ANCIENT MANIOC AGRICULTURE SOUTH OF THE CEREN VILLAGE, EL SALVADOR

Payson Sheets, David Lentz, Dolores Piperno, John Jones, Christine Dixon, George Maloof, and Angela Hood

The role of seed crops in the Maya diet is well understood. The role of root crops in the ancient Maya diet has been controversial, with some scholars suggesting they were staples, and others arguing they were not cultivated at all. Research in the 1990s found occasional manioc plants in kitchen gardens within the Classic period Cerén village, leading to the interpretation that manioc did contribute to the diet, but was not a staple. Recent research outside the village encountered sophisticated raised-bed monocropping of manioc over an extensive area. This area was harvested essentially all at once, about a week prior to the eruption. An estimated ten tons of tubers were harvested. The various uses of manioc include consumption as food, exchange with other settlements, fermentation, drying and storage as a powder, and as an adhesive. It is possible that many or all of these alternatives were being followed. At Cerén manioc was a staple, not just an occasional adjunct to the diet. Because Cerén is toward the wet end of the ideal range for manioc cultivation, other areas of the Neotropics that receive less than 1,700 mm of precipitation may be more suitable for manioc cultivation than Cerén.

Es probable que en la zona maya el cultivo intensivo de maíz y su consumo se remonten al periodo Preclásico Medio. No obstante, su importancia en la dieta maya está bien determinada desde el periodo Clásico hasta hoy. En oposición, la importancia del cultivo de raíces en la dieta de los antiguos mayas ha sido polémica. Dada la escasez de evidencia directa de su cultivo, proceso, y consumo, muchos arqueólogos han expresado incertidumbre sobre su papel en la dieta maya. Algunos de ellos han sugerido que las raíces no eran cultivadas en absoluto. En el otro extremo, hay quienes sugieren que su cultivo fue un componente dominante de la dieta. En el caso específico de la mandioca, hay quienes piensan que fue introducida al área maya desde el Caribe por los españoles. Durante nuestras investigaciones arqueológicas en el sitio de Cerén, en El Salvador, hemos contado con la ventaja del excepcional estado de preservación de los elementos enterrados por la ceniza de la erupción del volcán Loma Caldera, ocurrida cerca del año 630 d.C. En nuestras primeras excavaciones encontramos algunas pocas plantas de mandioca en los huertos de las casas del pueblo, lo que nos llevó a interpretar que sus tubérculos se cosechaban individualmente para ser incorporados en la dieta de forma ocasional. En esta etapa nuestra comprensión de la mandioca era escasa y pensamos que dicho tubérculo no era una parte importante de la dieta, y que sólo contribuía con unas cuantas calorías. En nuestras investigaciones más recientes, realizadas unos 200 m al sur del asentamiento arqueológico, encontramos un sofisticado monocultivo de mandioca sobre un área extensa, practicado sobre un sistema de amplios camellones. En contraste con el estilo de cosechar en los huertos caseros dentro del pueblo, en esta área de monocultivo, la producción completa de mandioca se cosechó en un sólo evento, una semana antes de la erupción del volcán Loma Caldera. Estimamos que se obtuvieron hasta diez toneladas de tubérculos con el procedimiento de arrancar la planta completa, jalándola por la base del tallo. Con esta técnica la mayor parte de los tubérculos de cada planta habrían sido recogidos de un sólo tirón, aunque algunas ramificaciones se habrían roto durante el proceso y permanecido enterradas en los camellones. Estos tubérculos desprendidos se descompusieron en el campo, dejando impresos su forma y volumen en huecos que fueron preservados por el depósito de ceniza volcánica. Cuando encontramos dichas oscuridades, las llenamos con yeso dental por lo que se conservarán perpetuamente. Un tubérculo de mandioca se descompone en pocos días después de su cosecha. Por ello los agricultores de Cerén...
The unusual preservation of the Cerén site (Figure 1), from the volcanic ash (tephra) from the Loma Caldera eruption (Sheets 2006), allowed organic materials such as thatch roofs, pole doors, cloth, stored foods, string, baskets, birds, and animals to be recovered. Only a few scattered manioc (Manihot esculenta Crantz) plants were found inside the village, such as one in the kitchen garden of Household 1 (Lentz and Ramírez-Sosa 2002; Sheets and Woodward 2002). The abundance of manioc surrounding each household, with only an occasional manioc plant, indicated manioc was a minor part of the diet.

However, excavations of agriculture outside the village, some 200 m south of Cerén, encountered surprisingly intensive and sophisticated cultivation of manioc in elevated planting beds (Figure 2). And all manioc was harvested essentially all at once, just a few days before the eruption. The harvesting of many tons of tubers raises questions about how it was processed, exchanged, preserved, and consumed. Durable indicators of manioc processing are being investigated that could preserve at other sites in the Maya area and beyond.

Initially we assumed because manioc tubers, roots, and the occasional stalk were so well preserved, so too would the microscopic indicators such as starch grains and pollen be preserved. As the roots of manioc produce few phytoliths, definitive phytolith evidence was not expected. Starch grains and pollen were recovered in low amounts. Starch grain preservation in soils and sediments is often poor and this is probably the main reason for the absence of manioc starch at the site. Manioc produces relatively few pollen grains that seldom have been found in archaeological settings. Preservation of starch and pollen may also have been compromised by the high heat of the volcanic ash layers that buried them. Henry et al. (2009) exper-
mented with the durability of starch grains under boiling water conditions and found them to be greatly modified or largely destroyed.

Ancient Maya Agriculture: Historical Context

For five centuries Westerners have been describing Maya food production, beginning with Bishop Diego de Landa (1938) describing maize in the early sixteenth century. Gage in the seventeenth century (Thompson 1958) and Stevens and Catherwood (1841) in the nineteenth century described how the Maya fed dispersed populations by maize-based milpa cultivation. Morley (1946) conferred academic acceptance onto the maize-milpa-swidden model by arguing that there had been no changes in agriculture over three millennia, and claiming it was the only form of agriculture possible in the Maya tropics because of uniformly poor soils.

