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 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 período 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 oquedades, 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

Payson Sheets ■ Department of Anthropology, University of Colorado, Boulder CO 80309-0233 (sheetsp@colorado.edu)
David Lentz ■ Department of Biological Sciences, University of Cincinnati, Cincinnati, OH 45221
Dolores Piperno ■ Program in Human Ecology and Archaeobiology, Department of Anthropology, Smithsonian National Museum of Natural History, Washington DC 20560, and Smithsonian Tropical Research Institute, Balboa, Republic of Panama
John Jones ■ Department of Anthropology, Washington State University, Pullman, WA 99164
Christine Dixon ■ Department of Anthropology, University of Colorado, Boulder CO 80309-0233
George Maloof ■ Instituto Costariccense de Electricidad, San José, Costa Rica
Angela Hood ■ Department of Anthropology, University of Cincinnati, Cincinnati OH 45221

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tuvieron pocas alternativas para procesar esta gran cantidad de mandioca. Es probable que una parte de la cosecha se haya consumido en la comunidad, pero un pequeño asentamiento de entre 100 a 200 personas no habría podido consumir una gran cantidad de tubérculos en tan corto tiempo. Es también posible que cierta porción de la cosecha se hubiera transportado rápidamente a otros pueblos o a los mercados de los centros regionales cercanos. Dos centros regionales con mercados se localizan respectivamente unos 5 km al sur y al norte de Cerén. Una posibilidad más es que los agricultores de Cerén hayan procesado la mandioca hacia un polvo que llaman almidón, *el cual puede almacenarse por tiempo indefinido mientras se mantenga seco. Otra cantidad de mandioca pudo haberse fermentado para ser consumida como bebida alcohólica durante la ceremonia de la primera cosecha del asentamiento, la cual se vio interrumpida por la erupción volcánica. Hemos identificado que una ceremonia de primicias, quizás una versión de la ceremonia maya tradicional "Cuch", estaba en marcha en la Estructura comunitaria 10. Con estos nuevos hallazgos, la mandioca de Cerén ya no puede considerarse únicamente como un suplemento dietético ocasional sino como un cultivo primario. Cerén se localiza en una franja de alta precipitación, que no es la más ideal para el cultivo de mandioca. Esto nos hace pensar que otras áreas de la zona maya, así como otras regiones neotropicales de México y Centroamérica, con precipitaciones menores a 1500 mm, hayan sido más propicias para el cultivo de la mandioca de lo que fue en Cerén. Para contrarrestar la alta precipitación, los antiguos cultivadores de Cerén preparaban sus camellones para el cultivo de mandioca con una pendiente de entre seis y 10º que facilitaba su desagüe.*

The ancient, historic, and contemporary Maya emphasize maize as their primary staple, and maize is the very stuff of which they were created by the deities. Maize preserves better than some other cultigens in the archaeological record, due in part to the multiplicity of plant fossils that identify its presence, such as macroremains, phytoliths, starch grains, and pollen. Most Mayanists until the mid-twentieth century believed swidden cultivation of these seed crops was sufficient to feed the assumed low population densities of the ancient Maya. However, surveys initiated during the 1950s and 1960s encountered vastly greater numbers of housemounds than anticipated (Willey 1982), indicating populations larger than could be fed by swidden with seed crops. The efforts to explore what could have fed such dense populations, estimated to be in the many hundreds per square kilometer (Culbert and Rice 1990), took two routes. Many scholars searched for evidence of agricultural intensification, and found terracing, raised fields as swamp reclamation systems, and water control features. Other scholars explored food sources other than seed crops, such as Bronson (1966) who proposed root crops as subsistence alternatives. Bronson's suggestion was greeted with a burst of enthusiasm, but researchers found scant direct evidence to support it. Because root crops are often planted by stem cuttings, often do not have hard parts that carbonize well, and often produce few or no diagnostic seeds, phytoliths, or pollen, they are exceptionally difficult to detect in the archaeological record.

