CLASSIC TIKAL AND SLASH AND BURN AGRICULTURE: POPULATION AND SUBSISTENCE IN A PREHISTORIC MAYA CENTER IN THE DEPARTMENT OF PETEN, GUATEMALA

by

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ABSTRACT

The question whether Prehistoric Tikal was agriculturally self-sufficient based on slash and burn agriculture is proposed. The problem is evaluated from the standpoint of its four most fundamental components: (1) Peten ecology; (2) Tikal population studies; (3) slash and burn agriculture; (4) the modern Maya diet. A computer simulation of Tikal's prehistoric population and agricultural production is made based on present population size. Estimates offered by Haviland (1969) and data from agricultural studies conducted by Cowgill (1961 and 1962) in the Peten. It is concluded that Tikal was not agriculturally self-sufficient using the slash and burn method of farming. Several alternative solutions to their subsistence problem are advanced.

ACKNOWLEDGEMENTS

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The author would especially like to thank her mother and father for teaching her the value and importance of education, for continuously motivating her and making all of this possible.

DEDICATION

to Pedro,

for understanding my purpose.

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1. INTRODUCTION

This study is concerned with the agricultural potential of the Prehistoric archaeological site, Tikal, in Northeastern Guatemala. Tikal is the largest and one of the most important of the Maya ceremonial centers situated in the tropical forest of Mesoamerica. The problem of agricultural potential is of particular interest in light of the most recent population estimates of the site, an approximate 49,000 (Haviland 1969:430). Such a high population figure questions whether Tikal was agriculturally self-sufficient within its tropical forest setting where today a subsistence farming method called slash and burn is employed.

Assuming that the same farm method was used by the Prehistoric Maya, various data were collected on the average acreage required per person annually, total cultivable land pertaining to Tikal and the production in pounds per harvest. These figures were collected with the intent of simulating Tikal's prehistoric agricultural production and possible population size using a mathematical model. To carry out such a test extensive research was necessary in four basic areas: (1) general information on the Maya; (2) an examination of the modern Maya farming methods; (3) a review of nutritional

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<u>American</u> <u>Anitiquity</u> is used as a pattern for format and style.

requirements and dietary customs of the modern Maya; and, (4) recent population studies of prehistoric Tikal.

The result of such research has been the following paper. Sections 2 and 3 provide the reader with some general background on the Maya, their development, achievements and the setting in which this civilization flourished. In Section 4, Tikal is specifically described in terms of its discovery, development, cultural sequence and the population studies subsequently conducted. Section 5 discusses the slash and burn farming system presenting the advantages and problems of this farming technique. Section 6 is a review of modern Maya food customs with emphasis on nutritional values, quantities and food processing. The archaeological evidence of the Prehistoric diet is presented and the importance of the early 16th century Spanish records emphasized. Finally the 7th section gives a brief summary of the important points of the research and presents the mathematical model used in deterimining Tikal's agricultural production and population size. Section 8, gives the test results as well as the author's conclusions about Tikal's agricultural self-suffciency.

2. MAYA LITERATURE SURVEY

Long before the Spanish conquest an Indian culture group settled the Yucatan Peninsula, Guatemala, Belize, parts of Honduras and El Salvador (Robiscek 1972:1). They shaped a magnificent civilization that flourished for centuries within the tropical rainforest. Scholars have called them Maya, but they probably knew themselves by other names (Lafay 1975:729).

By A.D. 300, the Maya, whose development took centuries, reached a cultural climax. For 600 years they thrived in what is apparently an inhospitable environment until at the end of their Classic period, around A.D. 900, the Maya civilization seems to have abruptly collapsed. When the Maya collapsed, they left only remnants of their grandeur. Today, two million indians of the Maya linguistic stock, descendants of the prehistoric Maya, still inhabit the area (Robicsek 1972:1).

The Maya origin and identity is obscure and a point very much in debate. Some speculate that the Maya were related to the Olmecs who occupied land west of Maya territory a thousand years before the time of Christ. Ultimately, they are believed to have moved into the Lowlands where their civilization developed and reached its peak. Still, others believe Maya culture actually originated in the Lowlands of Guatemala's Peten region (Lafay 1975:732). In any case, it seems that the cradle of Maya civilization was in the plains of the Peten and that sometime between 1800 and 1500 B.C. essential elements of this agrarian society, primitive pottery vessels and maize cultivation, appeared in the Mayan area (Robicsek 1972:2).

The Maya cultural development, not an isolated process, was considerably influenced by neighboring civilizations. The Maya belonged to a large diversified group of people that shared a Meso-american tradition (Willey 1966:85 - 87). They were characterized by important cultural traits which included an agricultural system, a strong religious tradition, organized village settlement, a system of hieroglyphic writing, books of bark paper and deerskin, the permutation calendar, pottery and the ball court where some type of game was played employing a rubber ball (Robicsek 1972:2). Robicsek points out that the similarities among these cultures lead us to conclude that not only were these groups from a single original stock but they continually interchanged ideas after developing their distinctive national characteristics.