The challenge to this dominant interpretation came not from direct agricultural discoveries, but indirectly from paleodemography. Researchers at Barton Ramie in the 1950s and Tikal during the 1960s found vastly greater housemound densities, and by inference population densities, than expected (Willey 1982:4). Culbert and Rice (1990) note estimates of many hundreds of people per square kilometer at many Classic period sites.

Figure 1. Map of the Ceren site, with the excavated part of the ancient village toward the top, and the 2009 excavations toward the south.
derived from those surveys. Black (1983:82) estimated average population densities in the Zapotitán basin zone at about 300 people per square kilometer in the Classic period. By the 1960s it was clear that swidden was insufficient to feed such populations, and archaeologists sought alternatives.

Bronson (1966) presciently proposed root crops as possible dietary supplements for the ancient Maya, and was in part responsible for a burst in enthusiasm for these cultigens. He documented manioc cultivation among seven out of 10 ethno- graphically recorded Maya groups. For instance, the Chorti, the geographically closest Maya group to El Salvador today, cultivated manioc in fields separate from other crops (Wisdom 1940:56). Bronson (1966) also mentioned that the Maya word
for manioc, "tz'ixm," was found in all major branches of Maya languages, indicating wide-
spread utilization, and perhaps significant time depth. Flannery (1982:xix) noted the surge of in-
terest in manioc among Mesoamericanists after Bron-
sen’s publication, but criticized scholars who "believed on faith [in precolombian manioc culti-
vation] because there is no archaeological evidence to support it." Flannery did mention two ancient manioc seeds discovered in Tamaulipas and Chiapas, but noted that both may be wild. The evidence for Classic period Maya cultivation of manioc was so weak that Marcus (1982:252) suggested outs-
siders may have introduced it during the Postclass-

ic period, or even that the Spanish may have intro-
duced it into the area from the Caribbean during
colonial times.

In the most extensive compendium of the ancient Maya, Sharer (2006:637–651) describes the current understanding of subsistence as a mix-
ture of extensive and intensive techniques focusing on maize, beans, and squash. He notes that the Classic period population increase required more intensive techniques, including kitchen gardens, terracing, raised fields, and irrigation. He also favored the multi-species mosaic model of inter-
cropping, mimicking the species diversity of the rainforest.

Fedick (1996) provides a detailed understand-
ing of ancient Maya agriculture in his felicitously titled book The Managed Mosaic. The 28 authors provide many facts and cases consistent with Sharer’s overview, and they document environmental heterogeneity in ways not imagined in previous decades. Many chapters present large-scale agricultural intensification features such as terracing, raised fields, canals, and reservoirs, because they preserve better in tropical climates than do smaller features. And, not surprisingly, the domes-
ticated plant species that have the greatest chances of being recognized in the archaeological record are featured, especially maize. A rough indicator of the predominance of maize is in the number of references to it in the text. The index provides 73 page references for maize, but only two for man-
oc. Significantly, both of the manioc references are by Cathy Crane (1996:271), stating how little evidence of cultivation of any root crop has been found among the Maya, and concluding "the role of root crops in the Maya diet is unknown."

The best evidence of manioc in the Maya low-
lands and environs has come from microscopic examination of soils and sediments during the past two decades. Pohl et al. (1996) found Manihot pollen in swamp cores from northern Belize, dat-
ing to about 3400 B.C. and Manihot pollen was dis-
covered more than a millennium earlier in Tabasco (Pope et al. 2001). It is important to note here that identification of these grains cannot be made below the level of genus, therefore strictly speaking leaving the issue of wild or domesticated unresolved. Because native wild Manihot occurs in Mesoamer-
ica, the discovery of Manihot pollen should not automatically be interpreted as the domesticated crop. The context of the grains in ancient field set-
ings and near habitation locales suggests they are of domesticated manioc. Manioc starch grains from central and western Panama date to ca. 4400–5600 B.C. (Dickau et al. 2007; Piperno et al. 2000). An earlier occurrence in Panama than in Mesoamer-
ica is expected because the plant probably was domesticated in South America (Olsen 2002; Olsen and Schaal 1999). DeBoer (1975) and Perry (2005) provide information on manioc in archaeological sites in South America. Miksieck (1991:80) identi-
fied some carbonized organic materials at Cuello as fragments of manioc stems, but he did not know if they were wild or domesticated. Hather and Ham-
mond (1994) report finding manioc soft tissue in three of six samples from Cuello. Jones identified Manihot pollen from a sediment core taken from Cobweb Swamp, but it is not well dated (Crane 1996). Evans (2008:133) summarizes much research that has found a paucity of manos and metates in lowland tropical Mesoamerica in the Early Formative, interpreted as likely indicating that maize was not a staple crop in that period. It is possible that manioc was a staple then, and it is also possible that it remained a staple in some areas, but has yet to be detected as such, except at Cerén. Maize was, of course, a staple in all subsequent periods. Intriguingly, Wilken (1971:442) states that Rafael Girard (1952:104–105) claimed one of the most ancient recorded Maya myths includes an agrarian deity represented by a root crop, not by a seed crop.

One manioc plant was found in the Household 1 kitchen garden at Cerén (Sheets and Woodward 2002), and a few isolated ones were found else-
where (Lentz et al. 1996; Lentz and Ramírez-Sosa
leading us to think that manioc provided little to the diet. That finding was consistent with general expectations that manioc was cultivated as isolated plants, only in gardens, and not as a staple-like maize in formal rows and in extensive single-species plots.