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 maize 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-

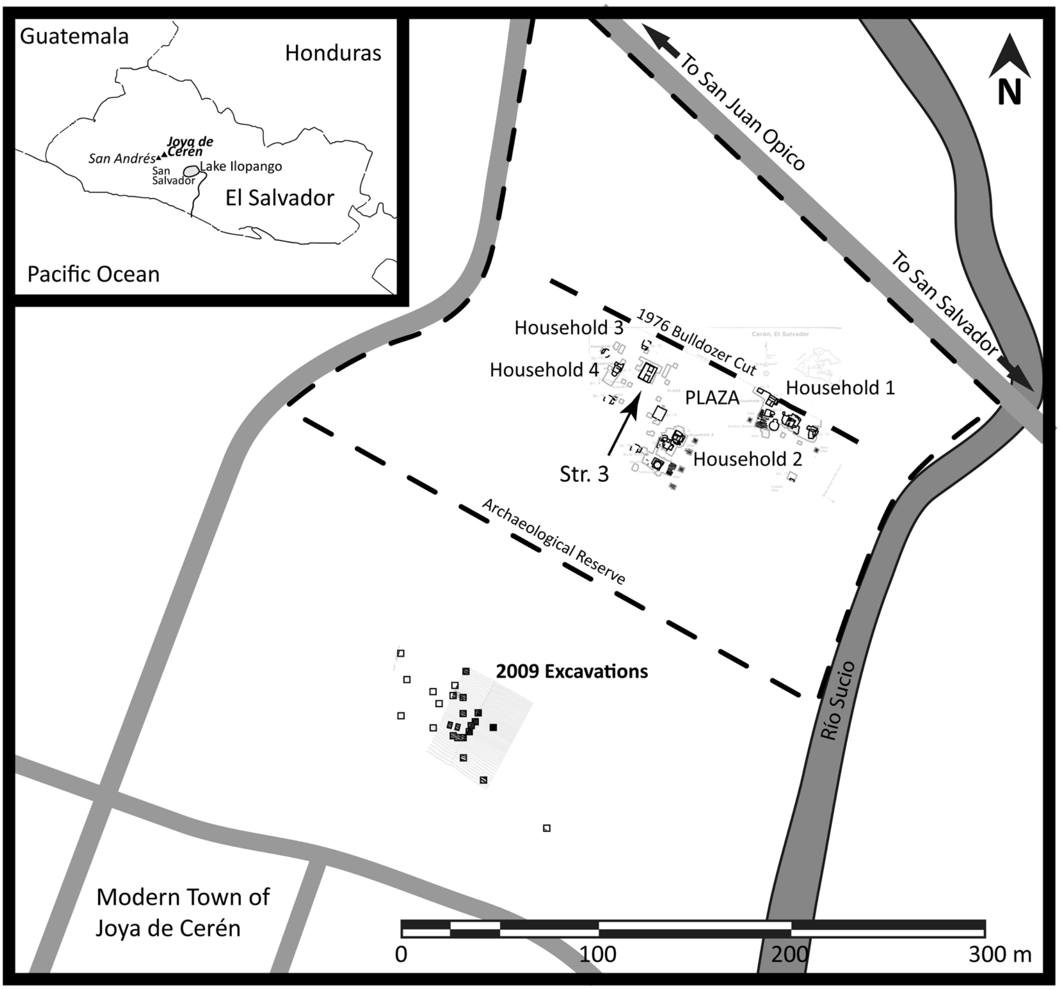

Figure 1. Map of the Ceren site, with the excavated part of the ancient village toward the top, and the 2009 excavations toward the south.

