Trees and shrubs: the use of wood in prehispanic Teotihuacan

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Abstract

Charcoal recovered from different archaeological excavations carried out in the Teotihuacan Valley, México was used to evaluate whether significant changes in the use of wood took place through time (approx. 400 B.C.–A.D. 1500). Sixteen taxa of trees and shrubs characteristic of the Basin of Mexico were identified (including Pinus, Quercus, Arbutus, Cupressaceae, Alnus, Prunus, Taxodium, Salix, Baccharis and Buddleia, among others). Variations in the proportions of taxa are interpreted as a reflection of the intensity of use rather than an indicator of deforestation. The analysis of the data shows a pattern of continuity in the utilization of taxa throughout the occupation. This includes the use of different vegetative parts (trunk and branches), genera and species with different life forms (trees, shrubs, herbaceous plants) and primary (Pinus and Quercus) as well as secondary taxa (Prunus and Arbutus). We propose that the inhabitants of the Teotihuacan Valley implemented practices to manage vegetation in order to assure resource availability in the region.

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1. Introduction

The Teotihuacan Valley, located in the NE sector of the Basin of Mexico, is best known for the archaeological site of Teotihuacan, the most important city in central Mexico during the Classic period (ca. A.D. 1–650). With a surface area of 20 km² and around 100,000 inhabitants (Millon, 1970, 1973), the city undoubtedly relied on an efficient supply network to guarantee its operation (McClung de Tapia, 1990). In addition to an external supply network, the city depended on the management of local resources to cover the basic needs of its inhabitants. Wood resources must have played an important role in the city's growth. However, little is known about the use and management of wood and the impact this had on the environment and human population.

Charcoal recovered from archaeological excavations provides data for the reconstruction of past vegetation as well as the use of forest resources, including aspects of management, changes in patterns of exploitation of diverse species and consequent impact on the environment (Salisbury and Jane, 1940; Godwin and Tansley, 1941; Minnis, 1978; Vernet, 1980; Kohler et al., 1984; Miller, 1985; Smart and Hoffman, 1988; Johannessen and Hastorf, 1990; Heinz, 1991; Newsom, 1993; Asouti and Hather, 2001; Scheel-Ybert et al., 2003; Rodríguez, 2004). However, this type of botanical evidence has received little attention in paleoethnobotanical research in Mexico, particularly in the Teotihuacan Valley. As a result there is a considerable shortage of studies that systematize and analyze information necessary to propose hypotheses concerning relationships between humans and their environment, particularly in forest ecosystems.

Until the end of the 1990s, studies did not concentrate on this type of material and the little evidence available was either unpublished or briefly incorporated into analyses of seed remains. Published information on charcoal analyses comes mainly from studies where the identification of seeds was the main focus and is only provided as complementary information. In such publications, only identified taxa are listed and inferences and interpretations about their uses are very general (Kovar, 1970; Ford, 1976; González, 1982; Álvarez del Castillo, 1984; Manzanilla, 1985; Flannery, 1986; González et al., 1993; Popper, 1995; Montúfar, 1996; Montúfar, 1999).

The first systematic effort to explore the potential of charcoal as evidence was undertaken by Adriano-Morán (2000). The objective was to contribute evidence for reconstructing the vegetation of the Teotihuacan Valley during the Classic period, when the landscape was dominated by the powerful city of Teotihuacan. Identified taxa were associated with temperate forest (Pinus, Quercus, Alnus, Baccharis, Buddleia), xerophytic scrub (Agave) and riparian vegetation (Fraxinus, Salix, Cornus). These genera suggested the existence of distinct vegetation types, of which a mixture of pine and oak comprised the main component of the valley's landscape prior to human settlement. This evidence led Adriano-Morán to propose that the utilization of different types of wood could be a function of...
their availability in the environment and that, apparently, there was a preference for certain genera over others. This study showed taxa that existed in the region and were used during the Teotihuacan period. Furthermore, it provided an important point of departure to compare with present day environmental conditions in the region.