**Agriculture within the Village: Kitchen Gardens and High Performance Milpas**

The kitchen garden of Household 1 held a variety of species, all planted on six small ridges oriented 30° south of east, in a 5-x-6 m area between the kitchen and the storehouse (Sheets 2006:58). One manioc stake had been planted in the northwest corner of the garden, and had grown two stalls. Presumably the tubers would have been harvested individually for immediate processing and consumption within the household, allowing the plant to continue growing and to replace that tuber. Based on the rarity of manioc inside the village, we concluded that it was a minor component of the diet. The 2009 research south of the village changed that dramatically. The rest of the northernmost kitchen garden row was occupied by *Xanthosoma violacium* Schott, locally called *malanga*, a root crop. Each *malanga* plant has a short stem with long vaginate petioles attached to a very broad sagittate leaf blade. Below ground the stems end in carbohydrate-rich tubers. The other five rows alternated between *Xanthosoma* and a small plant identified as *cebadilla* (*Schoenocaulon officinale [Schlecht. & Cham.] Gray ex Benth.*) (Sheets 2006:59). Seeds of the plant contain veratridine and other alkaloids that have violent emetic-cathartic properties and can be used as a medicinal plant when used sparingly (Williams 1981). Prior to being found at Cerén, *malanga* had not been found growing at other Mesoamerican sites (Lentz and Ramírez-Sosa 2002), although it was suggested as a possible Maya crop (Bronson 1966). It apparently provided significant calories for the villagers.

Speciality crops were grown in the garden of Household 4 (Lentz and Ramírez-Sosa 2002; Sheets and Woodward 2002). Those included arboriculture with *guava* (*Psidium guajava L.*) and cacao (*Theobroma cacao L.*), a large chile plant (*Capsicum annuum L.*), with *nance* (*Byrsonima crassifolia [L.] H.B.K.*) not far away, and an estimated 70 agave (*Agave sp.*) plants used for fiber.

Surrounding each household within the village was an extensive zone of milpa. Maize ridges are oriented the same way as the kitchen garden ridges, following the dominant architectural orientation of household and public buildings in the village. The maize ridges are small, at about 10 cm high and spaced 80 cm apart, and have 4–5 seeds planted in each digging stick hole, spaced about 70 cm along each ridgetop. In six of the eight places where milpa has been found, the corn had matured and the stalk was doubled over to dry the ear in the field. That the Loma Caldera eruption caught maize agriculture at the drying-in-the-field stage indicates it struck in the middle of the rainy season, probably in August. In one other location a second planting had been done, and in another location the field was in fallow. The mature maize cobs were preserved sufficiently well to allow estimates of productivity per unit area. Sheets and Woodward (2002:186) calculated over 5,000 kg of maize per hectare, a very high figure indeed. In spite of that high productivity, they calculated that in most years the milpas surrounding each household were insufficient to supply sufficient food to feed a family. Presumably the additional needed food production came from fields outside the village, and we proposed the villagers used a three-part agricultural strategy of kitchen gardens, infield milpas, and outfields.

**Agriculture South of the Cerén Village**

The origins of the 2009 research were two exploratory test pits (Figure 2) excavated in 2007 about 200 m south of the Cerén site (Sheets et al. 2007; Sheets et al. 2011). Those two pits, each 2 x 3 m, encountered very large planting beds, 7 to 10 times larger in volume than the maize ridges found inside the village. The beds were made of the juvenile soil developed on the tephra from the Ilopango TBJ eruption that may have occurred in the early fifth century (Dull et al. 2001) or more likely as late as A.D. 536 (Dull et al. 2010). Nothing was found growing above the ridges, but the stakes of manioc plants were found to have been planted just days before the Loma Caldera eruption. In addition some manioc tubers were found that had been missed in the harvesting. Intensive manioc cultivation was certainly unanticipated, and that discovery led to the proposal for research during the 2009 season.
Excavations. With the permission of individual landowners in the area of the 2007 test pits, excavations began in January 2009 to explore agriculture outside the village. A total of 22 3-x-3-m pits was excavated through about three meters of the Loma Caldera volcanic ash that had buried the landscape in about A.D. 630 (Sheets 2009).

Three different kinds of Classic period land use were discovered: cleared areas, cultivated and harvested manioc, and *milpas* where maize had matured but not yet harvested (Figure 2). The cleared areas likely were used for processing the harvested manioc, and probably for maize, and included some constructed platform areas on both sides of the fields. A maize field was found that exceeded the care in cultivation and productivity of maize grown within the village. An extensive area where manioc had been cultivated and harvested, with some areas where it had been replanted, was also discovered. These three land use zones are described and interpreted in the three sections that follow. The zones are separated by approximately parallel lines that are oriented 30° east of magnetic north (all directions in this article are magnetic as of 2009). In addition a large rectangular masonry block was found in Operation P that also oriented 30° east of north on one side, and 30° south of east on another side. It may have been a property intersection marker. If these orientations emanate from the village they could indicate highly structured village control over land use outside the village.

Cleared Areas. Two areas (Figure 2) were discovered that were kept clear of vegetation on each side of the intensive manioc cultivation area, and where platforms were constructed (Malloof 2009). In striking contrast to the high-density manioc agriculture adjacent to it, Ceren residents cleared a sizeable area of vegetation and built a platform to the west of the western land use line (Figure 3). Another cleared area with a platform was found to the east of the fields, at Operation P (Figure 4). Why would people farm manioc so intensively below that land use line, and maintain such a large cleared area next to it? Harvesting manioc a tuber at a time for household consumption from a kitchen garden (Sheets 2006) does not require a significant processing area. However, here people harvested an entire field by pulling up the stalks with most of the tubers attached, and that requires a large processing area. The activities would at least involve separating tubers from stalks, and saving stalks for replanting, and it apparently also involved cutting the cortex off of the tubers, and possibly cutting them into small segments for sun-drying.

Nine excavations west of the manioc cultivation zone encountered an extensive cleared area (Ops A, B, C, D, J, H, O, M, and W, Figure 2). The area is estimated to be at least 30 by 50 m. The Classic period surfaces were kept quite clear of vegetation, with only an occasional volunteer cultigen or weed growing (Malloof 2009). Three excavations (Ops D, H, and J) encountered the juncture of the manioc beds and the cleared area, and in all three cases the cleared area had been leveled by a cut-and-fill procedure. One notable exception to the effort to keep the harvest processing area clear of vegetation was encountered in Op D, where a tree had been growing years before the eruption. The tree was cut down about a year before the eruption, but the roots continued to live and sprouted three saplings that were allowed to grow. The sapling diameters were ca. 15 cm, so they grew into small trees that would have provided Ceren villagers access to their fields east of the village. The path appeared to continue in the other direction, to the southwest. Thus, the footpath could have provided Ceren villagers access to their fields.
fields and harvest processing areas. Also, residents of the modern village of Joya de Cérén have informed us of encountering evidence of some scattered ancient buildings farther south and west of our 2009 excavations, presenting the possibility that the path connected the village with some field houses or agrarian households.

