierra Tarahumara shows that over seventy percent of food resources for communities in that region comes from forest ecosystems (Bye 2019), so their incorporation into agricultural systems makes sense. Therefore, the indication of trees cultivated within the milpas at Cerén suggests that the ancient farmers valued the contributions of forest ecosystems within agriculture. Cerén's agricultural fields were dynamic and incorporated a variety of species that were likely encouraged to grow and utilized for a variety of reasons, not just for food. It is possible that trees served as landmarks to differentiate land ownership and serve as a division between field plots.

6. Conclusions

The extraordinary preservation in and around Cerén showcases direct archaeological evidence of various agricultural management practices that were likely widespread throughout Mesoamerica. The gardens adjacent to the domestic structures contained a variety of useful plants and were under careful and constant attention from residents, leading to well-maintained plots with strategically constructed activity spaces for daily tasks and social gatherings. Household members would have spent a large portion of their time in these spaces; the spatial arrangement and composition of the gardens reflect the great deal of care given towards them. Infield milpa plots at a short distance from the homes echo this practice, yet with less defined agricultural ridges and abundant weed growth. Nevertheless, these plots were still quite productive and incorporated a variety of edible herbaceous species. Both the garden plots and the maize fields exhibit polyculture farming practices that reveal the Cerén residents' efforts to intensify and diversify their agriculture.

Many indigenous groups within the Neotropics tend to practice poly-agricultural strategies which incorporate not just domesticated plants, but also semi-domesticated and tolerated species (Toledo et al. 2003). Milpa plots can often include trees, shrubs, herbs, and vines in addition to maize and manioc, creating a biologically and culturally diverse agroecosystem that benefits from multiple resources rather than a single crop (Altieri, 2004; Chappell et al., 2013; Medellin, 1988; McClung de Tapia and Acosta-Ochoa 2018; Nations and Nigh, 1980). The practice of intercropping additional species within milpas has been the foundation of food security in much of Latin America's rural communities for thousands of years (Altieri et al., 2012), and Cerén's unique preservation provides direct evidence for this type of agricultural strategy that is typically invisible archaeologically.

The paleoethnobotanical assemblage throughout the archaeological site demonstrates that individual households and farmers were able to manage their space in varied ways. The farmers tending to the milpa plots to the east and west of the earthen causeway practiced different strategies regarding weed management. The eastern fields contained a more diverse assemblage of wild and weedy plant species whereas the western fields revealed a significantly larger percentage of weedy species per flotation sample. These differences suggest varying perceptions among the ancient agriculturalists concerning what wild species are valuable and what intensity of weed removal efforts would have been appropriate within their fields.

Paleoethnobotanical studies at such a remarkably well-preserved site have shown just how diverse an ancient Maya farmer's diet could have been with the use of home gardens, polycultural milpas, and nearby forest ecosystems. Farmers inhabiting the Late Classic Zapotitán Valley took advantage of the fertile landscape and manipulated the land to benefit their way of life. Paleoethnobotanical investigations at Cerén demonstrate just how broad and diverse the plant assemblage would have been in the daily routines of villagers. Because the agricultural fields were preserved archaeologically, we get a rare, direct view of production, and therefore consumption patterns without having to analyze stomach contents, coprolites, or skeletal remains. Our detailed view of the gardens and fields at this village reveals a diverse and nutritious diet. Biodiversity supports multiple ecosystem functions and ensures greater environmental and social resilience. Research has shown that a biodiverse system including wild foods can also enhance a diet (Dufour et al., 2014; Frison et al., 2011; Powell et al., 2015), even if the foods include something a more high-ranking individual may eschew such as wild or weedy species. The Cerén residents had a variety of food resources incorporated into their diet and were not limited in terms of access to their thriving and bountiful environment. The gardens surrounding their domiciles would have increased their access to fruits and vegetables, whereas the agricultural fields supplied a secure source of staple crops as well as flavorful herbs and spices. Therefore, they likely lived quite a comfortable life both economically and socially where individual households had control over the composition, arrangement, and management of their own household gardens and agricultural fields. The ancient inhabitants of Cerén actively exploited their fertile, volcanic landscape and were knowledgeable of its available resources.