Based on this information, further investigation purported to reconstruct the patterns of use and exploitation of wood on the part of the valley’s inhabitants from the Preclassic through the Postclassic periods (ca. 400 B.C.—A.D. 1500). An understanding of the way in which these activities were carried out is important because deforestation, as a consequence of poor management of the landscape and its resources, has been cited by some authors (Sanders, 1965) as the cause of environmental deterioration in the region (soil loss and erosion, changes in hydrographic patterns) that could have been one of the factors leading to the fall of Teotihuacan.

In this study, statistical analyses are used to determine if significant differences are apparent in the proportions of taxa through time, in order to evaluate the evidence for changes in the use of wood between 400 B.C.—A.D. 1500. The long and continuous occupation of the Teotihuacan region, added to the apparent changes in its demographic history and settlement patterns through the course of its prehispanic history, make this an ideal region for such a study.

2. Study area

The Teotihuacan Valley is located in the NE sector of the Basin of Mexico (19° 34′ N, 99° 40′ W) between 2240 and 3100 masl (Fig. 1). Climate is semi-arid on the plain and temperate subhumid in the surrounding elevations. Because it is situated in a transition zone between dry and subhumid climate types, the region is highly susceptible to climatic variations. Average annual temperature is 14.9 °C, and varies between 12 °C and 18 °C below 2800 masl and between 5 °C and 12 °C above 2800 masl; mean annual precipitation for the region is 563.3 mm (García, 1968, 1988). The main drainages are Rio San Juan, El Huixulco and Rio San Lorenzo, which are largely seasonal and which infiltrate the subsoil to reappear as springs in the SW sector of the valley (Lorenzo, 1968; Mooser, 1968). Principal soil types in the region include phaeozems (40%), vertisols (16%), cambisols (13%) and leptosols (13.5%), many of which present an advanced state of erosion (McClung de Tapia and Tapia-Recillas, 1997).

Six main types of vegetation currently predominate in the region (Castilla and Tejero, 1987). The oak forest (Quercus crassipes, Quercus greggii and Quercus mexicana) community covers a small area restricted to the north slope of Cerro Gordo (2800–3050 masl) but may have extended over a broader area in the past, at least as far as the area covered today by oak scrub. Oak scrub (Quercus microphylla) is situated between the oak forest and xerophytic scrub (2850–3000 masl). It has been suggested that the oak scrub community replaces the pine–oak component of the temperate forests in the Basin of Mexico as a result of repeated fires (Rzedowski et al., 1964). However, Castilla and Tejero (1987) consider that its presence in the Teotihuacan region may be a consequence of cutting the oak forest. Xerophytic scrub (Opuntia streptacantha, Zaluzania augusta, Mimosa bicucifera) is the most representative vegetation type of the region and it occupies the largest area (2300–2750 masl). Grasslands (Buchloe dactyloides, Hilaria crenchoides, Bouteloua gracilis) cover a small part of the area and are mostly interdigitated with xerophytic scrub, oak scrub or scrub comprised of Senecio salignus and Baccharis conferta (associations within the oak scrub community). Hydrophyllous vegetation is comprised of seasonal taxa associated with the rainy season or artificial systems such as dams, irrigation ditches and water deposits. Natural stands occur in inundated areas. Anthropogenic vegetation includes secondary associations of agrestal and ruderal species that develop in areas of human impact.

The conformation of present day vegetation communities in the Teotihuacan Valley is undoubtedly a product of the combined action of natural and anthropogenic factors over time. Castilla and Tejero (1983) suggest that vegetation types in the past were possibly quite similar to the present although distributed more broadly. This is based on the idea that if past climatic conditions were similar to the present, climax communities (such as forest or scrub in temperate subhumid or semi-arid climates) should be the same. Evidence from recent studies (McClung de Tapia and Tapia-Recillas, 1997; McClung de Tapia et al., 1998, 2003; Adriano-Morán, 2000) supports the presence of these communities in the valley together with changes in their distribution as well as their floristic composition. The most noticeable change is the disappearance of Pinus from the present day flora in the region.