imented 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

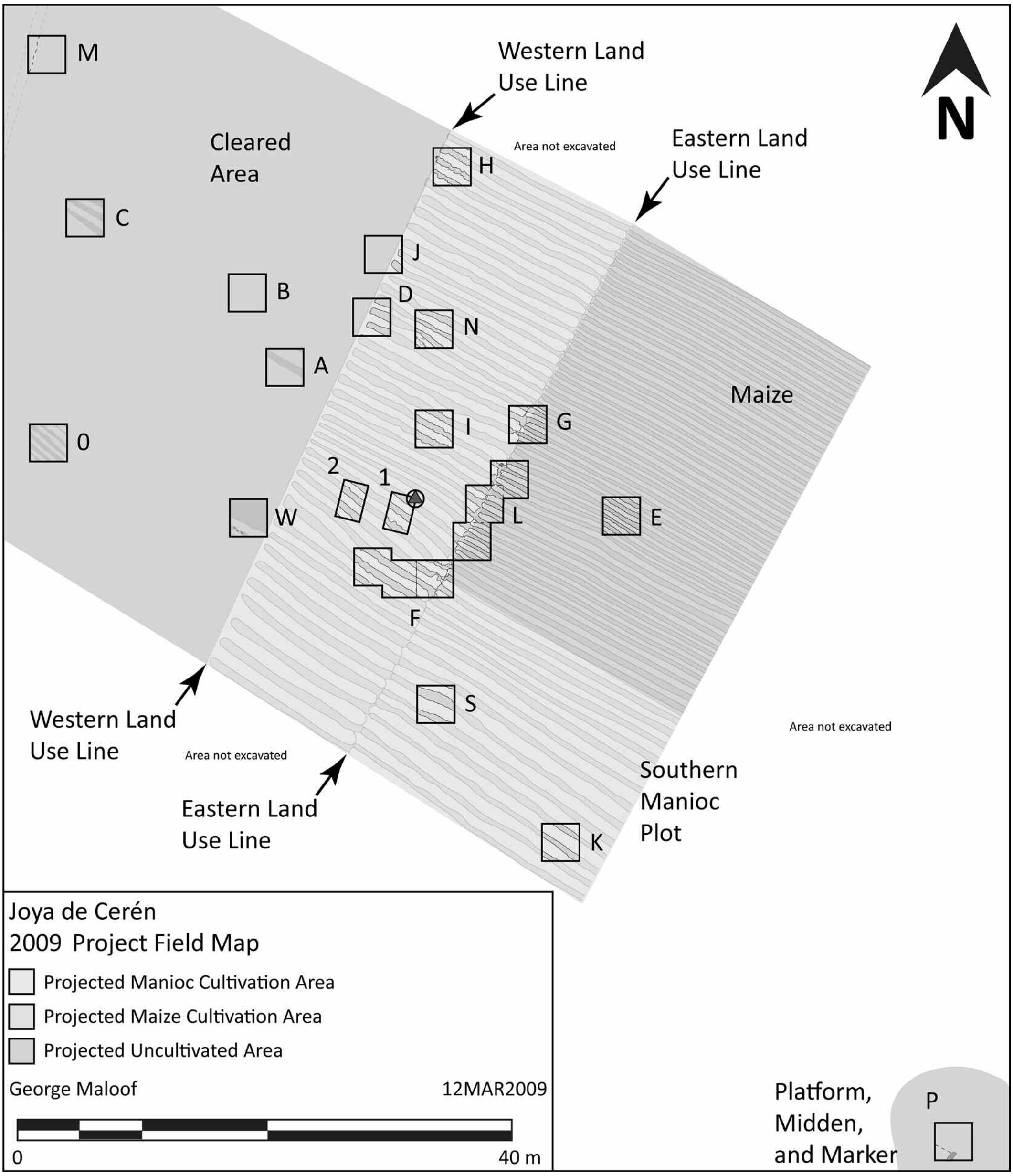

Figure 2. Map of the 2009 excavations, with cleared areas and platforms to the west and the southeast. The manioc beds are in the center.

derived from those surveys. Black (1983:82) estimated average population densities in the Zapotitan 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 ethnographically 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'iXn*," was found in all major branches of Maya languages, indicating widespread utilization, and perhaps significant time depth. Flannery (1982:xix) noted the surge of interest in manioc among Mesoamericanists after Bronson's publication, but criticized scholars who "believed on faith [in precolumbian manioc cultivation] 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 outsiders may have introduced it during the Postclassic period, or even that the Spanish may have introduced 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 mixture 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 intercropping, mimicking the species diversity of the rainforest.

Fedick (1996) provides a detailed understanding 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 domesticated 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 manioc. 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 lowlands 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, dating to about 3400 B.C. and *Manihot* pollen was discovered 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 Mesoamerica, the discovery of *Manihot* pollen should not automatically be interpreted as the domesticated crop. The context of the grains in ancient field settings 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 Mesoamerica 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) identified some carbonized organic materials at Cuello as fragments of manioc stems, but he did not know if they were wild or domesticated. Hather and Hammond (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 elsewhere (Lentz et al. 1996; Lentz and Ramírez-Sosa

2002), 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 stalks. 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 saggitate 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 officianale [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.

Specialty 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 annum* 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 testpits, 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 equaled the care in cultivation and in 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 adobe 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 (Maloof 2009). In striking contrast to the high-density manioc agriculture adjacent to it, Cerén 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 (Maloof 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 some shade for a few square meters of platform.

Four of the nine excavations in the cleared area contained evidence of cultivation at some time prior to the eruption (Ops A, C, O, and W) (Maloof 2009). Faint remnants of agricultural ridges remained, well trampled by activities in the months or more likely years after they had been abandoned, before the eruption. Although the smoothed ridges were barely perceptible, their spacing indicated that three of them had been planted in manioc (Ops A, C, and W). The very close spacing in Op O was tighter than even maize ridge spacing, and the prior cultigen or cultigens are unknown, but could have been small vegetables.