Operation P was excavated on the other side of the intensive manioc fields, downhill to the east (Figure 4). It encountered another cleared area largely devoid of vegetation just above the drop-off down to the river (Maloof 2009). It was excavated there to explore the eastward extent of the manioc fields, and the excavation was successful as formal fields did not extend into it. It probably is close to the eastern end of manioc cultivation, as one volunteer manioc stalk was found growing there, along with two volunteer maize plants. Also a carefully constructed flat platform was encountered, made of TBJ tephra brought in and leveled out, averaging 6 cm in thickness in the southern half of the excavation. It was likely for manioc tuber processing. Below the TBJ tephra platform as well as beyond it to the north was a shallow sheet midden composed of sherds, lithics, and plant macrofossils. Use wear on an obsidian prismatic blade from the midden, discussed below, suggests that decortication was being done promptly after harvesting at this location.

A sizeable adobe block was constructed from the clay-laden soil below the TBJ tephra and placed on top of that ash layer. It measured 65 x 45 cm, and averaged 25 cm thick. The edges were 30° east of north and 30° south of east, corresponding to the dominant architectural and agricultural azimuths, suggesting it probably was built at a property intersection and functioned as a boundary marker.

Maize Field. Prior to the 2009 field season at Cérén, maize was believed to be the only staple crop grown there. Maize had been previously identified both in kitchen gardens and in the infield milpas located adjacent to the village structures (Sheets 2002). During the 2009 excavations maize was again documented at Cérén. A maize field was identified to the east of the manioc beds discovered in 2007 (Figure 2). The eruption preserved much of

Figure 3. Operation J, with constructed platform to the left, and the beginnings of four manioc planting beds to the right. Ten centimeter scale at back.
the stalks and some of the ears, just like those found in the site center (Sheets 2002; Tetlow and Hood 2009). Stalks were bent over for drying in the field. This maize field borders the manioc fields to the west and south and extends an unknown distance to the north and east (Tetlow and Hood 2009).

The 10-cm high maize ridges of this area were spaced approximately 70 cm from each other, with plant clusters on each ridge spaced almost a meter apart (Tetlow and Hood 2009). The size and spacing of these maize plants is similar to maize plantings within the site center (Sheets 2002). It appears a similar high productivity of maize milpa extends to this region. What is unusual is ridge orientation. All previously excavated maize field ridges at Cerén were oriented perpendicular to ground slope, presumably to maximize infiltration and retard erosion (Sheets 2002). In contrast, the maize field south of the village is located downslope from the manioc fields. Those manioc beds and walkways were oriented to maximize drainage, and that excess water ran into the maize field, where drainage continued to be maximized.

Manioc Fields. The discovery of harvested manioc fields initially in 2007 (Figures 5 and 6) and in detail in 2009 has provided an unusually clear picture of intensive manioc production by Classic Period Maya villagers. The two initial test pits excavated in 2007 were positioned along the tie-lines between two ground-penetrating radar grids (Dixon 2007). No plants, including weeds, were found on the surface of the planting beds, indicating the careful maintenance of the area. Excavation of the manioc beds discovered five manioc tubers and seven cut manioc stalks. The stalks, called stakes, are sections of the manioc trunk that had been planted horizontally for the next cycle of plant growth (Dixon 2007; Sheets et al. 2007).

The 2009 field season was organized around the manioc beds discovered in 2007 with the aim of placing these beds in a wider context by investigating the surrounding area (Figure 2). This continued research yielded a previously unprecedented glimpse into the broader organization, the variation in cultivation, and importance of manioc at Cerén and potentially in other areas. The 2009 field sea-
son encountered Cerén manioc beds in a total of 12 operations and provided increased understanding of Maya manioc production.

Three separate fields were identified within the manioc cultivation zone. Manioc Field 1 includes the original beds discovered in 2007 and is the most extensive single plot found during our excavations thus far. The manioc beds excavated within this area had very uniform sizes, shapes, and styles of construction, and all had been harvested just prior to the Loma Caldera eruption, and some had been replanted (Dixon 2007, 2009; Sheets 2009). The beds in this plot average 20 cm in height, with almost vertical sides, and flat tops about 50 cm in width. Their cross-sections are quite angular. All beds were sloping 6–10° degrees, presumably to drain excess water. Precipitation at Cerén is 1,700 ± 300 mm, toward the moister end of manioc’s ideal range of 1,000–2,000 mm. It can be productive even down to 500 mm. Most of the Maya area is suitable for manioc cultivation, and much of it more suitable than at Cerén.

Manioc Field 1 extends 15 m between its western and eastern boundaries and an unknown distance to the north and the south. A land-use line establishes the western boundary of Manioc Field 1. A leveled platform was the first feature immediately to the west of the land-use line, presumably for processing manioc. The land-use line is oriented approximately 30° east of north.

The eastern boundary of Manioc Field 1 is marked by another land-use line that is also aligned about 30° east of north. The northern portion of this use-line creates the boundary between the manioc production of Manioc Field 1 in the west and maize production in the east (Figure 7). The northern maize ridges of the eastern field closely resemble maize ridges in the Cerén village, as their heights average 10 cm, and ridgetop-to-ridgetop spacings average approximately 70 cm. But
towards the southern regions the maize ridges gradually increase in ridgetop-to-ridgetop spacing between beds that approach spacing of manioc fields, at 110 cm. Maize plants were growing throughout this field at the time of the Loma Caldera eruption, so there is no doubt all these ridges were dedicated to maize production. However, it is possible that a portion of this field was used earlier for manioc cultivation and that this region is a transition between the maize field to the north and Manioc Field 2 to the south. Alternatively, it is possible that this southern portion of the maize field received more runoff from the cleared area and manioc field to the west, and thus the swales of the maize field needed to intersect the swales (walkways) of the manioc field to carry excess water toward the river.