3. Numerical analysis of botanical materials

Archaeobotanical and paleoethnobotanical investigations commonly use ubiquity to describe and analyze data. Ubiquity is a semiquantitative form of describing the data (Jones, 1991), defined as the number of samples of a collection in which a particular taxon is found, expressed as a percentage (relative frequency). Ubiquities are compared in graphs or tables that allow viewers to observe tendencies in the behavior of the taxa among contexts or through time. Often ubiquities vary noticeably from one context or time period to another that frequently are interpreted as significant differences, although without the application of statistical tests. A number of examples of this approach (Willcox, 1974; Minnis, 1978; Hastorf, 1988; February, 1992; Figueiral, 1993), where samples that have been grouped by contexts or periods are compared numerically without statistical testing, produce partial or even potentially erroneous conclusions. However, the paucity of statistical analyses in paleoethnobotanical studies, including significance testing, reflects the researchers’ awareness of random or nonrandom factors that affect the conservatism of botanical remains so that they are not “populations” representative of some larger universe and, as such, are not considered appropriate subjects for formal statistical analysis.

In recent years, the use of multivariate techniques for data exploration has increased, including correspondence analysis, principal components, cluster analysis and discriminant analysis (Prior and Price-Williams, 1985; Jones, 1987, 1991; Heinz and Thiebault, 1998; Scheel-Ybert, 2000; Asouti, 2003). In other cases, contingency tables and four-way log-linear analysis have been employed to explore categorical variables (Kohler and Matthews, 1988).

Studies in which significance testing has been used include techniques such as ANOVA and regression (Lepofsky et al., 1996; Johannessen, 1988). However, parametric statistical approaches require that data be normally distributed or close to it. Other suppositions of the model include independence and homoscedasticity. Archaeobotanical data are not normally distributed, and frequently a large number of samples contain a small number of taxa or small numbers of samples contain numerous taxa. Significance tests cannot be applied in this type of situation, and other methods or techniques that do not require a normal distribution must be employed.

Generalized Linear Models were developed to analyze both discrete and continuous data that do not comply with the normal model, while recognizing that many of the properties of normal distribution are found in the so-called exponential family, which, in addition to the normal distribution, includes the binomial, negative binomial, gamma and Poisson distributions. By means of these models, equations can be developed that permit estimates of the
behavior of the response variable as a result of one or more explanatory variables (Crawley, 1996).

The logit model is employed for the analysis of data expressed as proportions in a binomial distribution. Since ubiquity is represented as a fraction, it should follow a binomial distribution. The main advantage of this model is that it does not require that the data be normally distributed or that the groups of samples to be compared be of the same size (McCullag and Nelder, 1989; Crawley, 1996).

4. Method of analysis

A total of 2613 charcoal fragments, from 297 samples of charcoal recovered from various contexts in different excavations, were used in this study. Based on their association with specific contexts (floors, fill, hearths and various), it is assumed that the charcoal fragments represent wood used as fuel. The forms and sizes of the fragments indicate that branches and twigs as well as trunks were used.

The time frame represented by the samples is based on the ceramic chronology previously established for the Teotihuacan region by stratigraphic relationships and radiocarbon dating of charcoal associated with diagnostic ceramic types (Cowgill, 1996; Rattray, 2001). In this study the occupation phases defined by archaeologists (Cowgill, 1996) have been grouped into periods to form broader more manageable and comparable time units. Thus, the Preclassic period (ca. 400–100 B.C.) is considered as a unit, the Classic period is divided into Early (A.D. 0–250), Middle (A.D. 250–550) and Late (A.D. 550–650), and the Postclassic period (A.D. 650–1500) is also treated as a single unit. The approximate duration of these periods is based on Cowgill (1996). However, few excavations corresponding to the Postclassic have been carried out in the study region and available charcoal was insufficient to permit a finer chronological division.