Acknowledgements

Deepest gratitude for the help of our research colleagues at Cerén, including Christine Dixon, Rachel Egan, Alexandria Halmbacher, Rocio Herrera, Nancy Gonlin, Mercedes Haydeé Ramírez de Garcia, and Julio Eleazar Garcia. Special thanks to thesis committee members Vernon Scarborough and Sarah Jackson, and to Christine Hastorf and Andrés G. Mejía Ramón for comments on earlier drafts of this paper. Imaging of macrobotanical and anthracological remains were taken at the Chemical Sensors and Biosensors Facility in the Department of Chemistry and the Advanced Materials Characterization Center at The University of Cincinnati.

Funding

This work was supported by the US National Science Foundation [Grant # 1250629, 2013] and the Charles Phelps Taft Research Center at the University of Cincinnati.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaa.2020.101191.

References

Alcorn, J.B., 1984. Huastec Mayan Ethnobotany. University of Texas Press, Austin.

Altieri, M.A., 2004. Linking ecologists and traditional farmers in the search for sustainable agriculture. Front. Ecol. Environ. 2, 35–42.

Altieri, M.A., Funes-Monzote, F.R., Petersen, P., 2012. Agroecologically efficient agricultural systems for smallholder farmers: contributions to food sovereignty. Agron. Sustain. Dev. 32, 1–13.

Atran, S., 1999. Classification of Useful Plants by the Northern Petén Maya (Itzaj). In: White, C. (Ed.), Reconstructing Ancient Maya Diet. University of Utah Press, Salt Lake City, pp. 19-60.

Atran, S., Lois, X., Ek, E.U., 2004. Plants of the Petén Itza Maya: Plantas de Los Maya Itza' del Petén. In Memoirs of the Museum of Anthropology No. 38. University of Michigan, Ann Arbor.

Balick, M.J., Nee, M.H., Atha, D.E., 2000. Checklist of the Vascular Plants of Belize with Common Names and Uses. New York Botanical Garden Press, Bronx.

Bandiera, F.P., Blanco, J.L., Toledo, V.M., 2002. Tzotzil Maya ethnoecology: landscape perception and management as a basis for coffee agroforest design. J. Ethnobiol. 22, 247–272.

Beaubien, H., 2013. From Codex to Colabash: Recovery of a Painted Organic Artifact from the Archaeological Site of Ceren, El Salvador. J. Am. Inst. Conserv. 32, 153–164.

Berkes, F., Colding, J., Folke, C., 2000. Rediscovery of traditional ecological knowledge as adaptive management. Ecol. Appl. 10, 1251–1262.

Bharucha, Z., Pretty, J., 2010. The roles and values of wild foods in agricultural systems. Philos. Trans. Roy. Soc. B: Biol. Sci. 365, 2913–2926.

Brown, L., 2002. Household and community animal use at Cerén. In: Sheets, P. (Ed.), Before the Volcano Erupted: The Ancient Cerén Village in Central America. University of Texas Press, Austin, pp. 151–158.

Brubacher, D., Arnason, J.T., Lambert, J., 1989. Woody species and nutrient accumulation during the fallow period of milpa farming in Belize, CA. Plant Soil 114, 165–172.

Bye, R., 1981. Quelites: ethnoecology of edible greens, past, present, and future. J. Ethnobiol. 1, 109–123.

Bye, R., 2019. Forest Management in the Sierra Tarahumara. 60th Annual Meeting of the Society for Economic Botany, June 2-6, 2019, Cincinnati Ohio.

Chappell, M.J., Wittman, H., Bacon, C.M., Ferguson, B.G., Barrios, L.G., Barrios, R.G., 2013. Food sovereignty: an alternative paradigm for poverty reduction and biodiversity conservation in Latin America. F1000 Research 2, 235.

Cowgill, U.M., 1962. An Agricultural Study of the Southern Maya Lowlands. Am. Anthropol. 64, 273–286.

Daugherty, H., 1969. Man induced ecologic change in El Salvador. Ph.D. dissertation, University of California, Los Angeles. University Microfilms, Ann Arbor, MI.

