Chapter 7

The Cohune Ridge Agrarian Household Economy: Land and Labor

The house plots themselves were considered more or less permanent improvements, and the families acquired outright title to them by virtue of squatter’s rights or by some more formal procedure that has not been recorded. They could be inherited and they reverted to the community only if the whole family moved away (Farriss 1984: 274).

I have previously presented the results of my research largely from a regional perspective by detailing estimates for the Late Classic population and a basic description of the socio-economic structure of the study region. All of the latter data were derived from the surface characteristics of household remains. Through survey, excavation, and soil analysis I described the agro-engineering features found throughout the study region, illustrating that despite seemingly high labor requirements, most terrace construction was likely carried out with minimal labor inputs over the course of at least 100 - 200 years. Using computer simulation, I merged these two descriptions, presenting the settlement and agricultural features regionally and diachronically. The simulations demonstrated that terracing began as an early adaptation to declining yields associated with soil erosion and that construction and maintenance was likely carried out continuously until the end of the Late Classic.
These data, analyses and simulations provide as a whole, the most complete picture of terracing on the Vaca Plateau to date; however, one critical component is lacking, i.e., how households managed the plots of land surrounding each household. This chapter addresses that fundamental exigency.

In chapter two I introduced the smallholder approach as a possible framework to evaluate Classic Maya household agricultural decision making. I argued that Maya farmers produced most, if not all, of their subsistence requirements, that their agriculture was somewhat sustainable from a long-term perspective, that their production was achieved primarily by household labor, and that households would have had great incentive for tenure security on their intensively used lands at least on the Vaca Plateau. I acknowledged that Classic Maya households should not be considered equivalent to modern day smallholders, but argued that such an approach helps to re-focus regional settlement and agricultural studies back to the household, where daily and seasonal decisions were made about the need for terracing, cropping strategies, labor management and labor recruitment.

Accordingly, I now focus my quantitative analyses to the remains of individual households and the agricultural lands surrounding each household on the Cohune Ridge during the early Late Classic (AD 580 - 680), the peak period of population for Caracol, (figure 7.1) and present a preliminary analysis of the agrarian household economy. I
hope to follow up this dissertation research with intensive household excavation, which should serve to further document and elaborate the interpretations I put forward here. Thus, the following interpretations should not be seen as a final stage of research, but simply the first phase of a future complex model of agrarian household decision making. There are two sections in this chapter:

1. I model and calculate the extent of agricultural land surrounding each household unit on the Cohune Ridge during the early to late Late Classic, using spatial analyses carried out in GIS.

2. I estimate the labor requirements of agriculture for each household’s proposed agricultural land.

The basic assumption underlying all of the analyses presented here is that the core subsistence resources of any household were produced on the land immediately surrounding each household.

**Part I: Land and Households on the Cohune Ridge**

One of the primary assertions of the smallholder approach is that household or family size is related to farm size (Netting 1993). From casual field observations, I was convinced that such a relationship existed during the Late Classic for most households on the Cohune Ridge and the entire Vaca Plateau. I was first convinced of this because of the rather even spacing of the units, and second, because of the widespread presence of permanent landscape improvements, i.e., terracing. But I wanted to move beyond just
qualitative observations. Therefore, I quantitatively modeled that relationship using two methods:

1. Simple thiessen polygons (simple voronoi diagrams)
2. Weighted thiessen polygons (weighted voronoi diagrams)

Figure 7.1. Population history for Caracol. The peak population is recorded at AD 600.
Such diagrams (voronoi) have been commonly employed within archaeological research in a variety of cultural contexts, mostly associated with regional settlement pattern studies and socio-political research (Marcus 1976). This is the first example that I know of where such diagrams are used to model prehistoric household relationships.

Using each spatial model I measured the amount of total land surrounding each household, regardless of its productive potential. I then used these data to estimate the productive potential of lands surrounding each household, also calculating instantaneous productivity for each plot. Essentially, I examined whether the land surrounding each household was sufficient for each household’s subsistence needs. To finish this section I analyzed the relationship between household size and farm size, which can be viewed as another means to estimate the Cohune Ridge peak population.