Sixteen taxa of trees and shrubs characteristic of the Basin of Mexico, together with monocotyledons (Agave and Zea mays) (Table 1, Fig. 3), were identified in the samples which come from diverse archaeological excavations undertaken in the region over the past 30 years (Figs. 1 and 2). Ubiquity analysis shows important fluctuations in the percentages of different genera for contexts as well as time periods, possibly indicating changes in their uses.

In order to build the database for the analyses, numerical references were assigned to four contexts, five periods and 14 taxa. The context referred to as “various” includes samples that were recovered from fill, but directly associated with burials, offerings and storage features. Taxa that were present in a single sample or that could not be identified to the genus form the category referred to as “Others”. Fabaceae and Cupressaceae are represented as families due to the difficulty in identifying the genus of some of the samples. Z. mays was included because, although it is not a woody plant it occurs frequently among the charcoal samples and is considered an important fuel resource, as are other monocotyledons.

The statistical program GLIM 4.0 (Crawley, 1996) was employed for the analysis. One of the characteristics of an interactive procedure is that following the adjustment of a model that includes all of the variables and their interactions, the insignificant terms are
eliminated as the model is simplified. This procedure allows the testing of significance of each of the variables in the presence of the others, since the group of variables may explain patterns that individual variables cannot. All of the contexts, periods and taxa were compared with each other to establish which are significantly different in terms of the wood used. Because the fraction of samples from each group that was analyzed showed the presence of each taxon, a logit transformation of the data, a binomial error and a significance test (\( \alpha = 95\% \)) were employed.

5. Results

Comparison of all the contexts, time periods and taxa showed that many of the components are significantly different. However, only the values of total significance of each variable and its interactions are presented in Table 2. In the section dealing with the interactions themselves, the probabilities of significant variables are considered. With respect to the archaeological contexts under consideration, \( \chi^2 = 2.63 \) (Table 2), indicating that there is no significant difference among hearths, floors and fills and, as such, these may be considered as a single context. Thus, only two contexts differ from each other: (1) hearths/floors/fills and (2) various. The homogeneity observed in the majority of the contexts is responsible for the fact that context as a variable explains only a small proportion of variation among the data.

With respect to the time periods considered, only Middle Classic and Late Classic showed no significant difference. Therefore, these were combined into a single period, resulting in the following temporal divisions: (1) Preclassic; (2) Early Classic; (3) Middle–Late Classic; and (4) Postclassic. Once this adjustment was carried out, a \( \chi^2 \) of 63.36 was obtained (Table 2). The time periods alone account for 5.44% of the total variation.

Insofar as the taxa are concerned, *Pinus, Quercus, Cupressaceae, Z. mays, Monocotyledons* and “Others” were distinct from each other and from the rest of the taxa. The remaining taxa formed two groups: Group 1 included *Taxodium, Arbutus, Baccharis* and *Prunus*, and Group 2 included *Alnus, Buddleia, Fabaceae* and *Salix*. Thus, taxa were reduced from 14 to 8: (1) *Pinus*; (2) *Quercus*; (3) *Cupressaceae*; (4) *Taxodium–Arbutus–Baccharis–Prunus*; (5) *Alnus–Salix–Buddleia–Fabaceae*; (6) *Z. mays*; (7) *Monocotyledons*; and (8) Others. Probably this re-arrangement of taxa, all of the groups were significantly different from one another (\( \chi^2 = 914.9 \)).