Dufour, C., Kauffmann, D., Marsland, N., 2014. Strengthening the links between resilience and nutrition: A proposed approach (Vol.18): International Food Policy Research Institute.

Egan, R., Halmbacher, A., 2013. The Fertility of Cerén: Analyzing the Ancient Soils. In Sheets, P., Dixon, C. (Eds.), The Sacbe and Agricultural Fields at Joya de Cerén, El Salvador: Report of the 2013 Research. Electronic document, http://www.colorado.edu/anthropology/people/bios/documents/2013CerénResearchReport.pdf.

Espitia-Rangel, E., Mapes-Sanchez, E.C., Nunez-Colin, C.A., Escobedo-Lopez, D., 2010. Geographical distribution of cultivated species of Amaranthus and their wild relatives in Mexico. Revista Mexicana de Ciencias Agricolas 1, 427–437.

Farahani, A., Chiou, K.L., Harkey, A., Hastorf, C.A., Lentz, D.L., Sheets, P., 2017a. Identifying 'plantscapes' at the Classic Maya village of Joya de Cerén, El Salvador. Antiquity 91, 980–997.

Farahani, A., Chiou, K.L., Cuthrell, R.Q., Harkey, A., Morell-Hart, S., Hastorf, C.A., Sheets, P., 2017b. Exploring Culinary Practices Through GIS Modeling at Joya de Cerén, El Salvador. In: Sayre, M.P., and Bruno, M.C. (Eds.), Social Perspectives on Ancient Lives from Paleoethnobotanical Data. Springer International Publishing. DOI 10.1007/978-3-319-52849-6_5.

Ford, A., Nigh, R., 2010. The Milpa Cycle and the Making of the Maya Forest Garden. Res. Rep. Belizean Archaeol. 7, 183–190.

Ford, A., Nigh, R., 2015. The Maya Forest Garden: Eight Millenia of Sustainable Cultivation of the Tropical Woodlands. Left Coast Press, Walnut Creek.

Frei, B., Sticher, O., Heinrich, M., 2000. Zapotec and Mixe use of tropical habitats for securing medicinal plants in Mexico. Econ. Bot. 54, 73–81.

Frison, E.A., Cherfas, J., Hodgkin, T., 2011. Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. Sustainability 3, 238–253.

Garnier, E., 1992. Growth analysis of congenic annual and perennial grass species. J. Ecol. 80, 665–675.

Gleason, K., 1994. To Bound and to Cultivate: An Introduction to the Archaeology of Gardens and Fields. In: Gleason, K. (Ed.), The Archaeology of Garden and Field. University of Pennsylvania Press, Philadelphia, pp. 1–24.

Hilje, L., Araya, C.M., Valverde, B.E., 2003. Pest management in Mesoamerican agroecosystems. In: Vandermeer, J.H. (Ed.), Tropical agroecosystems. CRC Press, Boca Raton, pp. 59–93.

Hood, A.N., 2012. Testing the veracity of paleoethnobotanical macroremain data: A case study from the Cerén site, El Salvador. MA Thesis, Department of Anthropology, University of Cincinnati, OH.

Hutson, S.R., Stanton, T.W., Magnoni, A., Tery, R., Craner, J., 2007. Beyond the buildings: formation processes of ancient Maya houselots and methods for the study of non-architectural spaces. J. Anthropol. Anthropol. 26, 442–473.

Jones, G., Halstead, P., 1994. Maslins, mixtures and monocrops: on the interpretation of archaeobotanical crop samples of heterogeneous composition. J. Archaeol. Sci. 22, 103–114.

Kaplan, L., Lentz, D.L., Slotten, V., Sheets, P., Hood, A., 2015. Phaseolus from Cerén, A Late Classic Maya Site. Econ. Bot. 69, 150–160.

Killion, T., 1992. Residential Ethnoarchaeology and Ancient Site Structure: Contemporary Farming and Prehistoric Settlement Agriculture at Matacapan, Veracruz, Mexico. In: Killion, T. (Ed.), Gardens of Prehistory: The Archaeology of Settlement Agriculture in Greater Mesoamerica. University of Alabama Press, Tuscaloosa, pp. 119–149.