Ops B and M also encountered cleared surfaces, and those surfaces were so flattened that no vestiges of prior cultivation ridges could be detected. That flattening could have been deliberate, or inadvertent by considerable foot traffic over a long period of time. In the upper (western) end of Op M the remnants of a possible footpath leading toward the village core were identified (Maloof 2009). The foot path followed a trajectory of roughly 15° east of north toward the archaeological site. The path appeared to continue in the other direction, to the southwest. Thus, the footpath could have provided Cerén villagers access to their

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.

fields and harvest processing areas. Also, residents of the modern village of Joya de Cerén 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 Cerén, 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 Cerén. A maize field was identified to the east of the manioc beds discovered in 2007 (Figure 2). The eruption preserved much of

Figure 4. Operation P, with a volunteer manioc plant's stalk at the top, a large adobe block on the left, thin sheet midden, and 25 cm scale.

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-

Figure 5. Plaster cast of a Ceren manioc stem from Operation P on the left, and modern manioc stem on the right. Note prominent leaf scars arranged in spiral pattern on the modern stem. Arrows indicate prominent leaf scars in spiral pattern on plaster cast.

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

Figure 6. Planting stalk and manioc tuber from Test Pit #1, 10 cm scale.

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 30º east of north.

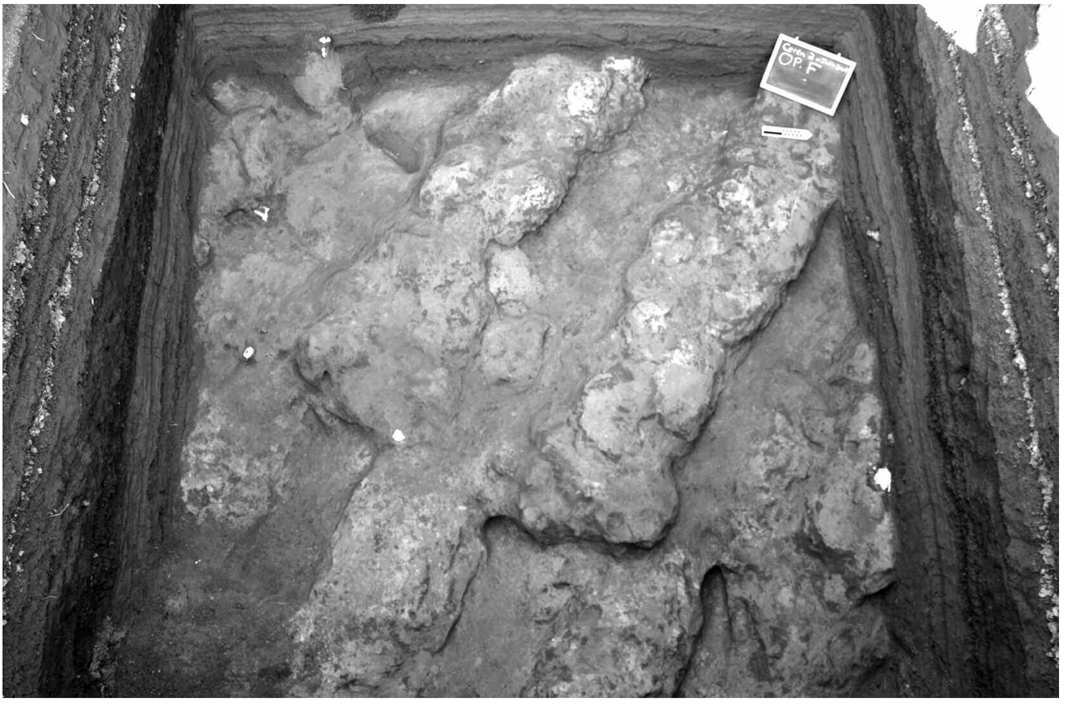

Figure 8. Operation F, intersection of harvested manioc beds of two farmers. Drainage is upper right to lower left. Scale 25 cm.

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

Figure 9. Operation F, closeup of intersection in Figure 8, and small waterfall lower right. Scale 10 cm.

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 Chunchucmil 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 Chunchucmil than at Cerén. A few striations similar to those on the Chunchukmil 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

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.

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 portion, 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 Macroremains. A large quantity of carbonized plant macroremains—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 macroremains 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 macroremains were transported back to David Lentz's Plant

Resources Laboratory at the University of Cincinnati for further analysis. All plant macroremains initially were sorted based on a broad classification separating wood charcoal, seeds, rinds, pits, roots, stems, leaves, and amorphous plant tissue with the aid of a stereomicroscope (8–50X magnification) illuminated by a fiber optic light. Wood charcoal was removed from the assemblage for this study to be examined further with scanning electron microscopy. Once sorted into these broad categories, each plant macroremain was individually analyzed for morphological and anatomical features indicating the plant's taxonomic name and part, with references made to Lentz's collection of comparative plant materials from Central America.

