THE PRODUCTIVITY OF MAGUEY TERRACE AGRICULTURE IN CENTRAL MEXICO DURING THE AZTEC PERIOD

Susan T. Evans

Maguey cultivators in the Basin of Mexico during the Middle and Late Postclassic (A.D. 1150–1521) periods pioneered the more agriculturally marginal parts of the environment, such as the sloping piedmont zone around the alluvial plain. In their land-use strategy, terraced interplantings of maguey and grain formed the house gardens (calmijll) of their villages. These villages were established sometime around the twelfth century, and by the time of Spanish Conquest they covered the piedmont zones of the Teotihuacan Valley, Texcoco region, and similar areas of the Basin of Mexico. Archaeological and ethnographic evidence permit reconstruction of the caloric productivity of this interplanted terrace system, using modern maguey yields. This productivity is compared with the needs of the maguey cultivators by looking at a particular archaeological example, the Aztec period village of Chiuhtecapan, in the Teotihuacan Valley.

Los cultivadores de maguey en el valle de México durante el período Postclásico (1150–1521 D.C.) fueron los primeros en ocupar las zonas agrícolas marginales de este ambiente como el somonte inclinado circunvecino a la planicie aluvial. Su estrategia de colonización consistía en entrecultivos de maguey y maíz en terrazas agrícolas. Sus casas estaban dispersas sobre el sistema de terrazas que en efecto formaban los huertos domésticos (calmiji) de sus poblados. Este patrón de asentamiento facilitaba a los residentes del poblado el cultivo de sus huertos domésticos y el mantenimiento de las terrazas. Poblados de esta forma fueron fundados durante el siglo doce, y para el tiempo de la conquista española cubrían el somonte del valle de Teotihuacan, la región de Texcoco, y áreas similares.

El tema de este estudio es uno de estos poblados llamado Chiuhtecapan que se localiza en la parte oriental del valle de Teotihuacan. Las 200 casas de Chiuhtecapan estaban dispersas sobre el sistema de terrazas cubriendo un área de 3.3 km² del terreno inclinado del Cerro San Lucas. La evidencia para el cultivo del maguey en esta región durante el período Azteca consiste en documentos etnohistóricos, y en material arqueológico como raspadores de obisidiana y basalto para la extracción de aguamiel y husos de cerámica para la preparación de fibra de maguey.

La productividad calórica de cultivos mixtos de maguey y grano durante el período Azteca se puede calcular de valores obtenidos en México durante el presente. En terrenos marginales el valor calórico de cultivos mixtos es más que el doble de los mismos valores obtenidos de cultivos de maíz solo. Cuando estos valores de productividad calórica son aplicados a los terrenos inclinados de Chiuhtecapan los resultados se pueden comparar con los requerimientos de la población estimada de este pueblo.

El modelo resultante de productividad calórica demuestra que Chiuhtecapan y otros pueblos de terraza podrían haber sido autosuficientes con respecto a sus requerimientos de comida así como en la manufactura de artículos de maguey y otros recursos.

Carl Sauer (1963:110) once wrote that maguey permitted settled life in the arid central highlands of Mexico. Where no other water or food is available, maguey (agave, century plant; Agave atrovirens and others) thrives and sustains human life, and beyond this subsistence role the plant provides medicine, fiber, building material, fuel, and even fertilizer from its ashes. Maguey cultivators in the Basin of Mexico during the Late Postclassic period (or Late Horizon, ca. A.D. 1150–1521) pioneered the more agriculturally marginal parts of the environment (such as the sloping piedmont zone around the alluvial plain) with a land-use strategy involving terraced interplantings of maguey and grain over the hillsides of their villages. Probably established in the twelfth and thirteenth centuries, these villages covered the piedmont of the Teotihuacan Valley, Texcoco piedmont, and similar areas of the Basin of Mexico by the time of Spanish Conquest. Archaeological and ethnographic evidence

Susan T. Evans, Department of Anthropology, The Pennsylvania State University, University Park, PA 16802

Copyright © 1990 by the Society for American Archaeology
permit us to reconstruct maguey's contribution to the caloric needs of the maguey farmers and apply this productivity value to an archaeological case, the Aztec period village of Cihuatepecan in the Teotihuacan Valley. The reconstruction is based on modern maguey yields and ancient settlement patterns.

The resulting model of Cihuatepecan's caloric requirements and productivity demonstrates the village's adaptive success in using this mixed agricultural strategy. Maguey farming permitted the village to be calorically self-sustaining, and the sap offered necessary liquid refreshment in a semiarid zone and added to the nutritional balance. The plant also provided the raw materials for a variety of crafts. Maguey was a crucial part of the economic base of this and many similar villages and secured Cihuatepecan's economic prosperity, evident in archaeological remains such as well-made, nicely finished houses. In spite of the marginality of this environment, the village could depend on its own land to support itself and also produce surplus goods.

HISTORICAL BACKGROUND

The large and complex structure of Aztec period society in Mexico rested on a base of peasant productivity. Feeding and fueling the huge capital, Tenochtitlan, and other large cities were the jobs of rural villagers who worked the land of the Basin of Mexico (Figure 1). Intensification practices and exploitation of locally available resources gave these peasant villagers a mixed economy, in many areas ensuring local prosperity while providing the larger society with valuable goods and services. The flow of goods and services through the peasant sector and upward ramified and intensified as sociopolitical complexity increased in the last century before Spanish Conquest. The fifteenth and early sixteenth centuries were a time of maturity for these villages, which had been established in the Late Toltec period.