The most obvious feature of Maya Classic times was the high level of cultural complexity (Culbert 1974:91 - 93). Maya achievements included a knowledge of mathematics, since a system of positional notation as well as the abstract notion of zero developed before A.D. 300. The Maya possessed the only true writing system in the New World which combined ideographic writing with phonetic writing. They developed three remarkably precise calendars, the Solar, Lunar and Venus calendars and were able to predict with accuracy solar and lunar eclipses (Culbert 1974:87 - 89). Their calendric calculations were impossible without some understanding of astronomy, which was intricately tied into their rich Mayan mythology (Benson 1:123). Benson describes the complex Maya cosmos as including 13 heaven and sky dieties, nine lords of night, seven earth dieties as well as gods of agriculture, the moon and maize. It was a dualistic nature worshipping religion, where the powers of good and evil, light and darkness fought over man's fate. Finally, Mayan architecture deserves mention on their list of achievements.

During the Classic period construction activity at the numerous Maya centers was at its peak. The centers were characterized by tall pyramids made of earth and rock fill, usually faced with limestone blocks. They built one limestone and plaster temple-pyramid after another, constantly recycling materials. Demolished buildings were used and reused as fill (Coe 1975:792). Besides the tall pyramids, temples, palaces and large stone pillars called stelae were erected. The buildings covered with stucco, were decorated inside with colorful frescoes. The roof combs at the top of some pyramids were purely decorative in fuction, usually covered with rich sculptural designs in plaster (Culbert 1974:30). Other constructions included ceremonial platforms, ritual baths, ball parks with stone benches, trade posts and well kept causeways connecting various parts of a center (Robicsek 1972:13).

The archaeological evidence indicates that the time between A.D. 250 and 900 was of tremendous success for the Maya. Certainly their progress was reflected in their developing cultural life. Their system appeared to be functioning smoothly and they had room for expansion. The results seem to have been growth, increasing prosperity and open communication both within the Lowlands and outside the rain forest area (Culbert 1974:104). From cultural climax the Maya experienced sudden collapse. Within a relatively short period of 50 to 100 years, construction ceased as did the manufacture of luxury items, population rapidly declined and centers were abandoned for no apparent reason (Adams 1973:22).

A number of explanations have been offered in an attempt to interpret the Classic Maya culture failure, but no one individual theory has been completely satisfactory. To mention a few, the theories have included ecological explanations whereby the Maya supposedly exhausted the soil or water loss and erosion seriously upset the food production capacity. The catastrophic approach proposes earthquakes or hurricanes were responsible for destroying the Maya civilization. Disease has been offered as a possible cause for their decline as well as foreign invasion (Adams 1973:23 - 34).

There are problems concerning most of these explanations. For some, the very lack of evidence forces their rejection whereas in other cases the explanation is valid for one locality rather than the whole Maya region. It also seems doubtful that a complex system functioning smoothly could be upset so easily by any one cause. Recently, a comprehensive approach has been taken, considering several of the theories in combination rather than individually. Though considerable study is still needed for a satisfactory explanation, the approach seems to be, in any case, more in line with the situation.

3. PETEN ECOLOGY

The region where the Maya civilization developed is humid and tropical for the most part. The total area, approximately 323.750 square kilometers, is naturally divided into 3 general sections. These are: (1) the southern Maya area including the Central American cordillera; (2) the central area including the Department of Peten and Southern Yucatan; and (3) the northern area comprised of northern Yucatan (Morley 1956:3). Of central focus in this study, however, is the Department of Peten, Guatemala, where the largest most important ceremonial centers, including Tikal are located.

The Peten is classified as a tropical seasonal forest (Aw) in Köppen's climate system based on temperature and rainfall (Muller and Kolenkow 1974:173). The area is described as a gently undulating limestone platform with an average elevation of about 500 feet above sea level. Topographical features include a series of flat topped limestone ridges as well as seasonally swampy depressions, called bajos, where there is almost no evidence of prehistoric occupation (Culbert 1973:6).

Temperatures are high, the mean annual temperature recorded for the region being 26.6° C with a variance of approximately 10° C (West 1964:228). During the coldest months temperatures dip to around 10° - 15°C whereas in the hottest months, April and May, temperatures rise to above 37.7° C.

Though the rainy season in the Peten extends from May through January, showers are not infrequent during the so called dry months, February through April. The seasonal rainfall is high, about 177.8 cm. annually for northern Peten, increasing southward to about 381 cm. annually (Morley 1956:11).

Tropical Forest

Generally, evergreen tropical rainforests consist of at least three and sometimes as many as five stories of woody plants reaching heights of 40 to 50 meters. Near the top of the forest, one or more of the stories form a closed canopy, so dense, that sunlight is prevented from reaching the lower levels and inhibits growth of vegetation. The most luxuriant growth near the ground is usually found along the streams and clearings where the flora is unlike the interior of the forest (West 1964:230).