A total of 1,557 plant macroremains was identified from the sub-TBJ midden assemblage in Operation P, including seeds, pits, roots, stems, and leaves (Table 1). The major cultigens traditionally thought to have comprised the ancient Maya diet—maize (*Zea mays* L.), beans (*Phaseolus* spp.), and squash (*Cucurbita* sp.)—are present in the assemblage, although maize and beans are the most abundant 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 recovered from the midden. 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 archaeological record of ancient Maya sites because the process of their preparation, soaking and boiling rarely leads to carbonization and subsequent preservation (Hammond and Miksecik 1981:268). The paucity of beans recovered from sites throughout the Maya area with well-studied paleoethnobotanical records such as Copán, 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 preservation of such large numbers of beans in the Operation 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 disturbances while Cerén was occupied. The Loma Caldera eruption further buried the feature, eliminating post-occupational disturbances.

A gourd rind (*Lagenaria siceraria* [Mol.] Standl.), a plant commonly found in archaeological contexts in Mesoamerica, was also recovered from the midden. Identified in larger quantities from Household 1 and Structure 11 (a food preparation 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, including *jocote* or hog plum (*Spondias* sp.), avocado (*Persea Americana* Miller), and *nance*. The presence 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 (*Crescentia alata* H.B.K.) in the village. *Spondias* fruits are eaten raw and grow in bountiful quantities throughout Central America (Standley and Steyermark 1949:193–194). 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 preservation 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 residents routinely cleaned all activity surfaces of food waste and other debris. Perhaps more likely, *Spondias* 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 Operation 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.

Taxon	Common Name(s)	Parts	# of Samples	Total Weight of Samples (g.)	Context
Anacardiaceae					
Spondias sp.	Jocote, hog plum	Pit	6	.24	Operation P Sub-TBJ midden
Cucurbitaceae:					
Cucurbita sp.	Squash, ayote	Rind	9	.22	Operation P sub-TBJ midden
Lagenaria sp.	Gourd, tecomate	Rid	1	.01	Operation P sub-TBJ midden
Dicot		Charcoal, stem, rind	10	.03	Operation P sub-TBJ midden
Fabaceae:					
Phaseolus sp		Cotyledon	1129	11.35	Operation P sub-TBJ midden
Phaseolus lunatus	Lima bean, frijol de media luna	Cotyledon	6	.15	Operation P sub-TBJ midden
Phaseolus vulgaris	Common bean, frijol	Cotyledon	133	4.43	Operation P sub-TBJ midden
Lauraceae:					
Persea Americana	Avocado, aguacate	Pit	1	.20	Operation P sub-TBJ midden
Malpighiaceae:					
Byrsonima crassifolia	Nance	Pit	1	.02	Operation P sub-TBJ midden
Monocot		Charcoal, stem	5	.03	Operation P sub-TBJ midden
Poaceae:					
Zea mays	Maize, maiz	Kernel, cupule, leaf	256	3.79	Operation P sub-TBJ midden

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 batata* [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 envaginated 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 macroremains, 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 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), *Cheno-Ams* (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 *Acrocomia* 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-

Table 2. Starch Grain Analyses by Dolores Piperno.

FS #	Location	Source of Sample	Results
FS 5	295-1-84	Metate scraping	No starch
FS 6	295-1-221	Metate scraping	11 starch grains
FS 7	295-1-116	Metate scraping	2 starch grains
FS 8	295-1-265	Metate scraping	1 starch grain, consistent w maize
FS 9	295-8-623	Metate scraping	No starch
FS 18	op-p-1	Sherd 1-soil underneath	No starch
FS 19	op-p-1	tbj level laja underside scraping	1 starch grain, consistent w maize
FS 20	op-p-1	tbj level laja underside scraping	No starch
FS 36 *	op-p-1	sub tbj midden beneath monolith	1 starch grain
FS 37 *	op-L-1	Sediment	No starch
FS 38 *	op-p-1	ash lens NW corner	1 starch grain, consistent w maize
FS 39	op-L-1	vessel sherd scraping	No starch
FS 40	op-p-1	sub tbj midden sherd #6 scraping	No starch
FS 41	op-p-1	sub tbj midden sherd #5 scraping	No starch
FS 42	op-p-1	sub tbj midden scraping from vessel #4	3 starch grains, maize
FS 43	op-p-1	vessel #3 inside scraping	No starch
FS 44	op-p-1	Scraping from inside burned sherd #2	No starch
FS 45	op-p-1	Scraping inside burned sherd #1	No Starch
FS 46 *	op-p-1	sub tbj midden olla jar top scraping	No starch
FS 47 *	op-p-1	sub tbj midden scraping laja #4	No starch
FS 48 *	op-p-1	sub tbj midden scraping laja #3	No starch
FS 49 *	op-p-1	Below tbj midden from inside vessel holder	No starch
FS 50	op-p-1	sub tbj midden scraping laja #5	No starch
FS 51 *	op-p-1	sub tbj midden scraping laja #2	1 starch grain
FS 52	op-p-1	sub tbj midden scraping laja #1	No starch
FS 53	op-p-1	sub tbj midden sherd #2 scraping (interior)	1 starch grain, consistent w maize
FS 54	op-p-1	Blackened potsherd scraping #1	2 starch grains, consistent w maize
FS 55	op-p-1	sub tbj midden scraper	No starch