**Methods**

For each residential unit on the Cohune Ridge, a point was placed in the centroid of the construction area using ArcGIS 8.1 *(figure 7.2)*. For each point in the Cohune Ridge survey area, two types of spatial models were interpolated: *simple thiessen polygons* and *weighted thiessen polygons*. Each of these modeling techniques has benefits and drawbacks, so the results of both models are presented here. Ultimately, I believe that the weighted thiessen polygons more accurately model the distribution of land on the Vaca Plateau.
Figure 7.2. Point map of the Cohune Ridge Survey Region.
Simple Thiessen

Simple thiessen polygons have been widely employed in archaeological research. Typically, this form of spatial modeling is used for large regional settlement pattern surveys and to establish some broad understanding of political and settlement boundaries among equally sized and influential polities. But this is just one manner in which the polygons can be and are used. According to Boots (1980: 247), thiessen polygons are primarily used in four types of research:

1) point pattern analysis,
2) organizing data for display purposes,
3) information theoretic approaches to point patterns,
4) modeling spatial processes

The common settlement and political uses in anthropology would fall under the first or fourth type, and I am using them for the fourth, modeling a spatial process. Yet, regardless of the type of research, Boots (1980: 249) indicates that there are four basic assumptions underlying simple thiessen modeling:

1. all points are present at the start of the assignment process;
2. all points remain fixed in location throughout the assignment process;
3. all points are weighted equally;
4. any location in the plane is assigned to the nearest point.
Several researchers have challenged the use of simple thiessen polygons for a variety of spatial data, primarily due to problems with the above listed assumptions (Boots 1980). I attend to these issues below by using a form of weighted thiessen polygon.

To construct a simple thiessen polygon, a line is drawn from each point in the study region to neighboring points, creating a triangulated network (figure 7.3). Perpendicular lines are then drawn to connect the midpoints of the interpolated lines. This is a standard or automated process in any desktop GIS. A basic voronoi diagram is created by this process (figure 7.4). Once the voronoi diagram is constructed, the thiessen polygons are created by clipping the diagrams to a study region or arbitrary buffer around the point distribution. I used a slightly modified version of the Cohune Ridge survey area as the clipping boundary (figure 7.5).

Using simple thiessen polygons is a somewhat standardized and simple means to model spatial processes but does have its drawbacks. The spatial proximity or density of points is the primary variable influencing the shape and the size of the polygons, and all points are treated equally and contemporaneous, as is illustrated by the assumptions listed above. Boots (1980: 249) suggests that while useful for modeling or analyzing some classes of spatial data, simple thiessen polygons may obscure the empirical reality of events or processes.
Figure 7.3. Triangulated Interpolated Network of household remains on the Cohune Ridge, used to construct simple thiessen polygons.
Figure 7.4. Voronoi diagram of households used to construct simple thiessen polygons.
Figure 7.5. Simple thiessen polygons constructed after voronoi diagram clipping.
**Weighted Thiessen Polygons**

Boots (1980) initially developed two alternatives for modifying the construction of thiessen polygons, even though he and others have since added a number of other refinements. These methods were used to address two of the issues with the assumptions underlying all simple thiessen polygon construction. One issue of primary concern to my analysis, is that not all the points in the study region are equal. That is to say that households fall into two very different categories, such as size, complexity or socioeconomic status (see Chapter 4) and consequently should not have equal influence on the shape and size of the interpolated polygons. While the majority of the residential units on the Cohune Ridge are similar (see chapter 4), a handful are very different, and likely had an influence on agricultural boundaries. Botanists and crop biologists illustrate an analogous issue when studying crop, tree and/or plant spacing. Both the diameter of the plant and the species of plant has an influence over the surrounding land and consequently need to be weighted accordingly. Human settlements can be thought of similarly. In fact, Boots (1980) illustrates this point by discussing the influence of population size on the shape and size of the polygons when modeling human spatial processes. He developed a minimum threshold approach to weighting the polygons. This method has been adopted, in part by crop biologists, and is the weighted method I chose to use.
Rationale for using minimum thresholds

If Late Classic Maya farmers were producing the majority of their own food for subsistence around each household, the size of the household would influence the quantity of necessary agricultural land surrounding each unit. Ultimately this relates back to the question of viewing the Classic Maya as smallholders. Using minimum thresholds ultimately assumes that there were both consumptive and productive needs for any given household and that those needs were more significant for larger households.