Population growth was derived from intrinsic increase and from migration into the basin during this period (A.D. 950–1150; Sanders et al. 1979:93, 137–149). The peasant villages founded then made use of thinly settled parts of the basin that were relatively marginal for grain cultivation when undeveloped, but which had considerable productive potential, given application of intensification practices such as drainage agriculture (in the swampy southern lakes of the basin) and terracing on the sloping piedmont surrounding the basin's alluvial plain.

These peasant villages were the building blocks of the cultural system's foundation and the fundamental units of production for the basic goods and labor of the society. Political control of the rural hinterland was an important prize in the ongoing struggles among the most powerful polities of the basin. It is important to note that prosperity of rural villages depended on the success of their strategies of land use, and these show an ingenious interplay of economic production and habitation.

In the terraced villages of the semiarid Teotihuacan Valley, for example, remains of housemounds distributed over the village's sloping arable land (Figure 2) indicate a probable pattern of small house lot gardens (called calmlli, singular calmil) surrounding the houses, similar to the dispersed-houselot land-use pattern known ethnographically from modern villages in the same kind of environment. If the ethnographic analogy can be extended, then the Cihuatepecanos probably also had other, larger fields (called milpas) that were part of the village's hillslope land but were not adjacent to their houses.

Cihuatepecan's pattern of houses on terraced lots reached its greatest extent in the early sixteenth century (Figure 3), perhaps 500 years after the village's establishment (according to ceramic chronology, see Evans and Abrams [1988], and obsidian hydration evidence, see Evans and Freret [1989]). The village probably was founded by one of the many bands of migrants from north of the Basin of Mexico, who had abandoned their villages when Toltec power declined. These displaced village agriculturists began to drift south to areas of greater security, to the Basin of Mexico and its adjacent zones to the east and west (Calnek 1982).

The pioneers found many areas of the basin already settled, with some towns of several thousand people, and small hamlets in the countryside. The density of settlement was light in comparison with that during the Late Aztec and Early Colonial periods, and there were still potentially productive
zones not in use and not yet developed into habitable and arable land. Development and settlement of these more marginal lands proceeded apace, and the migrants succeeded in using many such areas ingeniously. The city of Tenochtitlan provides an excellent example of this phenomenon; established in an uninhabited swamp in the fourteenth century (or possibly before [Reyes Cortés and García-Barcena 1979]), its population numbered 150,000–200,000 in 1520 (Calnek 1973:190). Other examples include the development of large-scale chinampa zones (intensive cultivation and settlement) in the marshy lakes of the southern basin (Armillas 1971; Parsons 1976), and the establishment of terraced villages described above (Parsons 1971; Sanders 1965; Sanders et al. 1979).

The expanses of Aztec period terraced settlement along the Teotihuacan Valley’s piedmont apparently began as a discrete set of small Late Toltec period settlements, according to the findings
of the Teotihuacan Valley Project (Sanders 1965). Late Toltec sherds usually comprise a very small component of the ceramic collection from Aztec period villages, but they are found in the core areas of these dispersed villages and evidence the pioneering phase (see also, for example, the Cerro Gordo site [Evans 1985]). The lack of Aztec period dispersed settlement over the alluvial plain might indicate that even in the Toltec period the alluvial plain was reserved for agriculture, with only a few nucleated settlements. The ethnohistorically known Late Aztec pattern of dividing up this area into estates for nobles or for the support of public offices probably was established hundreds of years earlier.

Some time after A.D. 1000 the village of Cihuaticapan was established; small quantities of Late Toltec period wares (Mazapan and Atlatlango types [Evans 1986:314]) were found in the surface and subsurface collections from many of the mounds on the south and southwestern slope. Cihuaticapan thereafter was occupied continuously as a village until the beginning of the seventeenth century. Judging from ceramic material in direct association with architecture, the period of greatest population at Cihuaticapan was in the fifteenth and early sixteenth centuries, when it was a village of about 200 houses, encircling the lower slope of Cerro San Lucas, a small volcanic cone (Figures 3 and 4).

Excavations at Cihuaticapan revealed evidence of several specialized craft activities, in particular obsidian tool production and maguey processing. There were several extensive dumps of gray–black obsidian debitage (one, measuring 25 × 35 m, is described in Abrams [1988]), probably from the Otumba (Estetes) source 3 km away, or from the barrancas nearer the village, where cobbles are readily available. Gray–black obsidian from this area is too highly textured to lend itself well to prismatic blade production, but it is good material for the unifacial and bifacial knives and scrapers that were found at the site (Evans 1988:45), and no doubt were traded away as well.
Gray–black obsidian endscrapers were common and are thought to have been used for maguey sap production. Production of maguey beverages (fresh *aguamiel* and fermented *pulque*) involved collecting the sap from the plants (probably by sucking it into gourds) and then transporting and storing the liquid in large jars. Sherds from large storage jars are common in the village and typically

Figure 3. Cerro San Lucas and the village of Cihuatecpan.