**Table 1**

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<td>Prunus serotina ssp. capulí (Cav.) McVaugh</td>
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<td>x</td>
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<td>Salix spp.</td>
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<td>x</td>
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<td>x</td>
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<td>x</td>
<td>x</td>
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<td>Not identified</td>
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<td>x</td>
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<td>x</td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

5.1. Variation of taxa among contexts

The next step in the procedure was to evaluate the behavior of the taxa in Contexts 1 and 2. The genera that show significant differences between contexts are: Pinus ($\chi^2 = 7.931, p = 0.0049$), Quercus ($\chi^2 = 13.54, p = 0.0002$) and Group 1 ($\chi^2 = 7.62, p = 0.0058$). The observed differences are due to the fact that in Context 1, these genera appear constantly in high proportions throughout the chronological sequence. In Context 2, Pinus occurs in a lower proportion of the samples and Quercus in a higher proportion, whereas the taxa that comprise Group 1 are practically absent. In this case, only Prunus was present (in low proportion and in a single period) (Fig. 4).

5.2. Variation among taxa through time

The last step of the procedure involved exploring variation among taxa during each of the time periods. Cupressaceae, Group 2 (Alnus–Salix–Buddleia–Fabaceae) and Monocotyledons showed no significant change between periods, whereas Pinus, Quercus, Group 1 (Taxodium–Arbutus–Baccharis–Prunus), Z. mays and “Others” did change significantly.

Once it was established which taxa varied, the periods during which variation took place were determined (Fig. 5). Pinus changed in periods 1, 2 ($\chi^2 = 3.951, p = 0.0468$) and 3 ($\chi^2 = 10.21, p = 0.0014$). For Quercus, on the other hand, variation was observed between periods 3 and 4 ($\chi^2 = 5.611, p = 0.0178$). For Group 1, all four periods are different (periods 1–2, $\chi^2 = 28.26, p = 0.0001$; periods 2–3, $\chi^2 = 49.67, p = 0.0001$; periods 3–4, $\chi^2 = 6.199, p = 0.0128$). Z. mays varied between periods 2 and 3 ($\chi^2 = 13.54, p = 0.0002$) and extending to period 4 ($\chi^2 = 15.8, p = 0.0001$). The change in “Others” took place between periods 2 and 3 ($\chi^2 = 18.83, p = 0.0001$).

6. Discussion

6.1. Variations in contexts, time periods and taxa

The fact that floors, fills and hearths were not significantly different from each other was evident from the ubiquity analysis (not shown), in which the composition of taxa in these different contexts is essentially the same although their proportions differ. This confirms the idea that the charcoal present in these contexts represents the remains of wood used as fuel.

The context referred to as “Various” differs from the others in the number of taxa present (six as opposed to 14 for the other contexts prior to grouping), the fact that those taxa do not occur consistently throughout the sequence of periods, and that there was considerably more variation in their ubiquity proportions. The results of the analysis may be pointing to the low diversity in taxa rather than to differential or particular use of wood in the domestic and ritual activities represented by this context.

One possible explanation for the lack of any statistical difference between the Middle and Late Classic periods is that the proportions of most of the taxa during these periods were very similar and in one case, Arbutus, the same. It may be that the model is unable to distinguish between such fine differences, and therefore, cannot distinguish between the periods, even though at least one taxon (Pinus) shows dissimilar values in these periods. The remaining time periods differ from each other based on the distinct proportions of taxa in each.

The variations in the proportions of Pinus during the Preclassic, Early Classic, and Middle–Late Classic periods may be due to more intense use and preference by the Teotihuacanos for this genus, particularly if we consider that these periods marked the development and florescence of Teotihuacan culture. The absence of change during the Late Classic–Postclassic...
transition probably indicates a reduction in the intensity with which this resource was exploited as a consequence of population decline in the region, the exhaustion of the resource or the loss of important trade routes as Teotihuacan came to its end.

In the case of *Quercus*, the proportions are stable during the Preclassic and the entire Classic, suggesting a constant but less intensive use than that of *Pinus*. The most noticeable change clearly takes place at the beginning of the Postclassic period, consisting of a drastic reduction in its proportion. This may indicate a reduction in the availability of oaks in the region, because of their depletion. Another possibility is a change in preference reflecting changes in the ethnic composition of the local human population.