In the Peten the forest grows to a height of 50 meters, the larger trees standing out as emergents, while the second story forms the canopy over the forest floor. There is an abundance of ramon trees, (*Brosimum Alicastrum*) commonly found on archaeological sites, like Tikal, in the Peten. Other emergents are chiefly mahogany, the mastic tree and wild figs. The lower story contains the hackberry, (*Eltis*) the laurel, (*Ocotea*) and many palms (*Opisandra*). Lianes of the bignonia family are abundant, orchids and spanish moss are also common (West 1964:228).

Within the forest 285 species of birds have been recorded, among them, the white heron, hawks, parrots, golden turkey, buzzards multi-colored humming birds. Abundant jaguar, puma, ocelot, peccary small deer and snakes populate the forest as well. Some of these animals are repeatedly represented in the Mayan art work that suggests the forest environment continues to exist today as it was 1500 years ago.

Soil Classification

The soils that have supported the major Maya centers in Guatemala are Rendzina and black calcareous lithosols similar to Rendzina (West 1964:30). These are considered good soils in the tropics since they are not easily exhausted despite continuous cropping. The underlying limestone in this area is an important factor enhancing the quality of the soil. Due to the considerable moisture during the rainy season, lime is constantly added to the soil through solution, making the soil remarkably good for continuous cropping (Ferdon 1959: 13).

In areas where excessive relief occurs there are problems of leaching and erosion. This is a region of karst topography, that is, an area characterized by caves, sink holes and underground streams, formed where thick jointed limestone beds are dissolved by solution in water. The karst landscape is lowered in spots by the action of percolating water and during this process valuable minerals are dissolved and removed from upper layers of the soil. A handicap created by this type of topography in northern Peten is the lack of fresh surface water supplies. Abundant rains penetrating the porous soils quickly drop far beyond the reach of men equipped with limited technology.

Because of the problems of leaching, erosion and few fresh water sources, careful selection of land is an important consideration for the Peten farmer. But even before the advent of modern technology, the Indians seemed well aware of the various soil types, their potentials, the importance of location and chose their lands accordingly (West 1964:267). Today, the Peten farmer faces the same problems as his predecessors and has his own method of land classification. He has developed an intimate relationship with the environment through close observation (Reina 1967:3). His livelihood today depends on his knowledge of the area, just as his ancestors, who thrived in the forest, required the same type of knowledge for their survival.

4. THE ARCHAEOLOGICAL SITE OF TIKAL

The prehistoric site of Tikal, located in the northeastern part of the Peten, is perhaps the most important and without a doubt the largest of all Maya ceremonial centers. Inhabited since Preclassic times from before 600 B.C., (see Fig. 4-1) the site was abruptly abandoned by all but a small remnant population in the Late Classic, A.D. 900 (Coe 1967:27).

Tikal's rediscovery was well over a century ago. As early as the 18th century, the Guatemalan archives contain references of people moving into the area. However, the first official expedition to the site was in 1848, by the Govenor and Commissioner of the Peten, Ambrosio Tut and Modesto Mendez, respectively (Coe 1967:12). Their report describing the journey, explorations and a description of temples as well as drawings of a number of stelaes attracted the attention of interested individuals, archaeologists and adventurers.

The first systematic exploration and mapping of the site was in 1881 and 1882 through the efforts of A.P. Maudslay, who under difficult circumstances, produced a map accurately locating Tikal's five Great Temples (Carr and Hazard 1961:iii).

The Peabody Museum subsequently sponsored Teobert Maler in 1904 to complete a map of Tikal, however because of problems between Maler and the institution, the map was never submitted, and in fact, has never been located. Again in 1910, the Museum sponsored an

PRECLASSIC PERIOD	800 B.C. - A.D. 300
EARLY CLASSIC PERIOD	A.D. 300 - 600
LATE CLASSIC PERIOD	A.D. 600 - 900
POST CLASSIC PERIOD	A.D. 900 - 1200

Fig. 4-1. The Maya cultural sequence (after Willey 1966:40, Fig. 3-9).

expedition under A.M. Tozzer who in 1911 presented the Peabody Museum with a complete map of the central area, sketched during his 23 day stay at the site (Carr and Hazard 1961:iii).

The University Museum of the University of Pennsylvania began a new survey of Tikal in 1957 that extended until 1960. The principal surveyors were Robert Carr and James Hazard who mapped a square area (see Fig. 4-2) measuring two kilometers north, south, east, and west from the Great Plaza or a total of 16 square kilometers (Carr and Hazard 1961:iv). The 11 year project sponsored by the University Museum began large scale excavation in 1956 with many specific objectives. A primary aim was to investigate the relationship of size to change--resistance or receptivity to innovation--as a long range goal. The question of origin, development and substance of Maya Classic ceremonialism was another major interest as was the eventual collapse of this culture. Still, another important concern was the preservation of Tikal, that without full cooperation from the Guatemalan government, would have been an impossible task. Realizing the value of the site as an archaeological monument, the area was declared a National Park, 576 square kilometers in size (Shook, Coe, Broman and Satterthwaite 1958:6 - 7).