Figure 4. Cerro San Lucas 1.5 km to the northeast, with maguey plants in the foreground (photograph by the author).
have a flaring neck and direct rim (see Evans [1988], and Evans and Abrams [1988] for utilitarian vessel frequencies). Body sherds from jars have not yet been analyzed to determine whether or not were used to store maguey beverages.

Basalt scrapers shaped like modern hoe blades were common at Cihuatépan and were found on the surface and in house excavations (Evans and Abrams 1988). These may have been the special tools for scraping down the maguey leaves (pecans) for fiber. Parsons and Parsons (1985:9, 17) describe modern maguey farmers doing this with a metal tool having a shape similar to that of the basalt scrapers (it is made from a section of automobile leaf spring), and their experimental use of the basalt implement in the scraping process showed it to be effective.

Maguey fiber was made into a variety of products, including woven textiles. We have no direct evidence of weaving at Cihuatépan (looms and other tools were all of perishable materials) but ceramic spindle whorls are common. Of the 122 spindle whorls recovered from excavation in houses, 62 were large, a type Linné assumed was used for maguey fiber (Linné 1934:128, cited in Parsons 1972:61). Parsons and Parsons (1985:35c) substantiated this assumption in their ethnographic studies of modern maguey farmers, and found a direct relation between spindle whorl size and thread thickness. The large spindle whorls at Cihuatépan are yet another indicator of maguey exploitation.

When Cihuatépan and other dispersed villages were at their most extensive, their terraces covered the valley's piedmont, and they held half the population of the Teotihuacan Valley (over 60,000 people out of a total of about 130,000 [Evans 1980:155]). The villages were patterned so as to take maximum economic advantage of a semiarid area, marginal for grain crop cultivation but ideal for xerophytic plants, such as nopal (Opuntia spp.) and particularly, maguey (Agave spp.).

**Maguey Farming and Settlement Patterning**

It should be noted that the ecological balance of the settlement strategy of these villages depended on the active maintenance of the terrace systems where maguey and other crops grew, and this demanded that the farmer live close to the crops, to tend the terraces (Sanders 1965) as well as the plants (Parsons and Parsons 1983, 1987). (Drennan 1988:285 cites labor requirements in general as a determinant of dispersed settlement in ancient Mesoamerica.) A further benefit of this pattern was the enrichment of the soil through use of household waste. In a setting lacking large draft animals and their fertilizing potential, the value of nightsoil and other biodegradable organic material applied to house gardens is not inconsiderable (Palerm 1955:29).

These constraints produced the dispersed houselot pattern. The map of Teotihuacan Valley settlement (Figure 2) shows how these villages extended along the valley's piedmont in a continuous sweep of settlement. This dispersed settlement type demonstrates the crucial relation between the nature of the environment and the adaptive patterns of culture. The lands on which these people had settled owe their high productivity to each household's commitment to the many facets of maguey exploitation, since the terraces were the calmitl and milpa plots of the village. On the alluvial plain were the more fertile fields, but control of these was divided up among various nobles and other landholders, and civil and religious functionaries. With the probable exception of Cihuatepan's headman (who may have had some alluvial-plain land dedicated to the support of his office), the beneficiaries of alluvial-plain productivity would have been urban dwellers, not peasant villagers.

**Land and Landholding in Aztec Times**

In order to reconstruct how Cihuatépan would have used its landscape, certain Aztec categories of landholding must be understood. The Aztecs recognized a multiplicity of named types of landholdings (Gibson 1964:257, 267) and in Table 1 those relevant to the upper Teotihuacan Valley are listed. The sum of a city-state's land, the altepetlalli (Gibson 1964:267), would encompass the communal lands of the polity's tribute-paying peasants (calpullalli) and the lands set aside for support of its political, social, and religious institutions (such as tlatoctalli for the ruler, tecpantalli for the barrio and village headmen, and teotlalli for the temples and priests). There were also some
Table 1. Land and Landholding.

<table>
<thead>
<tr>
<th>Categories of Landholding</th>
<th>Cost/Benefit</th>
<th>Tlatlalli</th>
<th>Tepantlalli</th>
<th>Teotlalli</th>
<th>Calmíl</th>
<th>Milpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altepeltalli (e.g., of Otumba city-state)</td>
<td>City-state ruler</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>possible +</td>
</tr>
<tr>
<td>Village headman</td>
<td>Village headman</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>possible +</td>
</tr>
<tr>
<td>Landed commoners</td>
<td>Landed commoners</td>
<td>- and +</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Headman's workers</td>
<td>Headman's workers</td>
<td>possible -</td>
<td>possible -</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: Minus signs (−) represent labor cost and plus signs (+) represent a benefit to be derived from control over the food resource being produced.

lands (pillalli, tecuhtlalli) that supported particular nobles and their heirs, but in these cases the workers on the land did not owe tribute to the local lord, and such lands would not be part of the altepeltalli.