Group 1, comprised of *Taxodium–Arbutus–Baccharis–Prunus*, fluctuates throughout the entire chronological sequence. The highest proportion corresponds to the Early Classic; the lowest in the Postclassic period. The permanence through time suggests that these genera were used frequently from the early occupation of the valley. It is possible that during the Early Classic they were used more intensively than in later periods. In the Postclassic, as in the case of *Quercus*, an important reduction in their proportion is observed.

The proportions of *Z. mays* are maintained without change during the Preclassic and Early Classic. However, they vary between Early Classic and Middle–Late Classic and again between this period and the Postclassic. This is apparently due to the absence of *Z. mays* in samples pertaining to the Middle–Late Classic and their reappearance during the Postclassic although in a higher proportion than during the other periods.

The taxon designated as “Others” changes only between the Early Classic and the Middle–Late Classic. Here the change consists of the reduction in ubiquity values.

### Table 2

Significance values obtained from logistic analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\chi^2$</th>
<th>df</th>
<th>Significance</th>
<th>% of variation explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxa</td>
<td>914.9</td>
<td>7</td>
<td>&lt;0.0001</td>
<td>78.66</td>
</tr>
<tr>
<td>Context</td>
<td>2.63</td>
<td>1</td>
<td>n.s.</td>
<td>———</td>
</tr>
<tr>
<td>Period</td>
<td>63.36</td>
<td>3</td>
<td>&lt;0.0001</td>
<td>5.44</td>
</tr>
<tr>
<td>Taxa vs. Period</td>
<td>68.69</td>
<td>6</td>
<td>&lt;0.0001</td>
<td>5.91</td>
</tr>
<tr>
<td>Taxa vs. Context</td>
<td>28.54</td>
<td>2</td>
<td>&lt;0.0001</td>
<td>2.45</td>
</tr>
</tbody>
</table>

$R^2 = 91.27\%$ (variation explained by the model); variation not explained by the model: 8%; df = degrees of freedom.
6.2. Use and management of vegetation: a hypothesis

Taxa present in the samples recovered from numerous archaeological excavations in the Teotihuacan Valley represent different types of vegetation: pine–oak forest (Pinus, Quercus, Arbutus), xerophytic scrub (Fabaceae, Agave) and riparian vegetation (Taxodium, Alnus and Salix). Because these taxa are evident since the Preclassic period, this mosaic of vegetation types was present in the valley at this time and, as a group, probably represents the vegetation of the region before human settlement. This agrees with Castilla and Tejero (1983), the results of Adriano-Morán’s initial study of archaeological specimens (2000), and studies of other materials such as pollen, phytoliths and soils (McClung de Tapia, 1996; McClung de Tapia et al., 1998, 2003).

The constant presence of wood from Pinus, Quercus and Cupressaceae indicates a preference for these taxa used as fuel. The variations in proportions of identified taxa do not indicate a change in the composition of genera utilized throughout the time of occupation [Asouti (2003) found similar evidence from a Neolithic site in Turkey] nor do they indicate that arboreal species utilized during the earlier occupation stages were replaced by shrub species in later stages, as would be expected if the main resource (trees) had been depleted by overexploitation (deforestation) as suggested by other studies (Newsom, 1993). The presence of Groups 1 and 2 (comprised of trees and shrubs) from the Preclassic suggests that both were being utilized from the initial occupation of the valley. Their constancy over time, especially in the case of Group 1, may indicate that they were preferred as fuel. It is probable that Pinus, Quercus, Cupressaceae and Groups 1 and 2 were utilized together as complementary resources rather than as substitutes for one or another.