Developmental Sequence

The first evidence of occupation at Tikal was sometime between 700 B.C. and 500 B.C., a time period called the Preclassic during which Maya patterns of living were formed (Coe 1967:27). These earliest remains consist of rare deposits of trash,

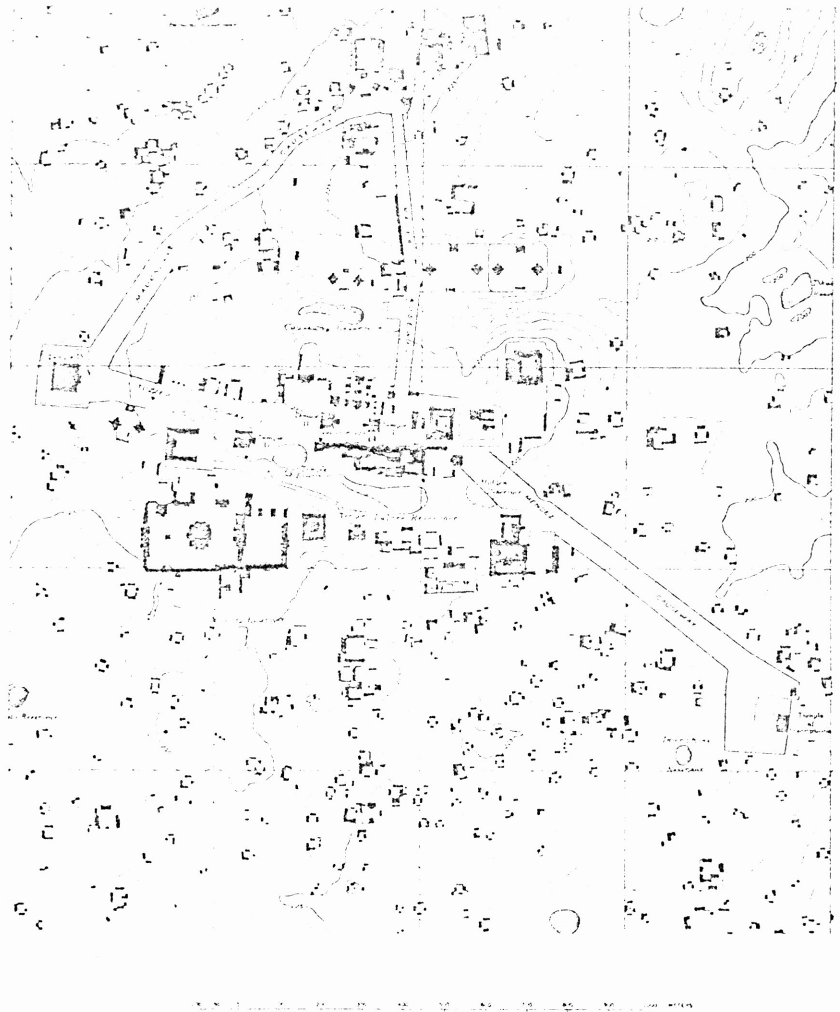

Fig. 4-2. Mapped portion of sixteen square kilometers surrounding Tikal (Culbert 1974:63, Fig. 18).

an occasional burial and pottery. The ceramic technology, at this early date, was quite sophisticated, and wide spread trade connections are confirmed by the existence of imported obsidian and quarzite. Nothing is known of Preclassic architecture since the Maya repeatedly destroyed their buildings at least partially, using the debris as fill for subsequent building activity (Coe 1967:96).

Around 500 B.C. pottery styles changed and new types of ceramic vessels appeared. Excavations of this period have uncovered floors, burials, pottery but no buildings or platforms have been identified. No doubt the buildings exist, however, the Maya tendency to destroy the old makes their discovery difficult (Coe 1967:96). By the 3rd century B.C. a new type of pottery was produced and archaeologist are certain architecture of a ceremonial nature was being constructed. An early version of the North Acropolis dates to about 200 B.C. (Coe 1967:97). By 100 B.C., the North Acropolis emerges as a platform 22.8 meters by 27.7 meters.

This civilization matured, grew spatially and architecturally into magnificence such that by 150 B.C. to A.D. 200 Tikal was an established major ceremonial center (Hunter 1974:45). As the population expanded, Tikal took on new dimensions with large temple pyramids, numerous plazas, hundreds of public buildings, causeways, range type structures, ball courts and stelaes accompanied by sculptured ornamentations all of which occupy an area the size of one square kilometer (Sanders 1973:327 - 328). Indeed, Tikal is the largest Maya center which is presently known (see Fig. 4-3). It's central portion is a mass of construction connected by four causeways with