* some sample left

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 tephra layers 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 nance. 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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References Cited

Beaudry-Corbett, Marilyn
2002 Ceramics and Their Use at Cerén. In *Before the Volcano Erupted: The Cerén Village in Central America*, edited by Payson Sheets, pp. 117–138. University of Texas Press, Austin.

Black, Kevin
1983 The Zapotitan Valley Archaeological Survey. In *Archeology and Volcanism in Central America: The Zapotitan Valley of El Salvador*, edited by Payson Sheets, pp. 62–97. University of Texas Press, Austin.

Bozarth, Stephen
1987 Diagnostic Opal Phytoliths from Rinds of Selected *Cucurbita* Species. *American Antiquity* 52:607–615.

Bronson, Bennet
1966 Roots and the Subsistence of the Ancient Maya. *Southwestern Journal of Anthropology* 22:251–279.

Bryant, Vaughn M., Jr., Richard G. Holloway, John G. Jones, and David L. Carlson
1994 Pollen Preservation in Alkaline Soils of the American Southwest. In *Sedimentation of Organic Particles*, edited by Alfred Traverse, pp. 47–58. Cambridge University Press, Cambridge.

Cock, James
1982 Cassava: A Basic Energy Source in the Tropics. *Science* 218:755–762.

Crane, Cathy
1996 Archaeobotanical and Palynological Research at a Late Preclassic Maya Community, Cerros, Belize. In *The Managed Mosaic: Ancient Maya Agriculture and Resource Use*, edited by Scott Fedick, pp. 262–277. University of Utah Press, Salt Lake City.

Culbert, T. Patrick, and Don Rice (editors)
1990 *Precolumbian Population History in the Maya Lowlands*. University of New Mexico Press, Albuquerque.

Cutler, Hugh C., and Thomas W. Whitaker
1961 History and Cultivation of the Cultivated Cucurbits in the Americas. *American Antiquity* 26:469–485.

DeBoer, Warren
1975 The Archaeological Evidence for Manioc Cultivation: A Cautionary Note. *American Antiquity* 40:419–432.

de Landa, Bishop Diego
1938 *Relación de las cosas de Yucatán*. Edición Yucateca, Mérida.

Dickau, Ruth, Anthony Ranere, and Richard Cooke
2007 Starch Grain Evidence for the Preceramic Dispersals of Maize and Root Crops into Tropical Dry and Humid Forests of Panama. *Proceedings of the National Academy of Sciences*, 104:3651–3656.

Dixon, Christine C.
2007 Classic Period Maya Agriculture: Test Pits 1 and 2, 5 and 6. In Joya de Cerén 2007 Preliminary Report, edited by Payson Sheets. Unpublished manuscript, Department of Anthropology, University of Colorado at Boulder.
2009 Manioc Agriculture. In *Report of the 2009 Maya Agriculture Project South of Joya de Cerén, El Salvador*, edited by Payson Sheets, pp. 50–82. Electronic document, http://www.colorado.edu/Anthropology/people/biosdocuments/2009ReportJoyadeCeren.pdf, accessed January 16, 2011.

Dufour, Darna
1994 Cassava in Amazonia: Lessons in Utilization and Safety from Native Peoples. *Acta Horticulturae* 375:175–182.

Dull, Robert, John Southon, and Payson Sheets
2001 Volcanism, Ecology, and Culture: A Reassessment of the Volcan Ilopango TBJ Eruption in the Southern Maya Realm. *Latin American Antiquity* 12:25–44.