The preference for the taxa mentioned above suggests that they were selected intentionally because they were considered to be good materials for fuel. If this were the case, we can suppose that the prehispanic inhabitants of the Teotihuacan Valley were familiar with the characteristics of the woods and, as a function of this familiarity, chose the most suitable for their purposes. In other words, they maintained a sort of quality control over the taxa chosen for specific purposes. Today in some of the rural communities of central Mexico in which wood remains the primary source of fuel, the genera employed include Pinus, Quercus, Prunus, Alnus, Arbutus, Baccharis, Buddleia and Salix because these are considered to be of good to fair quality based on the selection criteria: easy ignition, slow burning, intense flame, little smoke, production of embers and availability of the species (Camacho, 1985; Almeida, 1990; Estrada, 1996).

The behavior of Z. mays and other taxa such as monocotyledons indicate that they were also used in combination with other woody species rather than as a substitute due to a shortage of wood. The combinations of different woods (or other fuel materials) may be a function of the purpose and duration of the fire (for example, ignition, illumination, heating, cooking, firing ceramics) and would also include the use of different parts of the tree such as trunks, branches and twigs. This practice is reported among present-day rural communities where the species are utilized in different proportions according to the activity to be undertaken (Camacho, 1985; Martorell, 1995). For example, in an Otomí community in the State of Mexico, the first step of the firing process in the production of roof tiles is carried out with a combination of madroño (Arbutus)
and alder (Alnus), followed by the addition of “broom” (Baccharis) when the heat is intense, in order to produce the characteristic reddish tone. In this case, the intensity of calorific output and rapid combustion of the wood is important. Other genera, such as oak (Quercus) – which also has a high calorific output but burns more slowly – are not used because the tiles would break during firing. On the other hand, species of oak (and alder and madroño to a lesser extent) are preferred for domestic consumption because intense, longer lasting heat is required. In some cases, in order to get better heat yield from logs, branches and twigs from trees as well as shrubs (such as Prunus, Baccharis and Buddleia) are added as complements. In addition, other woody or combustible materials such as maize cobs and stalks as well as Agave leaves (pencas) are also used (Camacho, 1985).

Genera and families identified in the archaeological samples represent components of primary as well as secondary vegetation. Genera such as Pinus, Quercus, Taxodium and Cupressus are representative of temperate forests characteristic of higher elevations in Mexico and constitute primary vegetation or climax communities. Alnus, Salix, Juniperus, Prunus, Arbutus, Buddleia and Baccharis are commonly present as companion species in stands of primary forest but also play an important role as secondary taxa (Vázquez-Yanez, Jacobsen et al., 1999; Rzedowski and Rzedowski, 2001). When disturbance occurs, either natural or anthropogenic, species of these genera are pioneers in the succession. They establish in disturbed and open spaces because they are mainly heliophytes and, therefore, of considerable importance in the regeneration of the forest. Also, some of these species are able to reproduce vegetatively from shoots (such as Alnus, Prunus and Junipers), which allows more rapid recuperation of the vegetation. Because of these characteristics, Baccharis and Buddleia are considered indicators of secondary vegetation.

The presence of these genera among the samples from archaeological contexts in the Teotihuacan Valley may indicate perturbation of the vegetation from very early times and the possibility that vegetation types present in the region prior to human settlement persisted through time in different stages of regeneration (secondary vegetation). From this perspective, the inhabitants of the valley appear to have been intentionally using primary as well as secondary species. The extension of secondary communities must have been quite broad considering that these rapidly growing plants could establish in abandoned lands or fallow agricultural plots following the completion of their planting/harvesting cycle. The use and maintenance of secondary vegetation would guarantee a constant wood supply and, particularly in the valley, a large amount of wood suitable for domestic consumption, which would be advantageous for the human population by reducing costs of transportation and recollection (time and distance) of the resource. Independently, the acquisition of wood such as Pinus and Quercus from other parts of the Basin of Mexico was probably established early in the occupation of the region, based on estimates suggesting that only around 12% of the area was suitable to support primary pine–oak forest (McClung de Tapia and Tapia-Recillas, 1997). Therefore, it is likely that local availability was not sufficient to cover the needs of the valley’s inhabitants during periods of increased population.