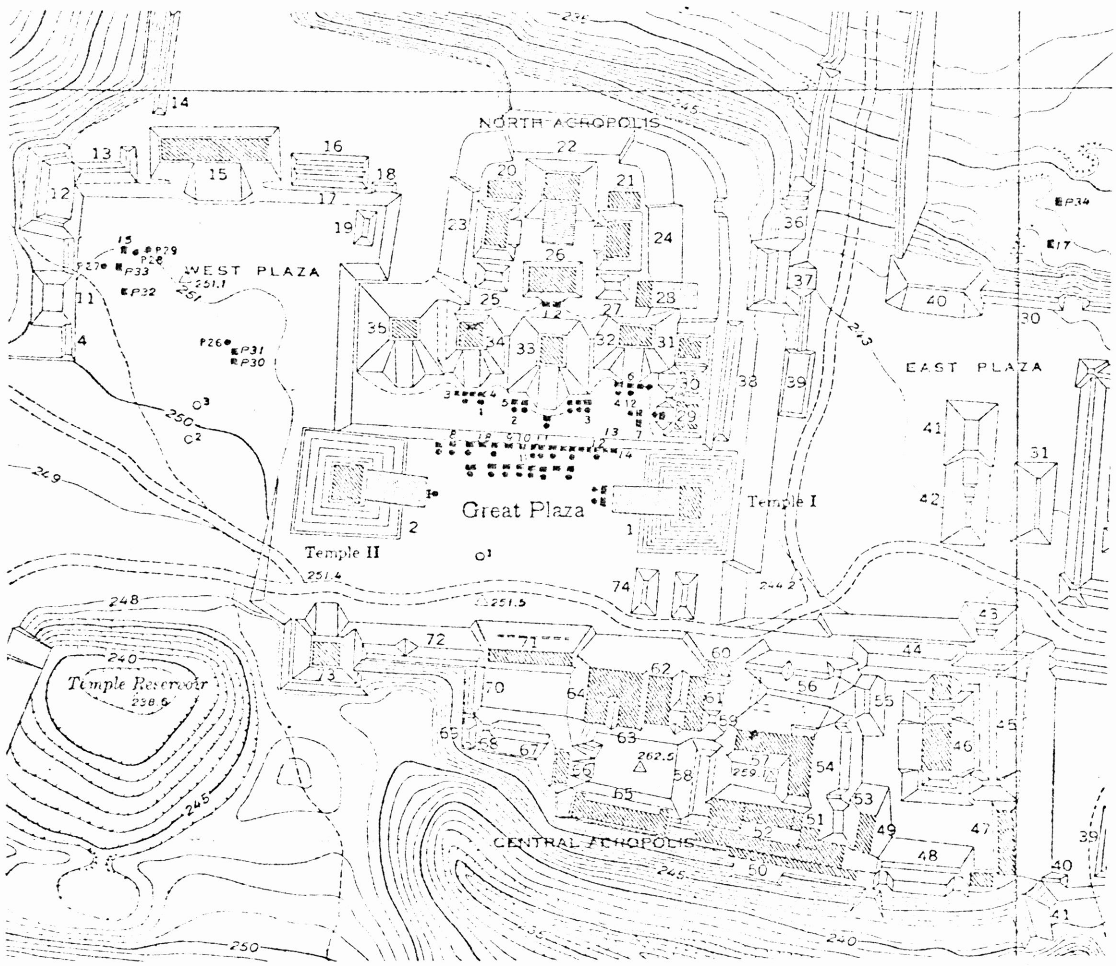

Fig. 4-3. Detailed portion of the central ceremonial area of Tikal (Coe 1962:481, Fig. 2).

virtually hundreds of small structures extending out from the center in all directions. Five pyramids, the highest ever constructed in the Maya area, dominate the entire site. Their heights range from 79 meters to 43.7 meters, Temple IV and Temple II, respectively (Andrews 1974:83).

As previously mentioned, by the Early Classic, Tikal had a well developed North Acropolis. Later Temples I and II were constructed closing off the open space in front of the North Acropolis and thus creating the Great Plaza. The Central Acropolis, covering four acres at the south end of the Great Plaza, was mainly a project of Late Classic times made up of solid palaces and plazas.

The numerous structures at Tikal have been repeatedly modified. Sometimes the Maya demolished entire shrines or ripped off roof combs, using the debris as a foundation for the next construction. Following Mesoamerican tradition, the earliest buildings were painted in brilliant colors (Hunter 1974:48). Coe (1962:43) has indicated that the amount of polychrome stucco facade decoration, specifically on the structures of the North Acropolis, must have been staggering, judging from the fragments found in construction fills.

The construction activity of Tikal apparently reached a peak around A.D. 692 to 751 at which time all important features as the North Acropolis, Central Acropolis, Temples III and V, Great Plaza, East and West Plazas, Plaza of the Seven Temples and causeways were built (Culbert 1973:73 - 74). However, ceremonial architecture was not the only type of construction found at Tikal. Small house structures arranged in clusters are found all over the site. Some houses were essentially built of stone and plaster with thatched roofs, though the range of quality is considerable. Ceramics and burials associated with the houses also vary in quality. The differences suggest social and economic diversity among Tikal's residents (Coe 1967:105).

In any case, the great bulk of construction was in the central part and the extension of this construction both ceremonial and residential strongly suggests Tikal's population was large. The immense structures represent millions of man labor hours both of unskilled crews and highly trained men. A good portion of Tikal's population must have been free to involve themselves in quarrying, shaping limestone blocks, burning lime for plaster, collecting rubble for pyramid fill and actual building (Culbert 1974:92). Recognizing the number of people actually needed for these constructions introduces a question about the size of Tikal's total population. Though a difficult problem to deal with, the subject is an important one, particularly in the context of the tropical forest where feeding a large population migh place heavy strains on the environment.