The southern portion of this western land-use line forms the boundary between Manioc Fields 1 and 2 (Figure 8). At this boundary the manioc beds of Manioc Field 1 become the furrows of Manioc Field 2, and the furrows become the beds. The staggered orientation of the manioc beds creates a clear boundary between the two fields. Water poured from one swale to the staggered one downhill over a miniature waterfall (Figure 9). These fields have manioc beds with uniform construction in shape, style, and size to each other (Figure 10) (Dixon 2009), but because they are separated by a clear land-use line, they presumably are of different cultivators. The eastern and southern boundaries of Manioc Field 2 have yet to be found.

The western boundary of Manioc Field 3 presumably is the continuing land-use line, and the northern boundary is where it abuts Field 2, but neither has been confirmed. Manioc Field 3 was so designated not by discovering land-use lines or field boundaries, but rather by the striking stylistic differences in manioc bed construction. The beds of Manioc Fields 1 and 2 were broad and flat-topped with almost vertical walls, while the beds of Manioc Field 3 were shaped like sine waves in cross-section. They are much higher, averaging 40 cm, and more widely spaced from ridgetop-to-ridgetop at 130 cm. Given their very different style of construction, these manioc ridges have been designated as a separate manioc field. While it is possible the larger and differently shaped manioc bed
Figure 7. Operation L, with harvested manioc planting beds on the right, draining down into maize ridges to the left. The land use line separating them is oriented 30° east of north.
construction of this plot might serve to prevent soil erosion, there are no ground slope differences between this field and the other areas of manioc production (Dixon 2009). There are no known advantages or disadvantages of these different styles of construction that we could discover. Thus, it seems probable the field differences are idiosyncratic in nature.

The two land-use lines and the large adobe block in Op P are oriented at about 30° east of north, which is close to the orientation of most architecture and agricultural field ridges inside the Cerén village (Sheets 2002, 2006). It is possible that they emanate from the village, and possibly even from Structure 3, interpreted as the political center of the village where the elders sat on benches of authority in the front room. However, it is also possible that the land-use lines emanate from a settlement to the south, possibly even San Andrés, the largest site in the valley, some 5 km away. It is also possible that they were simply local boundaries set up by mutual agreement among these agriculturalists, and do not relate to any settlement. This last alternative is considered the least likely.

*Artifacts.* Excavations within the Cerén village have encountered hundreds of artifacts made of pottery, obsidian, dacite, jade, bone, antler, and other materials, most in positions of storage, but some in loci of use (Sheets 2002, 2006). Virtually all were complete; in fact, it is unusual to find a sherd in or around a building what was not a part of a whole vessel. The opposite holds in the agricultural area investigated in 2009, where only broken/discarded artifacts were encountered. A total of 200 sherds were encountered in all operations, with types and frequencies consistent with those found within the village (Beaudry-Corbett 2002). More than half of the sherds (i.e., 111) came from a small sheet midden encountered in Operation P, at the southeast corner of the research area. In addition to sherds, miscellaneous fired clay artifacts were recovered, including olla handle fragments, *adornos*, a sherd spindle whorl, and a whistle fragment.

Only 12 obsidian artifacts were found, all from Operation P, and all are prismatic blade fragments (Sheets 2009:124). One blade had an unusual usewear in the form of many individual striations parallel to the edge. Along concavities of the edge...
the individual striations are clear. But along convexities where the blade would make more contact with the worked material, there are so many striations that the surface appears frosted. Only two examples of this kind of usewear in Mesoamerica or the Intermediate Area have been published, to the best of our knowledge. Hutson et al. (2007:461) report an obsidian prismatic blade from Chunchumil with striations parallel to the edge, which they suggest could have been used in cutting coarse fibers. We suggest it might have been used in manioc de-cortication. Given manioc’s resistance to drought, it might have been a more important domesticate at Chunchumil than at Cerén. A few striations similar to those on the Chunchumil and Cerén blades developed during replication experimentation by Suzanne Lewenstein (1987:126, Figure 85). An obsidian edge received a few striations parallel to the edge when used to slice the cortex off of manioc tubers at Cerros. It is possible that more extensive use could develop the high degree of striations seen on the Operation P blade. This kind of usewear may be a durable indicator of root crop processing, and possibly specific to manioc. Striations from removing the cortex of malanga (*Xanthosoma*) would be perpendicular to the edge. Usewear highly similar to this has also been found on a few prismatic blades from Chalchuapa. Experimentation currently underway has replicated this usewear on newly-manufactured obsidian cutting edges, while cutting manioc tuber cortex coated with a thin layer of volcanic ash from the TBJ eruption of Ilopango volcano.

Two non-obsidian chipped stone artifacts were found, a dacite scraper, along with a basalt flake that may have been debitage from early in the manufacture of another scraper (Sheets 2009:124). The dacite scraper had been extensively used, with considerable abrasive wear from motion perpendicular to the working edge. Traditional Amazonian natives remove manioc’s cortex by scraping or by cutting (Dufour 1994). An attempt to resharpen the scraper was unsuccessful and it was discarded. It was found in the midden of Operation P, adjacent to a prepared platform that may have been constructed for manioc processing following harvesting.

Manioc tubers deteriorate rapidly once they are out of the ground, and need to be consumed within
a day or two, or processed into another form rapidly. They deteriorate even faster once the cortex is removed. There are four possibilities regarding processing and use: direct consumption, drying and storing in powdered form, as an adhesive, and fermentation. The drying and storage option begins by decortication, cutting into small segments to sun-dry them and then grinding into a powder locally called “almidón.” Almidón stores indefinitely as long as it is kept dry. An extensive area would be needed to sun-dry the estimated 10 tons of manioc tubers harvested from this area days before the eruption (Sheets 2009). Manioc juice is an effective adhesive, and may have been the binder used to paint Structures 10 and 12. Another possibility is that tubers were fermented in ceramic vessels, and the fact the village was holding a harvest-oriented community ceremony and feast at Structure 10 when the eruption occurred suggests that fermented manioc beer perhaps was consumed. The fermentation presumably would have been done in ceramic vessels kept in the town, rather than in the field. We suggest that a large proportion, probably the majority, of the manioc tubers were being de-corticated, cut into segments, and sun-dried in the cleared areas, prior to being transported to the village and ground into almidón.