Not all of the households on the Cohune Ridge are equivalent. Some are significantly larger than the majority. This would certainly have influenced the location of household boundaries, whether physical or conceptual (Stone 1994). Such boundaries probably became heavily fixed as more and more households were established in the region and more labor was invested into the construction of terraces. By the time the peak population is predicted, terraces were very numerous and boundaries would have been well established. Additionally, new land was scarce in the early Late Classic.

Boots (1980) suggested that some minimum threshold, whether it is population size or some other variable, should be established, and that an equivalently sized circle should be drawn around each point for the ‘minimum threshold’. His method basically employed Descarte’s ovals and allows researchers to adjust the spatial model for well documented characteristics of point influence, such as site or household size. Ultimately, this approach would be similar to combining catchment analysis with thiessen polygons, the
only difference being that for catchment areas, a minimum carrying capacity oval is drawn. *Here, a minimum production buffer would not necessarily include the necessary productive lands for each household, but minimum boundary lines.*

For the weighted thienessen diagram, points were categorized using the type classification discussed in chapter four. Type I and II groups were bounded by a 70 meter radius minimum agricultural land buffer (1.54 ha), while Type III and IV groups were surrounded by a 100 meter radius buffer (3.14 ha)\(^{xxii}\). A triangulated network of the points was then drawn. For the weighted polygons, perpendicular lines were drawn at the midpoints not between the two points (or centroids of the households), but the midpoint between the border of the buffered space (*figure 7.6*). Thus, the border distance, was not from point to point, but from buffer to buffer.

There are several ways from which I could have weighted the buffer distance for the wide array of households on the Cohune Ridge. I chose to rely on the type classification for two reasons:

1. The household remains I surveyed on the Cohune Ridge represent the peak period of occupation for each household, which likely occurred at different times throughout the Late Classic. Therefore, use of the construction area or number of structures would have biased the results heavily before analysis. Thus, household growth by accretion and eventual decline is accounted for by using the type classification.
Figure 7.6. Buffered example of weighted thiessen construction.
2. Structure function has not been adequately established for the residences on the Cohune Ridge, and for that matter throughout the greater Vaca Plateau. So while I do use structure counts as a tool for analysis in chapter four, it would have significantly biased the results of the thiessen polygon weighting prior to analysis.

Because weighted thiessen polygons are not common in archaeological research, especially when modeling the spatial distribution of households, I have included the results of both the simple and weighted spatial models. Interestingly, each tells a similar story.

Results, Total Land: Simple Thiessen

Simple thiessens were drawn around each household, creating the map shown in figure 7.5. This thiessen polygon map only measures the raw amount of land surrounding each household. The distribution of these data is shown in figure 7.7, and a scaled three dimensional perspective of these data is shown in figure 7.8. Raw data is reported in Appendix D. According to the results, nearly 82% of the households on the Cohune Ridge had less than 5 hectares of land surrounding each household during the peak period. Just over 96% had less than 7 hectares of land surrounding each household. Four households had more than 7 hectares, with the largest having nearly 11 hectares surrounding it. The average size of household lands was roughly 3.5 hectares.
Figure 7.7. Histogram of raw land surrounding each household using simple thiessen polygons.
Figure 7.8. 3D perspective, looking northeast at the Cohune Ridge settlement. Polygons are extruded by the amount of total available land surrounding each household. Polygons are colored by the number of structures.
The boxplot, shown in figure 7.9 shows the mean and distribution of these data, categorized by a count of the number of structures per household unit. From the graph, it is clear that the general size of the household unit has some influence on the amount of raw land surrounding each household. Chaquistero, Cohune and a third categorically larger group (a Type III group) clearly exhibit the tendency for larger amounts of land. The three large groups have roughly 7 hectares of land surrounding the unit, more than twice as large as the average for the remaining 100 household units. Table 7.1 further illustrates this, showing the average size of land based upon the type classification of them. These data illustrate a significant difference between Type I and II and Type III and IV households. Thus, the results of the raw land calculation suggest the same household differences identified in quantitative analysis of the household units in chapter four.