All citizens of a particular city-state would be expected to participate in numerous public-service projects for various levels of government, from tending to the needs of their own village, to occasional household service in the palaces of the Acolhua confederation capital at Texcoco. Table 1 presents a breakdown of labor cost (minus signs) and benefit from control over the food resource being produced (plus signs) for various types of land, by relevant social categories. The behavioral model expressed by Table 1 assumes that the city-state ruler drew food from plots dedicated to his use and that calpalli land would have provisioned the villagers and their headman. In fact, it is unclear from documentary sources whether the food required as tribute in the Codex Mendoza would have come from the calpalli or from special plots, but food tribute for other offices clearly was produced on special plots probably located on the alluvial plain. This practice had the consequence of reducing the tax bite as it applied to productivity of calpalli land itself. Such land still was taxed in certain kinds of “produce” (for example, woven cloth from fibers harvested from maguey plants) but the actual food produced from the calpalli’s calmíl and milpa plots probably was under the control of the producers and their headman, to use or to trade.

Decline of Village Life

The productivity of village land began to decline not long after the Spanish Conquest of Mexico in 1521; throughout the sixteenth century, Chihuatpecan and many similar villages diminished in size. The precipitous decline in population size in many parts of the New World resulted from the deadly combination of European diseases and European greed. So diminished was the rural population of the Basin of Mexico that the colonial government took steps to bring the survivors together, forcing them to abandon their villages and take up residence in congregated communities. Chihuatpecan’s turn came in 1603, when the Orden de Congregación of October 3 called for San Lucas Siguatepec to be abandoned; the remnant group of villagers was ordered to relocate in nearby Ahuatepec (Archivo General de la Nación 1603).

After the mandated abandonment of San Lucas Chihuatpecan, some sporadic occupation continued, as evidenced by Colonial period sherds. These were concentrated around the south slope of the cerro, and a disproportionately large number came from Structure 6 (38 percent of all sherds, and 82 percent of the glazed sherds from 1984 research operations [Evans 1988:37–38, 43]), indicating that it continued to be occupied after most of the other houses had been abandoned. Chihuatpecan, the dispersed village of the Aztec period, had ceased to be, and the land around Cerro San Lucas probably became grazing land, like so much of the upper Teotihuacan Valley. The upkeep of the terrace systems would no longer be necessary or feasible, and erosion proceeded unchecked. The
ruins of Cihuacepan's houses were covered by water- and wind-borne soil, and the village was forgotten until the 1960s, when the site was mapped by the Teotihuacan Valley Project.

ENVIRONMENT AND AGRICULTURAL PRODUCTIVITY

Remnants of the ancient terrace system on Cerro San Lucas still exist, judging from the spatial relation of visible eroded terrace borders to Aztec period housemounds (though much of the upper south slope has been reworked recently with the help of bulldozers, leading to predictable damage to housemounds). The construction and maintenance of the ancient terrace system (presumably established at the same time as the village) represent the imposition over the landscape of a sophisticated artificial ecosystem, designed to optimize adaptation to the challenging climatic conditions of low rainfall (500 mm/yr), cool climate (frost possible between October and April), and high altitude (occupation zone ranges from 2,400 to 2,500 m asl).

Cihuacepan is in the upper reaches of the Teotihuacan Valley, and the valley as a whole has a cool, arid climate, with some variation in temperature and rainfall, depending on the topography. The valley covers about 600 km² and is defined by the drainage of a chain of hills (the highest, Cerro Gordo, is 3,050 m asl) surrounding a northeast-to-southwest expanse of alluvial plain that ends at the ancient shoreline of Lake Texcoco (at 2,240 m asl).

Rainfall in the Teotihuacan Valley is strongly seasonal (from late spring into fall) and follows a marked diurnal pattern, with torrential showers falling virtually every summer afternoon. The predictability of this daily pattern definitely works to the advantage of villagers living close to agricultural terraces, since situational channeling of runoff onto the terraces increases crop security.

The timing of yearly seasons is somewhat less predictable, and the onset and duration of the rainy season are chronic matters of concern; four years out of ten, rainfall is below 600 mm (Nichols 1987:604–605). The most critical time for the security of a good yearly harvest is spring, when late frost could kill off seedlings. However, when seeds are planted deeply and then irrigated, this risk is diminished considerably. Perhaps because of the Teotihuacan Valley's climatic marginality for grain cultivation, significant settlement there was established only a few hundred years before Christ, when exploitation of the permanent springs at Teotihuacan for agricultural use probably began, and irrigation ameliorated some of the effects of the climate in the lower valley.

In contrast, the water supply for the settlements in the upper valley in prehispanic times depended on the careful husbanding of runoff from occasional small springs and from rainfall. Water was stored in pond-like reservoirs now called jagüeyes (at Cihuacepan, one jagüey was located on the southern slope (described in Evans and Abrams [1988:84–86]), and runoff was channeled over terraces and into floodwater irrigation fields. In the lower Teotihuacan Valley, climatic exigencies (unseasonal frost, delayed rainfall) could to some extent be lessened by judicious use of permanent water sources, but in the upper valley there were fewer buffers to protect against the loss of seed crops from drought.

Terrace systems solved these problems, providing better soil conditions for plant germination and growth, plus the added productive value of maguey and nopal. The terraces harness erosion, since drainage of rainfall runoff through the system brings soil in solution as well as water itself onto the terrace surfaces, and in time crop security is enhanced by the combination of deeper soils and more deeply held moisture (Donkin 1979; Sanders 1965:39–44). The dynamic elements of the drainage process are used to create a particular cultivation system, and although agricultural conditions in the piedmont of the upper Teotihuacan Valley were marginal for maize and other grains, intensive labor inputs created a productive landscape by reducing risks and by diversifying the resource base, with the use of maguey and nopal edge plantings on the terraces.