The large surplus of manos and metates in Household 1, responsible for supporting the ceremonies in Structure 10 (Sheets 2006), may have been used for such grinding, as well as the individual mano-metate sets in other households. These alternative modes of processing and consumption are not mutually exclusive.

**Plant Macromains.** A large quantity of carbonized plant macromains—plant remains large enough to be seen by the unaided eye—was collected from the sub-TBJ sheet midden uncovered in Operation P. The plant remains from that unit were collected as they were encountered during the midden’s excavation, while additional plant macromains were recovered from soil samples taken from the midden and processed using a modified Apple Creek water flotation system (Pearsall 2000:15). These archaeological plant macromains were transported back to David Lentz’s Plant

![Figure 10. Operation F, manioc ridges with a long manioc root. It ran just a few centimeters below the top of the planting bed. Scale 25 cm on left.](image)
intrusive foot traffic, anim als, and other distur-
bances w hile C erén w as occupied. T he L om a
6 cm -thick TBJ tephra layer above the m idden to
vation p m idden is likely due to people depositing
hum an/plant relationships (Lentz 1991:275; Lentz
middens, and ultim ately our interpretations of past
processes and differential preservation have on the
ical records such as C opán, C han, and C uello
rarely leads to carbonization and subsequent preser-
ological record of ancient M aya sites because the
process of their preparation, soaking and boiling
abeled, although maize and beans are the most abun-
dant plant remains by both count and weight. Beans, both common beans (Phaseolus vulgaris L.)
and lima beans (Phaseolus lunatus L.), however,
are by far the dominant plant macrofossil recov-
ered from the m idden. Although present in large
numbers here and in other contexts within the Cerén
village (Lentz et al. 1996; Lentz and Ramírez-Sosa
2002), beans are generally infrequent in the archae-
ological record of ancient Maya sites because the
process of their preparation, soaking and boiling
rarely leads to carbonization and subsequent preser-
vation (Hammond and Miksicek 1981:268). The
paucity of beans recovered from sites throughout
the Maya area with well-studied paleoethnobotan-
ical records such asCopán, Chan, and Cuello
underscores the strong impacts that formation
processes and differential preservation have on the
taxa recovered from archaeological features like
middens, and ultimately our interpretations of past
human/plant relationships (Lentz 1991:275; Lentz
et al. 2012; Miksicek 1991:78). The unusual preser-
vation of such large numbers of beans in the Oper-
ation P midden is likely due to people depositing
a 6 cm -thick TBJ tephra layer above the midden to
create a flat platform, effectively sealing it off from
intrusive foot traffic, animals, and other distur-
bances while Cerén was occupied. The Loma
Caldera eruption further buried the feature, elimi-
nating post-occupational disturbances.
A gourd rind (Lagenaria siceraria [Mol.]
Standl.), a plant commonly found in archaeologi-
cal contexts in Mesoamerica, was also recovered
from the midden. Identified in larger quantities
from Household 1 and Structure 11 (a food prep-
ration area) in the village, gourd fruits are noted for
their wide array of uses as containers and utensils,
while their seeds are often eaten like those of related
squash species (Cutler and Whitaker 1961:483;
Lentz et al. 1996:249; Lentz and Ramírez-Sosa
2002:Table 4.1).
Several tree fruits of economic importance were
also identified in the Operation P midden, includ-
ing jocote or hog plum (Spondias sp.), avocado
(Persea Americana Miller), and nance. The pres-
ence of Spondias pits is particularly intriguing
because this is the first time the tree fruit has been
documented at Cerén, despite numerous examples
of other well-preserved tree crops such as guava,
cacao, and calabash (Crescencia alata H.B.K.) in
the village. Spondias fruits are eaten raw and grow
in bountiful quantities throughout Central America
Given that Spondias is ubiquitous throughout the
modern Central American landscape, and that the
fruit pits are frequently present at sites (Copán and
Cuello, for example) that lack the unusual preser-
vation conditions found at Cerén (Lentz 1991:274;
Miksicek 1991:72), it is surprising that this tree crop
has remained absent from the archaeological record
at Cerén until now. Possibly Spondias trees were
grown far enough away from the village that the
pits did not enter household spaces, or Cerén’s res-
idents routinely cleaned all activity surfaces of food
waste and other debris. Perhaps more likely, Spon-
dias fruits simply may not have been in season
when the Loma Caldera erupted, rendering it
imperceptible until uncovered in the Operation P
midden that contained refuse that was deposited
prior to the eruption.
The identification of tree fruits from the Oper-
ation P midden—coupled with extraordinarily
well-preserved, in situ tree trunks, branches, fruits,
stems, and stands of fruit trees planted within
household courtyards in the village proper (Lentz
and Ramírez-Sosa 2002:38)—provides extensive
evidence of arboriculture at Cerén. Such vivid
details of arboriculture are significant because they
Table 1. Macrobotanical Remains, by David Lentz and Angela Hood.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Common Name(s)</th>
<th>Parts</th>
<th># of Samples</th>
<th>Total Weight of Samples (g.)</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anacardiaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Spondias</em> sp.</td>
<td>Jocote, hog plum</td>
<td>Pit</td>
<td>6</td>
<td>.24</td>
<td>Operation P Sub-TBJ midden</td>
</tr>
<tr>
<td>Cucurbitaceae:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cucurbita</em> sp.</td>
<td>Squash, ayote</td>
<td>Rind</td>
<td>9</td>
<td>.22</td>
<td>Operation P sub-TBJ midden</td>
</tr>
<tr>
<td><em>Lagenaria</em> sp.</td>
<td>Gourd, tecomate</td>
<td>Rid</td>
<td>1</td>
<td>.01</td>
<td>Operation P sub-TBJ midden</td>
</tr>
<tr>
<td><em>Dicot</em> sp.</td>
<td>Charcoal, stem, rind</td>
<td></td>
<td>10</td>
<td>.03</td>
<td>Operation P sub-TBJ midden</td>
</tr>
<tr>
<td>Fabaceae:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phaseolus</em> sp.</td>
<td>Lima bean, frijol de media luna</td>
<td>Cotyledon</td>
<td>1129</td>
<td>11.35</td>
<td>Operation P sub-TBJ midden</td>
</tr>
<tr>
<td><em>Phaseolus</em> lunatus</td>
<td>Lima bean, frijol de media luna</td>
<td>Cotyledon</td>
<td>6</td>
<td>.15</td>
<td>Operation P sub-TBJ midden</td>
</tr>
<tr>
<td><em>Phaseolus</em> vulgaris</td>
<td>Common bean, frijol</td>
<td>Cotyledon</td>
<td>133</td>
<td>4.43</td>
<td>Operation P sub-TBJ midden</td>
</tr>
<tr>
<td>Lauraceae:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Persea Americana</em></td>
<td>Avocado, aguacate</td>
<td>Pit</td>
<td>1</td>
<td>.20</td>
<td>Operation P sub-TBJ midden</td>
</tr>
<tr>
<td>Malpighiaceae:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Byrsonima</em> crassifolia</td>
<td>Nancee</td>
<td>Pit</td>
<td>1</td>
<td>.02</td>
<td>Operation P sub-TBJ midden</td>
</tr>
<tr>
<td><em>Monocot</em> sp.</td>
<td>Charcoal, stem</td>
<td></td>
<td>5</td>
<td>.03</td>
<td>Operation P sub-TBJ midden</td>
</tr>
<tr>
<td>Poaceae:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Zea mays</em></td>
<td>Maize, maiz</td>
<td>Kernel, cupule, leaf</td>
<td>256</td>
<td>3.79</td>
<td>Operation P sub-TBJ midden</td>
</tr>
</tbody>
</table>
contextualize an emerging corpus of paleoethnobotanical data for tree crops at other ancient Maya sites where typical preservation conditions render non-carbonized plant remains virtually invisible. Chan, an ancient Maya farming village in west-central Belize, is such a site, with a diverse set of plant macrofossils including numerous tree crops (Lentz et al. 2012). Remains of avocado cotyledons in outdoor domestic spaces and nance pits recovered from terrace beds indicate that Chan’s residents likely planted orchards in household courtyards and further afield in terrace beds, an observation that mirrors the distribution of in situ tree fruits and the trees bearing them within the Cerén village, in addition to tree crops such as Spondias only documented outside of household areas. Overall, the lush evidence of plant use practices at Cerén provides a useful framework from which to interpret plant macrofossils and ancient landscapes throughout the Maya area.