Table 7.1. Raw land surrounding households using simple thiessen polygons.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Average Plot Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>22</td>
<td>3.27</td>
</tr>
<tr>
<td>II</td>
<td>78</td>
<td>3.61</td>
</tr>
<tr>
<td>III</td>
<td>1</td>
<td>6.97</td>
</tr>
<tr>
<td>IV</td>
<td>2</td>
<td>6.47</td>
</tr>
</tbody>
</table>
Figure 7.9. Box plot of simple Thiessen polygon areas by structure counts.
Figure 7.10. Histogram of weighted thiessen polygons, total area surrounding each household.
Results, Total Raw Land, Using Weighted Thiessen Polygons

The weighted polygons had a noticeable, albeit less than expected influence on the results. The weighted polygons accentuated the already noticeable differences between Type I and II groups and Type III and IV groups. Figure 7.10 illustrates the distribution of land, using a histogram and a three dimensional perspective. Raw data is reported in Appendix D. Similar to the simple thiessen polygons, nearly 80% of the households have less than 5 hectares of land surrounding them, while 94% have less than 7 hectares. The influence of the weighted thiessen is more evident in figure 7.11, which uses a box plot to compare the mean and distribution of raw land by numbers of structures per household. Clearly, the three larger groups are significantly different, with nearly 3 times the amount of raw land than the remaining 100 households. The difference between these three households is also clearly noticeable in table 7.2, which reports the average plot size for Type I and II households and Type III and IV households. Type I and II households average roughly 3.67 hectares of land, whereas Type III and IV average 9.67 hectares. This model emphasized the identifiable differences revealed in the simple thiessen model, which suggests that there was significant variation in the distribution of land surrounding households, depending on the relative size or socio-economic status of the group. From here on, only the figures derived from the weighted model will be reported because I believe it presents a more accurate spatial model based upon known confounding variables.
Figure 7.11. Boxplot of land area surrounding each household using a weighted thiessen polygon.
Figure 7.12. Top: 3D perspective of the distribution of the best agricultural lands. The red and orange extruded polygons are the largest households. The height of the polygon reflects the absolute size of the best agricultural lands. The three groups clearly show a trend towards more quality land. Bottom: Histogram of the distribution of the best agricultural lands.
Table 7.2. Raw agricultural land by group type using weighted thiessen polygons.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>N</th>
<th>Average Plot Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>22</td>
<td>3.27</td>
</tr>
<tr>
<td>II</td>
<td>78</td>
<td>3.59</td>
</tr>
<tr>
<td>III</td>
<td>1</td>
<td>11.04</td>
</tr>
<tr>
<td>IV</td>
<td>2</td>
<td>9.87</td>
</tr>
</tbody>
</table>

*Agricultural lands, simple and weighted thiessen polygons*

Using GIS, I extracted the type of land, based upon the classifications coded in EPIC, to determine the agricultural potential of the land for each household unit. The results fall in line with the analysis of total land. Type I and II groups have roughly 3.36 ha of agricultural land surrounding each household, whereas Type III and IV groups have more than 9 hectares of agricultural land. The differences between these two groups are even more evident by an analysis of the quality of the agricultural land surrounding each household.

Using a GIS, I classified the landscape, based upon slope and soil characteristics, into three agricultural classes: Class I is the best for agricultural production (with low slopes and deep soils) and Class III is the more marginal lands (i.e., steeper slopes and shallow soil), with Class II representing moderate lands. With regard to total agricultural land, Type III and IV groups have a greater percentage of the best agricultural land than the remaining 100 households. Type III and IV average 43% of the best lands when compared to all agricultural land, while Type I and II average just 19%. The larger
groups average 4.15 hectares of the best agricultural land around each household, while the smaller groups average 0.63 ha (figure 7.12).