Figure 3 shows the layout of the village around the cerro; the area between the dotted lines encompasses the cerro's slopes and delineates the ca. 330-ha survey zone. Below the lower survey limit the alluvial plain begins, and above the upper limit the slope becomes much steeper and now is covered with thorny shrubs. Habitation was continuous, but clear clustering of housemounds is demonstrated on the southern slope, the area where the roads and major drainage channels intersect, and the housemounds are here larger and denser than they are elsewhere on the cerro. The desirability
of this south slope results from the intersection of a variety of environmental and cultural features. Greatest access to sunshine and to drainage from the caldera of the cerro was important, but so was proximity to the trade route used by travelers between Otumba and the Gulf Coast (a route that followed or paralleled one of the present roads).

The terrace system around Cerro San Lucas encompassed two different kinds of horticultural strategies. First, grains would be grown on the flat areas and maguey or nopal on the embankments, and this would constitute milpa farming; second, the terrace surfaces close to the houses would be used for kitchen gardens (calmiili), where tomatoes, chiles, and other vegetables, as well as herbs, flowers, and a small amount of corn (for edible green corn and as a backup for next year’s seeds) would have been grown for household use. This pattern may have resembled that of the modern community of Eloxochitlan, a Totonac village of dispersed house lots in Puebla. There, calmiili plots averaged 0.5 ha per house, and each family also farmed a larger milpa plot, farther away (Bray 1972: 910; Palerm 1955:29).

If one were to map out an area on Cerro San Lucas that is adjacent to the house lots and encompasses 0.5 ha per house, about 101.5 ha of the village’s 330 ha of sloping land would be used; there remain about 228.5 ha of sloping land on the cerro for milpa. Thus the sloping land on Cerro San Lucas permits each household a small adjacent kitchen garden and a larger, more distant farm field.

The productivity of milpa land is in part based on the average harvest of maize or other grain. The Teotihuacan Valley as a whole was an important grain-producing area in Aztec times, probably capable of supporting its own population (Evans 1980:168; Sanders 1970:442) and exporting maize and other grains as part of the tribute requirement documented in the Codex Mendoza. The lion’s share of the valley’s grain production came from the permanently irrigated lower valley where yields may have equaled as much as 3,000 kg/ha, but on some parts of the piedmont maize yields might have been as little as 300 kg/ha. Around Cerro San Lucas, the average annual yield would have been about 400 kg/ha (Sanders 1976:144). Productivity here was somewhat lower than that of other piedmont zones, because the runoff available was dispersed all around the cone of the cerro, rather than being more concentrated (the latter effect characterizes the topography of the Patlachique–Malpais Ranges and their piedmont zones).

While the valley as a whole was capable of supporting its regional population, land varied greatly in quality, and if the piedmont dwellers had to depend only on grain crops from their terraces for local caloric needs, they could not support themselves very well. Williams used ethnohistoric documents to study the productivity of terraced villages in the piedmont zone around the Texcoco plain, just south of the Teotihuacan Valley. Grain productivity alone suggested that “[x]treme population pressure clearly existed” in this area (Williams 1989:720). Similarly, my calculations for Cihuatenango’s grain productivity determined that “Cerro San Lucas could not fill the food needs of the village” (Evans 1988:23). But both sets of calculations are limited to grain, and maguey sap may have constituted another major food crop, one which greatly expanded the nutritional base of maguey farmers.

Fresh sap, called aguamiel, is very watery with a pleasant sweet–tart flavor. Within a day the texture becomes viscous as the sap begins to ferment into pulque. But when the sap is at its freshest, it no doubt provided the standard beverage for maguey farmers and their families, and substituted for fresh water often lacking in the piedmont zones of the central highlands. This use of aguamiel illustrates Sauer’s (1963:110) comment; for these piedmont farmers, maguey is a source of potable (and nutritious) drink, without which habitation would be impossible.

Studies of maguey terrace agriculturists in Orizaba (an Otomi village in the Mesquital area, north of the Basin of Mexico [Parsons and Parsons 1985, 1987]), and the Teotihuacan Valley itself (Sanders 1965) have documented strategies and yields in maguey farming, and from these the productivity of the Cerro San Lucas area for the Cihuatenango can be estimated. It should be noted that these ethnographic studies calculated the productivity for maguey in mixed-farming contexts, where maize and other grains are interplanted.

In Table 2, values are calculated for the area and productivity of land in use in and around Cerro San Lucas, to estimate the ability of the land to support the Cihuatenango at a subsistence level. Here the combination of calories from these staples, maguey and grains, is assumed to make up
Table 2. Area and Productivity of Agricultural Land, Cerro San Lucas.