Population Estimates

Population studies have been an important part of the research program at Tikal and estimates have ranged from the claim that the site was virtually an empty ceremonial center (Brainerd 1958; Willey and Bullard 1965 cited in Andrews 1975:17), to a recent calculation of 49,000 for the entire area (Haviland 1969:429).

In 1960 a map of Tikal was completed covering an area of 16 square kilometers (Carr and Hazard 1961). Using this map, Haviland made a preliminary population estimate of 10,000 - 11,000 for Late Classic times based on the excavation of 117 small structures. The excavation according to Haviland, gave a precise idea as to how many of the structures were houses and how many were occupied simultaneously during the Late Classic. The importance of determining a structure's function and contemporaneity among the constructions cannot be stressed enough. These two points, however, are particularly troublesome and make population estimates a difficult task. Haviland, seems to successfuly handle the first problem determining structure function, suggesting that excation of the 117 structures compounded with an extensive ceramic test pit program, allows for a projection of the findings to all small structures within the 16 square kilometer boundary. The second problem, determining house contemporaneity is particularly difficult to overcome. Haviland, however, has indicated that the Maya when altering their small structures, kept in use a portion of the original older walls. If abandonment had taken place for any significant period, considering the tropical climate and its effects on the structures, reuse of any houses would have been impossible. So Haviland claims once houses were built they were continually occupied, though with frequent alterations, until abandonment (Haviland 1969:429).

Within the 16 square kilometer mapped portion of Tikal, 2750 structures have been recorded (Coe 1956 - 61:480). An approximate 1800 of these were small structures occupied between A.D. 700 - 830 and another 800, located in the center of the ceremonial area, were possibly elite residences (Haviland 1965:19). Using these figures, Tikal's population was estimated based on an average nuclear family of 5.4, as determined by Naroll's formula. Essentially, Naroll's (1962:587) cross cultural study has established a relation between total population size and total floor area of house structures, such that, for each member of a household an approximate 10 square meters are allocated. Haviland has also based his nuclear family size of 5.4 on modern Maya communities. His preliminary estimate, then, is approximately 10,000 - 11,000 for the 16 square kilometer portion of Tikal as mapped by Carr and Hazard or approximately 600 persons per square kilometer. These population results, as Culbert (1973:70) indicates, only correspond to an arbitrary limit, 16 square kilometers, that coincides with the major ceremonial area. Since Haviland's preliminary estimate, a new survey was conducted by Puleston in which four radial strips, each 500 meters wide and 12 kilometers long, running in the four cardinal directions were mapped totaling an area of 25 square kilometers.

The survey results suggest that clear boundaries possibly existed for Tikal coinciding with an earthwork discovered 4.5 kilometers north and 8.8 kilometers southeast from central Tikal (Puleston 1974:303). To the east and west the site's limit corresponds with extensive bajos, an area where no house mounds have been located. Haviland (1969:430) has calculated Tikal's sustaining area as roughly circular approximating 162.78 square kilometers. He proposes that the same population density previously calculated for the central 16 square kilometers applies for an extension of land up to 63.59

square kilometers from the center. At a density of 600 per square kilometer the population figures would total 39.000, a considerable increase over the original population estimate of 10,000 - 11,000. With increasing distance fróm the center the population noticeably drops, so Haviland has estimated for the remaining 99.19 square kilometers, a density of 100 per square kilometer, increasing the total population to 49,000.

Puleston's (1974:303) data differs from that of Haviland in that he calculates 120 square kilometers as the sustaining area for Tikal. It should be emphasized, however that Puleston's calculations are based on available upland areas, excluding bajo areas intruding into the site limits as well as the square footage of existing house mounds. For this reason Puleston's estimates a much higher density per square kilometer for central Tikal at 900 persons per square kilometer and 300 per square kilometer for the periphery. Haviland, on the other hand, excludes no land from within the 162 square kilometers he considers Tikal's sustaining area. Despite their differences, both Puleston and Haviland have estimated high population figures for Tikal with a noticeable concentration in the central part and a marked decline as the distance from the center increases.

The implications of this large population are particularly disturbing in the context of the tropical forest since the population pressures create problems where subsistence is concerned. The conventional method of agriculture used in the tropics today, slash and burn, is a system well adapted to the tropical ecosystem, however its capacity to adequately support particularly large populations in a limited area indefinitely, is debatable. Any effort to determine with relative assurance whether slash and burn agriculture satisfied Tikal's subsistence problem would first require a thorough review of this system, its potential as well as a close familiarity with Maya food habits and nutritional requirements.

5. SLASH AND BURN AGRICULTURE

Slash and burn agriculture or milpa farming as it is commonly called in Central America is a system of cultivation frequently used in the tropics (Muller and Kolenkow 1974:248) and presently practiced by the modern Maya (Reina 1967:1; Cowgill 1961:13).