From these analyses a clear pattern between relative household size and land surrounding each household emerged. The largest architectural groups, in terms of type classification (Type III and IV), have significantly larger and more productive plots of surrounding land. The smaller households, while exhibiting a great variation in the quality and the quantity of land surrounding them, average significantly less total and productive land. This model will now be used to evaluate aspects of population and labor with regard to agricultural production.

**Land vs. Household size**

*Results: Comparing Household Size to Agricultural Plot Size*

The final component of this analysis was a statistical comparison of household size (as measured and reported in Chapter four), to the plot sizes derived previously. I performed a series of regression analyses to determine whether plot size was an effective predictor of household size, and could thus be used as a better predictor of population size. As with the regressions carried out in chapter four for different characteristics of the households, I had expected a patterned relationship between some measure of household
size and some measure of agricultural plot size. But unlike the clear pattern visible in chapter four for the relatedness of household characteristics, (e.g., construction area vs. number of households), there appears to be no significant relationship (highest $R^2$ was 0.13) between construction area or volume, number of structures and the total area surrounding each household (figure 7.13). It seems as if only the major difference, i.e., between Type I and II groups and Type III and IV groups is significant.

There are a number of very plausible explanations for these negative results. First, these data emphasize the fact that the residential remains I surveyed represent the peak size for each plaza group, which occurred at different times for each household during the Classic Period. Simply, not all of the household groups were at peak size in AD 600. Yet, my survey only records the peak size of each household. Additionally, the sample is heavily weighted to smaller groups. These data have been slightly skewed by the preponderance of Type I and Type II groups in the sample.

The critical result still stands, however. Two major groupings of households can be easily separated by analyzing household size and access to land or agricultural land. These results align exactly with the results of household analyses presented in chapter four. While all households likely had sufficient land for subsistence, a small percentage had access to at least two, if not three times that amount. In turn, this was likely to have a significant effect on the number of people who could have been supported by those lands as well as the available labor to work the land.
Results, demographic reconstructions

Using the simulation results, I derived instantaneous carrying capacities for each plot of land for the peak period of population (figure 7.1). After dividing up the land using the weighted thiessen polygons, I returned to the simulations at the peak period to identify the management strategy in use and the productivity for each type of land. Total productivity was derived, a small quantity was removed for next year’s crop and other possible losses (25%) and the figure was divided by 150 kg of maize per person per year\textsuperscript{xxv}. The calculations produced an average household size of 10 persons for all of those sampled on the Cohune Ridge. Type I and II groups together averaged 10, while the larger more imposing groups averaged 32 persons. The total population calculated was 1076, directly in line with the peak population estimates of between 805 and 1343 I reported in chapter four based solely on the surface characteristics of plaza groups.
Figure 7.13. Regression plot of construction area vs. total land using weighted thiessen polygons.
Summary of Land Analyses

When I initiated work on the Cohune Ridge, I was convinced that there was a quantitative relationship between household size and space between households. The results I have presented are somewhat mixed. There certainly is a relationship between household size and plot size, but it is only evident between the two major types of groups found in the settlement. This likely has something to do with the fact that the household remains I recorded were the process of several generations of growth and modification. The most important finding was that even during the peak population, many, if not all of the households on the Cohune Ridge theoretically would have been able to produce the majority of their subsistence requirements on the lands surrounding each household. But a critical question remains; did the households have sufficient labor to carry out the very intensive agriculture modeled for this time period? Therefore, I now calculate whether the Cohune Ridge households had the necessary labor to meet the demands of the intensive agricultural production, modeled for AD 600.
Evaluation of the labor economy

General Labor Requirements

Numerous studies have been carried out over the course of the last eighty years detailing the labor requirements of tropical rain-fed agriculture. Empirical observations of farmers show rather consistent results. There are essentially four sets of tasks involved in the agricultural process:

1. Field Preparation
2. Planting
3. Cultivation (hoeing and weeding)
4. Harvesting

For each plot of land derived previously by the weighted thiessen model, I estimated the labor requirements based upon the figures summarized in table 7.3, which were taken from Stadelman and applied to the management strategies reported in chapter 6 (Stadelman 1940). A number of studies report quantitative estimates for labor input for the variety of tasks discussed above. The majority of the studies report labor estimates that fall between the low and high estimates reported in table 7.5 and used for these calculations.