Although we did not find carbonized manioc remains in Operation P, we did find two manioc stems, cast in dental plaster, volunteering from the midden (Figure 5). The manioc stems could be identified because of the unusual leaf scars and nodes found on the stout main stem which can grow up to 5–6 cm in diameter. As seen in the modern sample shown in Figure 5, at each node of the manioc stem there is a prominent circular leaf scar subtended on either side by a horizontal protuberance. Even more telling, the nodes are alternate in arrangement, but are distributed on the stem in a spiral pattern. Although the circular leaf scars are not particularly well-preserved on the plaster casts of the manioc stems, the horizontal protuberances are evident as are the spiral node arrangements, leaving little doubt that these casts represent Manihot esculenta. Furthermore, other potential candidate plants for these casts can be eliminated because of their stem morphology. Maize, for example, has about the same stem diameter as manioc, but maize stems are covered with leaf sheaths above each node. The leaf sheaths have the parallel venation characteristic of monocots and these are readily observable in the numerous maize casts that have been recovered from Cerén. Also, the phyllotactic arrangement in maize is distichous, with single nodes distributed alternately on either side of the stem and not spirally arranged as in manioc. Two other New World root crops, yams (Dioscorea trifida L.) and sweet potatoes (Ipomoea batatas L. Lam.), grow as prostrate vines unless offered some scaffolding. Malanga, as cited above, has been identified at Cerén, but their true stems barely emerge above the ground surface and the englantated leaf petioles are the parts most commonly seen in plaster casts. Achira (Canna edulis Ker.) and arrowroot (Maranta arundinacea L.) are other cultigens that might be candidates (Piperno and Pearsall 1998) for plaster casts at Cerén, but they are both monocots and the parallel venation would be apparent, as with maize. Also, the stems of achira and arrowroot are far less robust than the cast seen in Figure 5. Finally, the manioc plants are adjacent to the ancient manioc field described above, perhaps one of the most extensive known in the ancient New World (Tetlow and Hood 2009:14).

Manioc is typically propagated vegetatively by planting cuttings from the plant’s mature stems in the ground (Cock 1982:756) and not by seeds, eliminating a potential source of evidence for manioc in the archaeological record. Furthermore, manioc roots, along with macrofossils of root crops in archaeological contexts throughout the world, preserve poorly and prove difficult to identify even when preserved via carbonization, desiccation, or from waterlogged conditions (Pearsall 2000:153). Preparation techniques for manioc discussed above — grating, grinding, and fermentation — in addition to boiling (Miksicek 1991:80), further decrease the probability that manioc root tissue would become carbonized and preserve in archaeological contexts. Despite this seemingly pessimistic outlook on the chances of identifying manioc from sites in the Maya area lacking the unusual preservation conditions at Cerén, archaeologists working in Mesoamerica should be encouraged to incorporate programs of paleoethnobotanical study into their research designs to systematically recover potential macrorerains, as well as microremains (i.e., pollen, phytoliths, and starch grains), in an effort to broaden the paleoethnobotanical record of a botanically as well as culturally diverse region.