<table>
<thead>
<tr>
<th>Land-Use Categories</th>
<th>Categories of Landholding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Altepetlalli</em> (e.g., of Otumba city-state)</td>
</tr>
<tr>
<td></td>
<td><em>Tlailmil</em></td>
</tr>
<tr>
<td>Type of land</td>
<td><em>Calmil</em></td>
</tr>
<tr>
<td>Crops cultivated</td>
<td>maguey and vegetables</td>
</tr>
<tr>
<td>Caloric value/ha/yr</td>
<td>2,087,650 (from maguey)</td>
</tr>
<tr>
<td>Area in use (ha)</td>
<td>101.5</td>
</tr>
<tr>
<td>Caloric yield, in millions of kcal/yr</td>
<td>211.89647</td>
</tr>
<tr>
<td>Number of individuals supported (at 2,500 kcal/day, or 912,500 kcal/yr)</td>
<td>232</td>
</tr>
<tr>
<td>Total</td>
<td>1,115</td>
</tr>
</tbody>
</table>

*a The *tecpan* probably housed about 25 people and offered hospitality and charity to many others. If we assume the *tecpan* supported 50 people a day, each needing an average of 2,500 kcal, then the total caloric requirement for the year would be 45,625,000, and 11 ha on the alluvial plain would be required to provide this (each hectare supporting 4.5 people at 912,500 kcal/year each).

*b The area of these plots and the village's investment of time are not known. The caloric value would be calculated as above.

Most of the diet. (As Sanders [1976:109] has pointed out, maize makes up 80 percent of the diet in many peasant communities of Mexico and Guatemala today.)

Maguey contributes significantly to the diet, and this is calculated as the caloric value of *aguamiel*, *pulque*, or the solid sugar products derivable from *aguamiel* (the caloric yield per plant remains generally the same, no matter how the sap is processed). To understand the productivity, in calories, of maguey in mixed maguey and grain cultivation we use observations from ethnographic studies.

The maguey holdings in use and their productivity are estimated from the following observations: (a) A single household “cultivates a few dozen maguey plants, and produces a few dozen liters of pulque a day” (Parsons and Parsons 1987:83), and (b) for steady production of about 5 l/day, about 40 plants (including nonproducers) are needed (Parsons and Parsons 1987:84; Sanders 1965: 45). Therefore, average yield is roughly .125 l/day/plant, or 45.6 l/year/plant. Average sap production/year in mixed holdings = 4,855 l/ha (Parsons and Parsons 1987:88); 4,855 l divided by 45.6 l/plant = 106 plants; therefore, planting density/ha = 106 plants, producing 13.25 l/ha/day.

To apply these values to Aztec period Cihuatepecan, we assume a mixed planting strategy and use land area as our basis for extrapolating productivity. We assume that each household at Cihuatepecan cultivated a *calmil* plot and a *milpa* plot; the areas of these (according to this model) are assumed to be (respectively) .5 ha and 1.1 ha, based on 203 houses and 330 ha available. *Milpa* productivity may be calculated as a sum of maize and maguey productivity in kilocalories (caloric values are from Woot-Tsun and Flores [1961]). Note that the calculations use probable values for interplanted crops, and the values per unit of area are understood to be cumulative rather than mutually exclusive: If maize (400 kg/ha; 3,600 kcal/kg) = 1,440,000 kcal/ha, and maguey (4,855 l/ha; 430 kcal/l) = 2,087,650 kcal/ha, then *milpa* (interplanted maize and maguey) = 3,527,650 kcal/ha, a daily yield of 9,665 kcal and 13.3 l potable beverage per hectare. Each household’s *milpa* = 1.1 ha = 3,880,415 kcal/year, and 5,340.5 l of potable liquid. Daily yields are 10,631 kcal and 14.6 l per average *milpa*.

Productivity of *calmil* plots is more difficult to calculate. While the important nutritional contribution of crops grown in these kitchen gardens is significant, their caloric value is typically low,
and the zone covered by the house and circumhouse activity areas also reduces this value. In this model, the caloric value of such crops will not be estimated. The caloric value derived from maguey planted in the calmil area of .5 ha as a terrace border and among other crops will stand as the basic caloric productivity of the calmil. The same general density of planting will be assumed, since the houses were built on the terrace beds, not astride the borders where many of the maguey plants were established. If maguey produces 2,087,650 kcal/ha, then the .5 ha calmil plot would yield 1,043,825 kcal/year and 2,427.5 l of potable liquid. Daily yields are 2,860 kcal and 6.7 l.

Thus, the total productivity (grain plus maguey sap) of each household’s milpa and calmil plots (together, 1.6 ha) is 4,924,240 kcal/year, including 7,768 l of potable liquid. Daily yields are 13,491 kcal per day, including 21.3 l of potable liquid. That this is sufficient calorically to support at least 5 or 6 people at the subsistence level is impressive, since that number of people was probably the average household size, based on ethnohistoric evidence from the Colonial period and inferred from the sizes of excavated houses (Carrasco 1976; Evans 1989; Harvey 1985). Chinatepecpan would have had a valuable kind of economic self-sufficiency, buffering the village from the potentially devastating consequences of permanent reliance on the city markets for food. Thus, the slopes of Cerro San Lucas were sufficient to provide for the population of Chuatepecpan, given a mixed strategy of maguey and grain cultivation.