Lamb, C., 2011. An Ethnographic Examination of Present House-lot Gardens of Joya de Cerén: Preliminary Results for Future Ethnoarchaeological Study. In: Sheets, P., Dixon, C. (Eds.), Maya Agriculture South of the Cerén Site. El Salvador, Field Report, pp. 99–111.

Lentz, D.L., Beaudry-Corbett, M.P., Reyna de Aguilar, M.L., Kaplan, L., 1996a. Foodstuffs, Forests, Fields, and Shelter: A Paleoethnobotanical Analysis of Vessel Contents from the Cerén Site, El Salvador. Latin American Antiquity 7, 247–262.

Lentz, D.L., Dickau, R., 2005. Seeds of Central America and Southern Mexico: The Economic Species. The New York Botanical Garden, New York.

Lentz, D.L., Reyna de Aguilar, M.L., Villacorta, R., Marini, H., 1996b. *Trachypogon plumosus* (Poaceae, Andropogoneae): Ancient Thatch and More from the Cerén Site, El Salvador. Econ. Bot. 50, 108–114.

Lentz, D.L., Ramírez-Sosa, C.R., 2002. Cerén Plant Resources: Abundance and Diversity. In: Sheets, P. (Ed.), Before the Volcano Erupted: The Ancient Cerén Village in Central America. University of Texas Press, Austin, pp. 33–42.

Mapes, C., Basurto, F., Bye, R., 1997. Ethnobotany of Quintonil: Knowledge, Use and Management of Edible Greens *Amaranthus* spp. (Amaranthaceae) in the Sierra Norte de Puebla Mexico. Econ. Bot. 51, 293–306.

McClung de Tapia, E., Acosta-Ochoa, G., 2018. Early Subsistence and Settlement in the Basin of Mexico: Preceramic and Pre-urban Indicators. Paper presented at the 83rd Annual Meeting of the Society for American Archaeology, Washington D.C.

McNeil, C.L., 2006. Introduction: The Biology, Antiquity, and Modern Uses of the Chocolate Tree (Theobroma cacao L.). In: McNeil, C.L. (Ed.), Chocolate in Mesoamerica: A Cultural History of Cacao. The University Press of Florida, pp. 1-30.

Medellín, S., 1988. Arboricultura y Silvicultura tradicional en una comunidad totonaca de la Costa. Tesis Maestría en Ciencias. Instituto Nacional de Investigaciones sobre Recursos Bióticos. Xalapa, Veracruz, México.

Messer, E., 1972. Patterns of "Wild" Plant Consumption in Oaxaca, Mexico. Ecology of Food and Nutrition 1, 325–352.

Miksicek, C.H., 1987. Formation processes of the archaeobotanical record. Advances in Archaeological Method and Theory 10, 211–247.

Moran, E., 2016. Sacred Consumption: Food and Ritual in Aztec Art and Culture. University of Texas Press, Austin.

Morehart, C.T., Lentz, D.L., Prufer, K.M., 2005. Wood of the Gods: The Ritual Use of Pine (Pinus spp.) by the Ancient Lowland Maya. Latin American Antiquity 16, 255–274.

Nations, J.D., Nigh, R.B., 1980. The evolutionary potential of Lacandon Maya sustained-yield tropical forest agriculture. J. Anthropol. Res. 36, 1–30.

Olson, G.W., 1983. An Evaluation of Soil Properties and Potentials in Different Volcanic Deposits. In: Sheets, P.D. (Ed.), Archaeology and Volcanism in Central America; The Zapotitán Valley of El Salvador. University of Texas Press, Austin, pp. 52–61.

Powell, B., Thilsted, S.H., Ickowitz, A., Termote, C., Sunderland, T., Herforth, A., 2015. Improving diets with wild and cultivated biodiversity from across the landscape. Food Security 7, 535–554.

Qasem, J.R., Issa, N., 2005. Proceedings of the 4th World Congress on Allelopathy, Establishing the Scientific Base, Wagga Wagga, New South Wales, Australia, 21-26 August 2005, pp.258-262.

Robin, C., 2003. New directions in classic maya household archaeology. J. Archaeol. Res. 11, 307–356.