Dull, Robert, John Southon, Steffen Kutterolf, Armin Freundt, David Wahl, and Payson Sheets
2010 Did the Ilopango TBJ Eruption Cause the AD 536 Event? Paper presented at the American Geophysical Union conference, San Francisco.

Evans, Susan
2008 *Ancient Mexico and Central America: Archaeology and Culture History*. Thames & Hudson, New York.

Fedick, Scott (editor)
1996 *The Managed Mosaic: Ancient Maya Agriculture and Resource Use*. University of Utah Press, Salt Lake City.

Flannery, Kent
1982 Preface. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by Kent Flannery, pp. xvii–xxii. Academic Press, New York.

Girard, Rafael
1952 *El Popol-Vuh, fuente histórica*. Editorial del Ministerio de Educación Pública, Guatemala.

Hammond, Norman, and Charles H. Miksicek
1981 Ecology and Economy of a Formative Maya Site at Cuello, Belize. *Journal of Field Archaeology* 8:260–269.

Hather, Jon, and Norman Hammond
1994 Ancient Maya Subsistence Diversity: Root and Tuber Remains from Cuello, Belize. *Antiquity* 68:330–335.

Henry, Amanda, Holly Hudson, and Dolores Piperno
2009 Changes in Starch Grain Morphologies from Cooking. *Journal of Archaeological Science* 36:915–922.

Holst, Irene, J.Enrique. Moreno, and Dolores R. Piperno
2007 Identification of Teosinte, Maize, and Tripsacum in

Mesoamerica by Using Pollen, Starch Grains, and Phytoliths. *Proceedings of the National Academy of Sciences* 104:17608–17613.

Hutson, Scott, Travis Stanton, Aline Magnoni, Richard Terry, and Jason Craner
2007 Beyond the Buildings: Formation Processes of Ancient Maya Houselots and Methods for the Study of Non-architectural Space. *Journal of Anthropological Archaeology* 26:442–473.

Lentz, David L.
1991 Maya Diets of the Rich and Poor: Paleoethnobotanical Evidence from Copan. *Latin American Antiquity* 2:269–287.

Lentz, David, Marilyn Beaudry-Corbett, María Reyna de Aguilar, and Lawrence Kaplan
1996 Foodstuffs, Forests, Fields, and Shelter: A Paleoethnobotanical Analysis of Vessel Contents from the Cerén site, El Salvador. *Latin American Antiquity* 7:247–262.

Lentz, David L., and Carlos R. Ramírez-Sosa
2002 Cerén Plant Resources: Abundance and Diversity. In *Before the Volcano Erupted: The Ancient Cerén Village in Central America*, edited by Payson Sheets, pp. 33–42. University of Texas Press, Austin.

Lentz, David L., Sally Woods, Angela Hood, and Marcus Murph
2012 Agroforestry and Agricultural Production of the Ancient Maya at the Chan Site. In *Chan: An Ancient Maya Farming Community in Belize*, edited by Cynthia Robin, pp. 89–112. University of Florida Press, Gainesville.

Lewenstein, Suzanne
1987 *Stone Tool Use at Cerros: The Ethnoarchaeological and Use-wear Evidence*. University of Texas Press, Austin.

Maloof, George O.
2009 Platforms, Walkways & Other Cleared Areas. In *Report of the 2009 Maya Agriculture Project, South of Ceren, El Salvador,* edited by Payson Sheets, pp. 34–49. Electronic document, http://www.colorado.edu/Anthropology/people/bios/documents/2009ReportJoyade-Ceren.pdf, accessed June 2, 2011.

Marcus, Joyce
1982 The Plant World of the Sixteenth and Seventeenth-Century Lowland Maya. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by Kent Flannery, pp. 239–274. Academic Press, New York.

Miksicek, Charles
1991 The Natural and Cultural Landscape of Preclassic Cuello. In *Cuello: An Early Maya Community in Belize*, edited by Norman Hammond, pp. 70–84. Cambridge University Press, Cambridge.

Morley, Sylvanus
1946 *The Ancient Maya*, 1st ed. Stanford University Press, Stanford.

Olsen, Ken M.
2002 Population History of *Manihot esculenta* (Euphorbiaceae) Inferred from Nuclear DNA Sequences. *Molecular Ecology* 11: 901–911.

Olsen, Ken M., and Barbara Schaal
1999 Evidence on the Origin of Cassava: Phylogeography of *Manihot esculenta*. *Proceedings of the National Academy of Sciences* 96:5586–5591.

Pearsall, Deborah M.
2000 *Paleoethnobotany: A Handbook of Procedures*. 2nd ed. Academic Press, San Diego.