In addition to the calories, and in some sense equally important in permitting successful adaptation to this challenging landscape, is the yield of potable liquid. Each person would be provided with about 3 l of fresh maguey sap per day, sufficient to substitute for much of the basic water requirement. A survival ration of water for drinking is 1 l per day per adult male in a neutral (stress-free) physiological state (Davidson et al. 1979:542). Matheny’s (1978:204) research on present-day water use in the Edzna Valley (Yucatan Peninsula, Mexico) indicates an average of 12.5 l/day per person, including frequent bathing but excluding watering animals and washing clothes. If Chuatepecpanecos used much of their maguey-sap harvest as a fresh beverage, their general need for water would be much reduced. The capacity of the jagüey at Chuatepecpan can be estimated from its projected depth and surface area, and would have been about 260,000 l. If we assume a village population of about 1,000, it is clear that one jagüey would have been insufficient to serve all the village through the dry season, and furthermore, jagüey water easily can become too polluted to drink (Siliceo 1922:190–192). In providing a year-round reliable potable beverage, maguey permitted settlement in areas lacking permanent water supplies.

It should be noted that the system of local land use modeled here is not expandable, and there is little capability of creating food surpluses by further intensification. However, it also should be noted that the values of maguey and grains produced on Cerro San Lucas are revealed in an artificially depressed state when considered only as caloric inputs. The market value for pulque and other maguey products may have been so high that it was economically advantageous for the Chuatepecpanecos to trade pulque for maize and other grains, grown elsewhere in the Basin of Mexico.

OTHER COSTS AND BENEFITS

Having established this very basic relationship between the villagers and their local food supply, the model must now be adapted to account for village life in the larger cultural context. The ability of aguamiel and maguey hearts to sustain life in starvation times no doubt served Chuatepecpan well in the famine years of the mid-fifteenth century, but in normal times, maguey products could be traded for other goods or food, worth much more than the basic caloric value of the maguey plant.

Sap

The average household production of 7,768 l/year of aguamiel was discussed above as a potable beverage with a caloric content similar to pulque (which is similar to that of beer). What was not drunk as fresh sap in the village was either permitted to ferment, for local use or trade, or processed into solid sugar, which has the advantage of long-term storage stability. At 16 l aguamiel per 1 kg sugar, a household could produce up to 485.5 kg of sugar a year and probably devoted some of its
aguamiel to this purpose. The details of this process are unclear, but it may well have required considerable valuable fuel.

Food Value of Other Parts of the Maguey

The maguey heart can be chewed for the sap, but the fiber is indigestible. Maguey quids are common at Early Formative camp sites in Mesoamerica, and to this day maguey heart is known as a reliable buffer against starvation. It provides few calories for the effort of mastication, however, and this use would preclude the many other ways of exploiting the plant; for these reasons one assumes that the quids were chewed only in times of extreme hardship. When any other food was available, the plant would serve its multiple purposes, and the heart of maguey might be processed into luxuriously silky thread; when the famine years came, the heart of maguey kept the edge off raw hunger and provided a few calories, some phosphorous, iron, and B and C vitamins (extrapolated from Woot-Tsuen and Flores [1961:91]).

Fibers

Fibers from the heart of the maguey, but even more importantly, from maguey pencas (leaves) were vital to the village economy. At Chihuatepecan evidence of fiber production is found in every house. Basalt maguey scrapers (to strip down the fibers from the pencas) and ceramic spindle whorls document two phases of the complex fiber- and cloth-production process. In addition to producing thread and standard woven mantles, the households probably also made rope, nets, and baskets as these were needed by the family or could be marketed. Woven textiles constituted a sort of currency in the three exchange systems (tribute, long-distance trade, and marketplace), and weaving skills were valued highly in women, because women were the household-level producers of massive numbers of textiles. To fulfill its share of the Codex Mendoza tribute alone, each Chihuatepecan household had to produce four long woven mantles a year.

Other Uses

Other uses of the plant include medicines derived from the sap, the probable use of pencas for construction material, and for animal fodder (if the pencas are immature). The dead plant is burned for fuel, and its ashes would have been used as fertilizer.

The maguey plant is clearly a mainstay of the village economy, and in essential value it outweighed nopal cactus, the other common xerophytic “orchard” plant in the Teotihuacan Valley. The foods produced by nopal (cactus paddles as a green vegetable, and tuna, the pink, heart-shaped fruit) are important for rounding out the diet (Woot-Tsuen and Flores 1961:33, 37, 59, 62) but do not sustain life. Nor is nopal suited to a wide range of nondictory uses, as is maguey. Nopal did, however, produce a very valuable crop, the cochineal insect. The processing of the insect into dye can be managed easily with implements found around the Aztec house, and so valuable was the dye that even the rinse waters of the implements were used to impart color to fibers. Because specialized tools apparently were not used, and the residues of the dye were removed in the dye process, archaeological evidence for this industry is lacking (or indistinguishable from evidence of more ordinary pursuits). But early colonial documents refer to the strength of the industry in this general area, and to its importance (second only to gold) in the colonial export economy (Gibson 1964:354). Cochineal also was valued highly in Aztec times and would have been a natural sideline of textile production at Chihuatepecan.

CONCLUSIONS

The cultivation of maguey and other xerophytic plants in the central highlands of Mexico transformed the sloping piedmont zone into a productive landscape several centuries before the Spanish conquest. Maguey gave peasant farmers a stable source of raw materials for craft production, as well as providing for basic caloric and liquid requirements. The versatility of maguey’s uses permitted
the settlement and exploitation of a broad area, contributing substantially to the demographic and economic strength of the Aztec period.