The milpa farming process, as practiced in the Peten, begins with partial clearance of a plot of land. Some trees are cut down, weeds are slashed and the boundaries of the plot well defined, separating the debris from the forest edge. The vegetation, left on the ground to dry for a few weeks, is burned sections at a time just prior to the heavy rains. The burning, a delicate matter, is done cautiously in late afternoon when the winds are their calmest and the dangers of an uncontrolled fire the least (Reina 1967:4).

After burning, but immediately before the rains the seed is planted in the hot soil which is moist with a juice drawn from the soil, excellent for seed germination. The planting, usually in the last week of April and the first week of May, is done with the aid of a digging stick with which the farmer or milpero makes a small hole to a depth of 15 centimeters where he deposits several seeds (Cowgill 1961:18 - 19). These recently planted seeds, that draw nutrients from the burned ash, begin a slow maturation process until fully grown and harvested in October (Reina 1967:1). After several harvests the milpero is forced to abandon his land for more productive ones since with each harvest his plot produces less. Then, the milpa cycle begins once again.

Selection of Land

There are many factors influencing a milpero's choice of land. Soil quality is one of the most important considerations. Near Lake Peten, milperos have developed their own system of soil classification based on their experience and observation of the environment. Four general soil types are recognized (Reina 1967:2). The first of these, Sernis, is a sandy, porous, manageable soil, highly favored by milperos since it conserves moisture well. Tierra Negra, or black soil does well with a dry season crop and the milpero recognizes its benefits however, he will not cultivate on this soil if Sernis is available especially if rainfall is not predicted to be normal for the year. Tierra Colorada, the third variety of soil requires a much longer growing season as compared to the sandy Sernis. While the latter produces a crop in three months the Tierra Colorada needs four to five months and the milpero realizes the risk of losing his crop increases with a longer growing season. The last general soil type Tierra Blanca is less desirable since working in this soil requires more energy. A milpero feels that, while the Tierra Blanca may be productive the time involved and consequently the risk is not worth the effort (Reina 1967:2).

But soil type alone is not responsible for the milpero's choice of land. When questioned about the factors involved in land selection

(Cowgill 1961:13) the men have emphasized (1) a location where weeds and grasses are minimal but vegetation high indicating a lengthy fallow period; (2) where the milpero, through previous experience with a piece of land knows he can expect a good crop; (3) where land is not excessively high, preventing an erosive problem caused by sun and wind, nor the terrain too low where swampy conditions, unfavorable for plant growth, might occur. Other considerations included proximity to a water source and the desire to be near town, however both were apparently of less importance.

Finally, the milpero must consider the time of year he chooses to plant, when deciding on location for the milpa (Cowgill 1961:14). The milpero can cultivate up to four crops annually, two regular harvests, the dry and wet season crops and two emergency ones, planted only when the regular harvest is poor and food shortages exist. Should the farmer decide to cultivate a dry season crop, he must choose land in February in a low swampy area, called bajo, where his seed is insured sufficient water. On the other hand, the wet season crop requires a steep area with good drainage. The milpero selects his land in September avoiding locations where water accumulation would definitely inhibit plant growth.

Land Usage

The milpero might cultivate the same plot for two or three harvests, after which he must abandon the land that progressively yields less with each crop. The number of successive harvests on the same plot is a decision that depends on the milpero's assessment of his land's productive capacity. The same plot may be replanted until the soils, depleted through continuous use, are no longer productive. Two successive harvests for the same plot is a usual practice for the Peten and Yucatan, however three and even four consecutive harvests have been recorded for the latter (Cowgill 1961:29).

But the milpero is well aware that something is happening to his land's soil when its productivity progressively decreases. When production drops below his investment of labor hours, the milpero wisely abandons the land in search for more productive ones. His old plot lies unoccupied for a length of time referred to as a fallow period, during which the adjacent forest invades the plot, lost nutrients are restored, and a higher productive level reached. This fallow period varies with the milpero, the time span ranging from 2 to 20 years, depending on the number of successive harvests and the quality of soil.

In a study conducted by Cowgill (1961:31) at Lake Peten, 40 milperos were interviewed as to their farming practices. When questioned about the length of the fallow period needed after one single harvest, 60% answered two years, 20% responded three years and the remainder one year. In northern Yucatan, the length of the fallow period significantly increases, averaging a 10 year fallow after two successive harvests. For those in the Peten planting two consecutive crops before moving to a new location, 60% reported a necessary five year fallow, 20% favored a three year fallow and the remainder between one to five years.

Advantages of Slash and Burn Farming

From the description of milpa farming the five part system appears relatively simple.

(1) Appropriate land is chosen and partially cleared.

(2) Vegetation, left to dry, is burned.

(3) The seed is planted.

(4) A crop is harvested.

(5) The milpero forcibly abandons the land.

Though simple in theory, this subsistence technique requires quite a bit of insight on the kinds of terrain suitable for the various crops, a knowledge of soil types, an acute sense of timing as well as intuition.