Roumet, C., Urcelay, C., Díaz, S., 2006. Suites of root traits differ between annual and perennial species growing in the field. New Phytol. 170, 357–368.

Sanders, W., 1973. The Cultural Ecology of the Lowland Maya: A Re-evaluation. In: Culbert, T.P. (Ed.), The Classic Maya Collapse. University of New Mexico Press, Albuquerque, pp. 325–336.

Sauer, J.D., 1967. The Grain amaranths and their relatives: a revised taxonomic ad geographic survey. Ann. Mo. Bot. Gard. 54, 103–137.

Sharer, R., 2009. Daily life in Maya civilization. Greenwood Press, Westport.

Sheets, P., 2000. Provisioning the Cerén Household: the vertical economy, village economy, and household economy in the Southeastern Maya Periphery. Ancient Mesoamerica 11, 217–230.

Sheets, P. (Ed.), 2002. Before the Volcano Erupted: The Ancient Cerén Village in Central America. University of Texas Press, Austin.

Sheets, P., Woodward, M., 2002. Cultivating Biodiversity: Milpas, Gardens, and the Classic Period Landscape. In: Sheets, P.D. (Ed.), Before the Volcano Erupted: The Ancient Cerén Village in. Central America. University of Texas Press, Austin, pp. 184–191.

Sheets, P., Dixon, C. (Eds.), 2011. Maya Agriculture South of the Cerén Site, El Salvador. Electronic document, https://www.colorado.edu/anthropology/sites/default/files/attached-files/thereport2011_001.pdf.

Sheets, P., 2006. The Cerén site: An ancient village buried by volcanic ash in Central America, second ed. T. Wadsworth, Belmont, CA.

Sheets, P., Dixon, C., Guerra, M., Blanford, A., 2011. Manioc Cultivation at Cerén, El Salvador: Occasional Kitchen Garden Plant or Staple Crop? Ancient Mesoamerica 22, 1–11.

Sheets, P., Lentz, D., Piperno, D., Jones, J., Dixon, C., Maloof, G., Hood, A., 2012. Ancient Manioc Agriculture South of the Cerén Village, El Salvador. Latin American Antiquity 23, 259–281.

Sheets, P., Dixon, C., 2013. The Sacbe and Agricultural Fields at Joya de Cerén, El Salvador: Report of the 2013 Research. Electronic document, http://www.colorado.edu/anthropology/people/bios/documents/2013CerénResearchReport.pdf.

Slotten, V., 2015. Paleoethnobotanical Remains and Land Use Associated with the Sacbe at the Ancient Maya Village of Joya de Cerén. MA Thesis, Department of Anthropology, University of Cincinnati, Ohio.

Standley, P.C., Calderon, S., 1925. Lista Preliminar de Las Plantas de El Salvador. San Salvador, El Salvador.

Standley, P.C., Steyermark, J.A., 1946. Flora of Guatemala. In: Fieldiana: Botany Vol. 24. Field Museum of Natural History, Chicago.

Steggerda, M., 1941. Maya Indians of Yucatan. Carnegie Institution of Washington Publication 531.

Stepp, J.R., Moerman, D.E., 2001. The importance of weeds in ethnopharmacology. J. Ethnopharmacol. 75, 19–23.

Toledo, V.M., Ortiz-Espejel, B., Cortés, L., Moguel, P., Ordoñez, M.D.J., 2003. The multiple use of tropical forests by indigenous peoples in Mexico: a case of adaptive management. Conservation Ecology 7, 9.

Wilk, R., 1997. Household Ecology: Economic Change and Domestic Life Among the Kekchi Maya in Belize. Northern Illinois University Press, Dekalb, Illinois.

Williams, L.O., 1981. The useful plants of central America. Ceiba 24, 1–342.

Zier, C.J., 1992. Intensive Raised-Field Agriculture in a Post- Eruption Environment, El Salvador. In Killion, T.W. (Ed.), Gardens of Prehistory. University of Alabama Press, Tuscaloosa, pp. 217-233.

Zimdahl, R.L., 1992. Fundamentals of Weed Science, 2nd ed. Academic Press, San Diego.