Pearsall, Deborah M., Karol Chandler-Ezell, and Alex Chandler-Ezell
2003 Identifying Maize in Neotropical Sediments and Soils Using Cob Phytoliths. *Journal of Archaeological Science* 30:611–627.

Perry, Linda
2005 Reassessing the Traditional Interpretation of "Manioc Artifacts in the Orinoco Valley of Venezuela. *American Antiquity* 16:409–426.

Piperno, Dolores
2006 *Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists*. AltaMira, Lanham, Maryland.

Piperno, Dolores, and Deborah M. Pearsall
1998 *The Origins of Agriculture in the Lowland Neotropics*. Academic Press, San Diego, California

Piperno Dolores, Anthony Ranere, Irene Holst, and Pat Hansell
2000 Starch Grains Reveal Early Root Crop Horticulture in the Panamanian Tropical Forest. *Nature* 407:894–897.

Pohl, Mary, Kevin Pope, John Jones, John Jacob, Dolores Piperno, Susan DeFrance, David Lentz, John Gifford, Marie Danforth, and Kathryn Josserand
1996 Early Agriculture in the Maya Lowlands. *Latin American Antiquity* 7:355–372.

Pope, Kevin, Mary Pohl, John Jones, David Lentz, Christopher von Nagy, Francisco Vega, and Irvy Quitmyer
2001 Origin and Environmental Setting of Ancient Agriculture in the Lowlands of Mesoamerica. *Science* 292:1370–1374.

Sharer, Robert, with Loa Traxler
2006 *The Ancient Maya*. Stanford University Press, Stanford, California.

Sheets, Payson
2002 Summary and Conclusions. In *Before the Volcano Erupted: The Ancient Cerén Village in Central America,* edited by Payson Sheets, pp. 197–206. University of Texas Press, Austin.
2006 *The Ceren Site: An Ancient Village Buried by Volcanic Ash in Central America*. 2nd ed. Thomson Wadsworth, Belmont, California.
2009 Considerations, Summary, and Conclusions. In *Report of the 2009 Maya Agriculture Project, South of Joya de Ceren, El Salvador*, edited by Payson Sheets, pp. 121–125, Electronic document, http://www.colorado.edu/Anthropology/people/bios/documents/2009ReportJoyade-Ceren.pdf, accessed June 2, 2011.

Sheets, Payson, Christine Dixon, Adam Blanford, and Mónica Guerra
2007 Descubrimientos de investigaciones geofísicas y arqueológicas al sur de Joya de Cerén. *El Salvador Investiga* 3(6):20–26.

Sheets, Payson, Christine Dixon, Mónica Guerra, and Adam Blanford
2011 Manioc Cultivation at Ceren, El Salvador: Occasional Kitchen Garden Plant or Staple Crop? *Ancient Mesoamerica* 22:1–11.

Sheets, Payson, and Michelle Woodward
2002 Cultivating Biodiversity: Milpas, Gardens, and the Classic Period Landscape. In *Before the Volcano Erupted: The Ancient Cerén Village in Central America*, edited by Payson Sheets, pp. 184–191. University of Texas Press, Austin.

Standley, Paul C., and Julian A. Steyermark
1949 Flora of Guatemala. *Fieldiana: Botany* Vol. 24, Part 6. Field Museum of Natural History, Chicago.

Stevens, John, and Frederick Catherwood
1841 *Incidents of Travel in Central America, Chiapas, and Yucatan*. Harper & Brothers, New York.

Tetlow, Andrew P., and Angela N. Hood
2009 Classic Period Maize Agriculture South of Joya de Cerén. In *Report of the 2009 Maya Agriculture Project South of Joya de Cerén, El Salvador*, edited by Payson Sheets, pp. 9–33. Electronic document, http://www.col-

orado.edu/Anthropology/people/biosdocuments/2009ReportJoyadeCeren.pdf, accessed January 16, 2011.

Thompson, J. Eric S.
1958 *Thomas Gage's Travels in the New World*. University of Oklahoma Press, Norman.

Wilken, Gene
1971 Food-producing Systems Available to the Ancient Maya. *American Antiquity* 36:432–448.

Willey, Gordon
1982 Dennis Edward Puleston (1940–1978): Maya Archaeologist. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by Kent Flannery, pp. 1–15. Academic Press, New York.

Williams, Louis O.
1981 The Useful Plants of Central America. *Ceiba* 24 (1–2): 1–342.

Wisdom, Charles
1940 *The Chorti Indians of Guatemala*. University of Chicago Press, Chicago.

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