Table 7.3. Labor requirements expressed in person hours adjusted for stone tool use.

<table>
<thead>
<tr>
<th></th>
<th>Low (Acre)</th>
<th>High (Acre)</th>
<th>Low / (ha)</th>
<th>Hi / (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparing</td>
<td>83</td>
<td>415</td>
<td>205</td>
<td>1025</td>
</tr>
<tr>
<td>Planting</td>
<td>26</td>
<td>26</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>Cultivations</td>
<td>208</td>
<td>249</td>
<td>514</td>
<td>615</td>
</tr>
<tr>
<td>Harvesting</td>
<td>120</td>
<td>150</td>
<td>297</td>
<td>371</td>
</tr>
<tr>
<td>Prep with grass*</td>
<td>240</td>
<td>---</td>
<td>593</td>
<td>---</td>
</tr>
</tbody>
</table>
Some generalizations can be put forward. Eight hundred and fifty three (853)xxvi persons would have been required on an annual basis working six hours a day for 200 days per year to complete all of the agricultural labor necessary during the peak period throughout the entire Cohune Ridge. This is a great deal of labor. It represents about 20 times the amount of labor reported for modern Maya populations engaged in milpa. For example, Stadelman (Stadelman 1940) reports that roughly 10% of any given village would be engaged in agricultural activity for between 400 and 600 hours per acre per year. The labor estimates for the Cohune Ridge are incredibly high. When these figures are individually compared to the number of persons that could be supported in AD 600 by the lands surrounding each household another pattern emerges.

The largest households, i.e., Type III and IV groups would have had more surplus labor than the Type I and II groups. Cohune and Chaquistero, for example, could have supported 37 and 30 persons respectively. In order to produce that food, each would have required the labor of 21 individuals for six hours a day and 200 days per year. Simply, between 58% and 69% of the persons feeding off of the produce would have had to have contributed the balance of their annual labor. In contrast, the Type I and II groups exhibit very little labor surplus. 30 of the 100 smaller groups would have required more labor than could have been supported on the plots of land. Twenty-two would have required more than 80% of the total possible production. More than half of the households would have had to have invested most, if not all of their available labor, just
to maximize production on the plots of land directly surrounding their households. And this does not account for the inevitable labor bottlenecks that would have been experienced during preparation and harvesting. Thus, the householders on the Cohune Ridge were not only constrained by the landscape to produce on the lands directly surrounding each household, they were also constrained by labor requirements, at least during the peak population period.

**Summary and Discussion**

What do all of these spatial models and analyses really mean? Some interpretations can now be put forward in light of the results. The Classic Maya were a low energy society. They did not have beasts of burden or any efficient transportation system available to them (certainly this is the case for the Vaca Plateau). The Classic Maya relied on human labor and hand tools. We can consequently think of the Maya as a ‘tight’ agricultural system. Basic resources probably leaked out of the system and away from households, but no real surpluses were regularly mobilized and transported great distances. The data presented in this chapter, reemphasize such a perception of the Maya. Essentially, the analyses confirm a basic description of the Late Classic Maya presented by Webster (1985: 381). Webster (1985:381), while discussing surplus production and labor for the Late Classic put forward two assumptions about agrarian behavior:

1. “The Maya lived in classic agrarian societies in which virtually all work was accomplished by the food energy which powered human muscles.”xxvii
2. “...prehistoric Maya agrarian systems were probably quite closed in terms of the export of bulk food energy, although not all Mayanists would agree (e.g., Phillips and Rathje 1977). The dependence on foot transport severely limited the distances over which heavy, high bulk staple food products could be moved efficiently.”