The use of secondary vegetation among indigenous groups (Huastecs, Totonacs and Maya) is well documented for the warm–humid tropics in Mexico as well as other parts of Latin America and represents one of the strategies included in a diversified management system or multiple-use strategy (Alcorn, 1983; Toledo et al., 1995, 2003). Such indigenous strategies purported to maximize diversity and the range of available options in resource exploitation to meet subsistence needs and minimize risks. They include the use of different families or species, life forms, parts of plants, habitat and its manipulation, all of which imply a broad familiarity not only with the plants themselves but also with ecological processes. Indigenous communities are able to adapt and integrate new practices into the original multiple management strategy in response to recent economic changes (Toledo et al., 2003). However, it is also possible that some of these strategies have been employed since prehispanic times.

Several authors have suggested that Maya communities during the Classic period (ca. A.D. 250–900) used and managed the tropical forest (Barrera et al., 1977; Alcorn, 1981), resulting in the present day floristic composition and distribution visible in association with ancient sites. Sylviculture formed part of the management strategies that included the use of multiple resources from prehispanic times. In the temperate zones of the central highlands of Mexico indigenous agricultural practices, including shifting cultivation with fallow periods, are mentioned in 16th and 17th century documents. In shifting cultivation, the fallow periods and rotation of plots were employed as a means of regenerating vegetation as well as soil fertility (Rojas, 1985). In addition, there are indications that at least the Aztecs recognized that the vegetation growing on fallowed plots was different from the original. Based on Molina’s (1992) 16th century vocabulary, the term quauhtapaçolli refers to brambles or upland weeds and can be understood to refer to secondary vegetation, whereas quauhtla, meaning mountain, woods or forest and quauhyouacatla meaning forest or dense woods, suggests primary vegetation.

7. Conclusions

The use of wood by the prehispanic occupants of the Teotihuacan Valley was a complex activity that required considerable knowledge on the part of the inhabitants of the resource and the processes that controlled its availability.

The taxa show a pattern of continuity with respect to the exploitation of particular genera from the Preclassic through the Postclassic period. This pattern is characterized by the utilization of distinct genera including trees and shrubs, as well as herbaceous (Monocotyledons) and cultivated taxa (Z. mays); in addition it comprises the use of different parts of trees and shrubs such as branches and trunks. Both the taxa employed and their specific vegetative parts were used in diverse combinations and quantities, depending upon the energetic requirements. Changes in the proportions of different genera are interpreted as reflecting preference and intensity of usage and not as indicators of regional deforestation.

Deforestation, as a consequence of the use of wood, could have been of two types: (1) partial, in which isolated patches of natural vegetation were maintained throughout the region through time; or (2) total, in which the resource was rapidly extinguished, resulting in the disappearance of the arboreal community early on in the history of human occupation. The results of this study support the first option; however, it is also possible that the alternative scenario occurred at some point in the past but is unobservable in the archaeological record.

The population of the Teotihuacan region apparently selected firewood based on its quality. The data suggest that the preference for certain genera was diversified instead of limited; in other words, various genera with similar characteristics (e.g. easy cutting, quick ignition, slow burning and intense heat production) were exploited rather than a single taxon. This practice contributed to maintaining the availability of preferred taxa (such as Pinus, Quercus, Cupressaceae, Group 1) in the region throughout the period of prehispanic occupation.

The exploitation of taxa from primary as well as secondary communities supports the idea that the inhabitants of the region employed management strategies oriented towards maintaining local vegetation zones that provided wood for daily use. These
zones played an important role as seed reservoirs contributing to the partial regeneration of local vegetation. Based on McClung de Tapia et al. (2005), this restoration likely occurred during periods following important declines in human population (i.e. after ca. A.D. 650). From this perspective, the development of these zones would contribute to erosion control and overall landscape stability. The implementation of different management strategies would be an important contributing factor to the duration of the prehispanic population for over 1000 years in an otherwise heavily impacted region.

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