Phytoliths and Pollen. Pollen and phytolith analyses were conducted by Dr. John Jones in the Palynology Laboratory(8,6),(987,995) at Washington State University. A total of 37 sediment samples were submitted for analysis, all of which came from sub-Loma Caldera tephra contexts, and most of
which came from the middle-Classic horizon contemporary with the Cerén village. A few samples came from earlier sub-Ilopango TBJ contexts and thus antedated the principal Cerén occupation. Extraction procedures followed techniques modified from Piperno (2006).

Although disappointing, it was not unexpected that pollen was nearly completely absent from the Cerén samples. It is likely that the high heat from the Loma Caldera tephra destroyed most grains, along with other organics in the sediments and/or that pollen preservation generally was poor, as often is the case in archaeological sites where natural oxidizing conditions are present. A few poorly preserved fossil grains were noted in a couple of samples; those grains may have been buried prior to the eruption and thus protected somewhat. The few grains that could be identified include Poaceae (grasses) Asteraceae (composites), Chenopodiaceae (goosefoot, pigweed) and Zea mays (maize). These types are usually overrepresented in pollen records because they are durable, they are produced in abundance, and their distinctive morphologies make them readily recognizable, even when highly degraded (Bryant et al. 1994).

Phytoliths on the other hand were abundant and well preserved in the Cerén sediments. All of the phytolith samples from Cerén are dominated by a number of typically common phytolith types from the Poaceae and various other families or groups of plants. The discussion will focus on economically significant plants and cultigens.

Several phytolith types encountered in the Cerén samples represent economically significant plants. A single spherical, scalloped Cucurbita phytolith was noted. This type is diagnostic of the fruit rinds of Cucurbita (Bozarth 1987; Piperno 2006). The size of the phytolith, 58 microns long, overlaps those of wild Cucurbita species, precluding a definitive identification as a domesticated squash. Considering the chronology and overall context of Cerén it is likely that the phytolith is from a domesticated species. Zea mays (maize) is a heavy phytolith producer, with different types of diagnostic phytoliths being produced in its leaves and cobs. Both maize leaf and cob phytoliths were recovered from every sample except 30, 31, and 32. Maize leaf phytoliths are represented by large “cross-shaped” phytoliths and cob phytoliths by “wavy-top” rondel phytoliths (Pearsall et al. 2003; Piperno 2006).

Palms are all heavy phytolith producers and some different phytolith groups are recognized (Piperno 2006). The very few palm phytoliths encountered in the Cerén samples are all spherical types, which occur in many palm genera including Sabal; however, genus-level identification cannot be made. However, their rarity suggests that palms were not common in the Cerén area. Conical-shaped palm phytoliths produced by genera such as Bactris and Acronymia were absent, suggesting that these plants were not being cultivated near the sediment collection areas. Lentz and Ramírez-Sosa (2002:40) also noted the presence but paucity of palms at Cerén, which is unusual when compared to so many other Maya sites.

Two samples (Lab numbers 37 and 38) represent scrapings of carbonized materials on ceramic sherds. Both samples were dominated by carbonized and partially carbonized organic materials, and phytoliths were isolated from these materials with some difficulty. Both contained maize phytoliths.

Starch Grains. Starch grain studies were carried out on a total of 28 samples, including scrapings from the surfaces of metates, insides of sherds, and general midden contexts. Starch analyses followed protocols developed by Dolores Piperno (e.g., Piperno et al. 2000) and identifications were made by reference to Piperno’s large modern reference collections housed at the Smithsonian Institution. Starch grain content was poor in many samples studied (Table 2). Three starch grains with morphological and size features diagnostic of maize were isolated from one of the midden scrapings (Sample FS 42) and five other samples each had one or two starch grains with attributes consistent with those of maize. However, sample size is not large enough to make a definitive identification. (See Piperno et al. 2000 and Holst et al. 2007 for descriptions of the maize identification technique.) In other samples where starch was present the grains could not be identified to a taxon either because the grains were damaged or because the type present is not currently represented in our modern reference collections. No starch diagnostic of manioc tubers was recovered. Given the apparent poor preservation of the starch remains, this is not surprising.

Detailed phytolith studies require a separate processing technique, but some phytoliths are typ-
ically separated with starch grain procedures and they were observed in some of the samples. A few “wavy-top” and “ruffle-top” phytoliths diagnostic of maize cobs (Pearsall et al. 2003) were identified in two samples, FS 46 and FS 47, and large-sized Variant 1 cross-shaped phytolith characteristic of maize leaves (Piperno 2006) occurred in FS 40 and FS 41. The phytolith data extend the record of maize beyond that provided by the limited starch grain record.

**Summary, Conclusions**

Certainly the most important discovery of this research is the extensive area outside the village devoted exclusively to monocrop manioc cultivation in sloping elevated planting beds. It is now clear that manioc was a staple at Cerén. It is highly unlikely that manioc was a staple crop only at Cerén, and manioc may be more suitable as a crop in parts of the Maya area that are less moist than Cerén. Unfortunately, root crops such as manioc are very difficult to detect in the archaeological record. Durable indicators of manioc processing are being sought. The magnitude of the manioc harvest, just completed about a week or so before the Loma Caldera volcanic vent erupted, was very great. What the villagers did with such volumes of manioc tubers is unknown, along with how it was processed, stored, exchanged, and consumed. The fine-grained moist tephras of the Loma Caldera eruption preserved the occasional manioc stalk and some manioc tubers that were left behind after harvesting. Those moist layers were deposited at 100° Celsius, followed by extremely hot layers deposited at over 575° Celsius. Evidently those layers destroyed most fresh pollen and starch grains because they are largely water. Only a few durable pollen and starch grains consistent with maize survived. Some phytoliths from maize cobs and leaves were identified.

In contrast to the sparse preservation of pollen and starch grains are the results of carbonized plant macrofossil analyses, where 1,557 were identified.
in flotation samples from the small Op P midden. Maize and especially beans were abundant, with squash and bottle gourd also found. Tree fruits were identified, including jocote, avocado, and nanse. Many species are common outside and inside the village, but it is notable that jocote was found only outside the village in these samples. And of course the striking disjuncture is how few manioc plants were growing inside the village and how abundant it was outside.

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