Basically, Webster (1985) goes on to describe some similar characteristics later put forward by Netting (1993) in his smallholder approach. He (Webster 1985) argues that most Maya (i.e., more than 80%) produced their own subsistence requirements, leaving little in terms of surplus for elites to exploit.

Basically, Webster’s article was designed to examine a common misperception of ‘exploited’ Maya farmers. He (1985) illustrated that the Maya were probably not over-taxed or over burdened by the demands of the elite, and suggests that there was likely little in the form of surplus for the elite to exploit. Such a perception of ‘exploited’ Maya farmers has fallen out of favor recently, but not due to Webster’s conclusions. Instead, many of the recent reconstructions of Classic Maya behavior suggest a system with a great deal of surplus capacity for exchange.

The above reported data clearly illustrate that, consistent with Webster’s suggestions, each household on the Cohune Ridge produced little in the form of agrarian surplus. The only aspect that could be added to Webster’s description would be that not only was agricultural surplus limited, but labor was also limited, due to the requirements of
intensive household based agriculture on the Cohune Ridge in the Early Late Classic. So, similar to smallholders, the Classic Maya not only had a shortage of land in the early Late Classic, but likely had some severe labor bottlenecks that could have further limited the ability of the elite to mobilize labor.

**Labor Productivity and Urbanization**

In the previous chapter, I discussed the measure of labor productivity as used by economic demographers for comparing pre-industrial and industrial urban regions of Europe. While this is only a cursory analysis, built upon a spatial model of a 4.1 km$^2$ region of Caracol, an interesting comparison can be presented that supports the brief discussion of urbanism I presented in chapter four. Table 7.4 reports the data from Bairoch’s (Bairoch 1990) study on European urbanization. To these data I have added an estimate for the labor productivity of the Cohune Ridge (calculated as millions of calories per agricultural laborer).

Table 7.4. Labor Productivity reported for pre-industrial and industrial regions of Europe, as compared to those modeled and calculated for the Cohune Ridge Maya (Bairoch 1990).

<table>
<thead>
<tr>
<th>Region</th>
<th>1800</th>
<th>1908-1912</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole of Europe</td>
<td>6.0</td>
<td>11.1</td>
</tr>
<tr>
<td>Germany</td>
<td>6.5</td>
<td>30.6</td>
</tr>
<tr>
<td>Belgium</td>
<td>7.0</td>
<td>21.2</td>
</tr>
<tr>
<td>United States</td>
<td>15.4</td>
<td>47.0</td>
</tr>
<tr>
<td>France</td>
<td>6.5</td>
<td>17.6</td>
</tr>
<tr>
<td>Italy</td>
<td>5.0</td>
<td>6.8</td>
</tr>
<tr>
<td>UK</td>
<td>13.2</td>
<td>24.1</td>
</tr>
<tr>
<td>Russia</td>
<td>5.6</td>
<td>7.4</td>
</tr>
<tr>
<td>Switzerland</td>
<td>5.8</td>
<td>15.7</td>
</tr>
<tr>
<td>AD 580 - 600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohune Ridge Maya</td>
<td>0.6624</td>
<td></td>
</tr>
</tbody>
</table>
If the model is reasonably accurate, a clear and fundamental difference is illustrated for industrial and pre-industrial European regions and the Vaca Plateau. The Maya must have had a categorically different form of central place, as required by the low labor productivity figure. Clearly European cities showed increased urbanism between 1800 and 1908/1912. They also demonstrate an overall increase in labor productivity between these two periods. With these data, I believe it is impossible to compare Maya central places to Industrial and modern European or American cities as well as pre-industrial European and American cities. They were categorically different from a labor productivity perspective.

While the model I present here oversimplifies a certainly complex and diachronic issue, I believe it provides a means to begin evaluating some of the variables not included in the model, such as tax and tribute, part-time specialization and community labor. The model also sets the stage for future research I hope to initiate in the region that will provide for more accurate and diachronic reconstruction of the household economy. To build such a model will require not only more complex agricultural simulation, but a great deal of household archaeology, in order to develop a better understanding of household composition and lifespan.