These conclusions are drawn from information compiled from archaeological, ethnohistorical, and ethnographic sources. The Aztec period village of Cihuatepecan is the case study, the basis for reconstruction of the agricultural resource base. Ethnohistorical documentation of maguey production, and ethnographic studies on maguey, as well as documentation of settlement and agricultural patterns, permit us to estimate the agricultural strategies in use at Cihuatepecan and the maguey's importance there and in countless other peasant villages. The interplay of maguey farming and settlement of the piedmont lands resulted in Aztec period population levels in the Teotihuacan Valley that were nearly as high as those of the Classic period, a thousand years before. What exploitation of the springs at Teotihuacan had done to expand the productivity of the valley's alluvial plain during the Classic period, exploitation of maguey did for the slopes, a millennium later.

Acknowledgments. Excavations at Cihuatepecan were supported by National Science Foundation (NSF) grant BNS-8317830 and study of materials was facilitated by NSF grant BNS-8519834. This study has benefited from thoughtful comments by Thomas Killion, William T. Sanders, Michael E. Smith, B. L. Turner, David Webster, and several other reviewers.

REFERENCES CITED

Abrams, E. M.

Archivo General de la Nación

Armillas, P.


Barlow, R. H.
1949 The Extent of the Empire of the Culhua Mexico. Ibero-Americana No. 28. Mexico City.

Bray, W.

Calnek, E.


Carrasco, P.

Cobeán, R., and A. G. Mastache

Cobeán, R., A. G. Mastache, A. Crespo, and C. Díaz

Codex Mendoza

Códice Xolotl

Davidson, S., R. Passmore, J. F. Brock, and A. S. Truswell
Diehl, R. A.
Donkin, R. A.
Drennan, R. D.
Evans, S. T.
Evans, S. T., and E. M. Abrams
Evans, S. T., and A. C. Freter
Gibson, C.
Harvey, H.
Healan, D. M., R. H. Cobeán, and R. A. Diehl
Ixtlilxochitl, F. de A.
Kelley, J. C.
Linné, S.
Matheny, R.
Motolinía, T.
Nichols, D.
Palerm, A.
Parsons, J. R.
Parsons, J. R., and M. H. Parsons
Parsons, M. H.
Reyes Cortés, M., and J. García-Barcena
Senders, W. T.
1965 The Cultural Ecology of the Teotihuacan Valley. Department of Sociology and Anthropology, Pennsylvania State University, University Park.
Sanders, W. T., J. R. Parsons, and R. Santley
Sauer, C. O.
Silicco Pauer, P.
Simeon, R.
1984 Diccionario de la lengua Nahualt o Mexicana. Siglo Ventiuno, México, D.F.
Vega Sosa, C. (coordinator)
Williams, B. J.
Woot-Tsuen, W. L., with the cooperation of M. Flores
1961 Food Composition Table for Use in Latin America. Interdepartmental Committee on Nutrition for National Defense and The Institute of Nutrition of Central America and Panama. Bethesda, Maryland, and Guatemala City.

NOTES

1 On the use of the term “Aztec”: At the time of Conquest, most of the peoples of the Basin of Mexico were Nahua speakers and claimed at least partial descent from migrant groups from the north who arrived sometime after A.D. 1000. These migrants were diverse ethnically, but had interwoven histories and origin myths, and a major feature they had in common was the idea of a legendary origin place, Aztlan. These groups came to be called “Aztecs” because of this, and even though that name is most closely associated with the Mexica of Tenochtitlan, it applies, by and large, to most of the peoples of the Basin of Mexico from A.D. 1150 to 1521, an era called the Aztec period. This reconstruction from documentary sources of the early colonial period (most important, for the Teotihuacan Valley, are the Codex Tolteco [1980] and the Obras historicas [Ixtlilxochitl 1985]) has been substantiated by the archaeological evidence gathered by the Basin of Mexico Project (Sanders et al. 1979) and by Instituto Nacional de Antropología e Historia (INAH) research (e.g., Vega Sosa 1979).
2 Milpa, in this context, means an agricultural plot located at some distance from the house, “en el campo” (Simeon 1984:276), a pattern found in many parts of Latin America today.
3 Generalizations concerning the florescence of Tula and contemporaneous sites are based on ethnohistoric and archaeological evidence, such as that reported by Cobean and Mastache (1989), Cobean et al. (1981), Diehl

Pages 21 and 22 of the Codex Mendoza (1980) list a number of Teotihuacan Valley towns, including Otumba, Ahuatepec, and Axapusco, and the tributes required are bins of maize, beans, chia, and amaranth (Barlow 1949: 71), fabric and clothing, war dresses, and shields. Motolinia describes the tribute owed by Teotihuacan Valley towns to Texcoco as including lime, stone, firewood and firebrands, lumber, and peasant labor (Motolinia 1971: 394–395).

The settlement pattern of the valley strongly favors the piedmont zone right above the alluvial plain, permitting conservation of the best land for agriculture, and easy access to it. Gibson (1964:259) notes that the "[l]ands worked in common for the benefit of local caciques and principales are described as adjoining the towns and worked by 'all the people together' for periods of two or three hours per day. . . . they were 'common' lands for the support of the offices of rule."

Received December 27, 1989; accepted April 12, 1990