Still, the milpa farming technique, employed for multiple reasons offers definite advantages to the farmer in terms of productivity per hour of labor. That is, the milpero's labor input never exceeds his crop output, such that he produces a subsistence crop for himself and his family with a minimum of expended energy (Clark 1966:357). The milpa farming system is apparently well adapted to the tropical ecosystem and in fact simulates the natural processes of the forest environment in three ways (Geertz 1966:16).

The milpa plot, intercropped with numerous plant domesticants, imitates the forest which is also "intercropped" with a variety of plant species. In both systems, the source of nutrient material is locked up in living forms rather than in the soil. Finally, the milpa, growing in only a partially cleared plot, depends on the remaining trees for protection against excessive rainfall and sun exposure just as the forest relies on its second story canopy to prevent damage to soils in the way of leaching or erosion. So it appears that the milpa farming technique, if employed properly does no damage to the environment and actually offers the farmer a time investment advantage that he would not enjoy if more intensive forms of agriculture were used.

Problems with Slash and Burn Farming

Despite the advantages, milpa farming is a delicate system with problems. The correct balance between the fallow and productive period must be kept so that the environment is left undisturbed (Geertz 1966:25). As long as the agricultural cycle of fallow to productive years is respected and land available in quantity, the farming system is successful. However, if for any reason the fallow period is shortened and soil regeneration not adequate, production can be expected to decrease (Palerm 1955:60 - 61). This has obvious implications for population growth (Clark 1952:98; Dumond 1961:304). Just the support of a single permanent household requires considerable land, since large areas of fallow land are needed in proportion to the land actually in production at any given time (Cowgill 1962:276). A large population therefore would demand large amounts of land and growth for a specific area would be tolerable only to a point, after which shortages would eventually limit growth.

While it appears that milpa farming more adequately serves the needs of smaller less dense populations its production capacity does vary considerably for each location. Since productive potential depends on variables as soil type, rainfall, terrain type and kinds of crops, an evaluation of these factors is required to determine milpa farming's capacity for producing food. Three of these factors, soil type, rainfall and terrain type have been dealt with previously. The last variable, types of crops are examined in the following section.

6. MAYA DIET

Presently, it is difficult to determine with complete assurance the actual food habits of the prehistoric Maya. However, a reconstruction of the ancient diet is attempted based on data obtained from three information sources: (1) the MacNeish rock shelter investigations; (2) the 16th century ethnographic reports of the Spanish; and (3) modern Maya dietary information.

General trends in all areas of culture are observed in Mesoamerica. As part of this tradition the Maya no doubt shared common food patterns with neighboring groups. With respect to general trends in diet, the investigations of R.S. MacNeish in the rock shelters of Tamaulipas and the Tehuacan Valley have provided a long record for the origin of agriculture in Mesoamerica. His cave discoveries document a stage by stage change of food habits which begin with a hunting period that slowly evolves into an incipient agricultural stage prior to 7000 B.C., finally evolving into full cultivation (MacNeish 1964:9).

In his attempt to reconstruct the ancient diet, MacNeish and his workers have shown how over a period of 9000 years the proportion of hunted meat in the diet steadily decreased from 70% to 15%, while the importance of cultivated plants gradually increased (MacNeish 1964:10 - 12). Specifically, the MacNeish evidence strongly suggests that the measurable portion of maize in the diet grew in quantity so that by 2000 B.C., the foundation of Mesoamerican agriculture had been laid. Maize seems to have been the primary domesticant in highland Mesamerica with beans, squash and chile peppers sharing an important part of the Indian diet (Willey 1966:85). It is necessary to mention that although MacNeish's work pertains to an area north of the Maya territory, it is the only information source which provides us with a quantification of dietary data over time. His information is also valuable since it offers a basic idea of the diet which might apply to surrounding areas.

A second major source of information on the prehistoric Maya diet are the early Spanish records. Interestingly, food items considered essentials in the modern Maya diet are continuously referred to in the Spanish accounts of the Sixteenth Century. "Posole" or "saca", the modern Maya drink is described by Spanish writers as made of cooked maize and drunk lukewarm. References are made to "tamales", a dish made of meat mixed with corn bread, "zaca", a drink of Cacao and maize, "tortillas", a bread made of maize, "sapote", a sweet honey tasting fruit, beans, squashes, wild pigs, turkey, deer and fish (Means 1917:23, 28, 30, 63, 138, 167). From the repeated references in the Spanish literature it seems that the foods of the modern Maya are similar in many respects to that of the prehistoric, at least as far back as 1500 to 1700 and probably much earlier than that (Benedict and Steggerda 1936:180).

The modern Maya food practices serve as the third and final information source on Maya diet. To make any conclusive statement about prehistoric food habits a thorough knowledge of modern food types, their energy values, amount of consumption and processing techniques is required. Then, working on the assumption that the modern Maya preserve at least a part of the ancient practices, an analogy between modern and ancient populations can be drawn, lending credibility to the diet reconstruction. A comprehensive food study of modern Maya customs conducted by Benedict and Steggerda (1936) has provided insight into the subject. Their research consisted of an analysis of Maya food customs, describing the various food types, a breakdown of their content and daily amounts consumed per individual and per family. The procedure involved collecting meal samples from several families for three consecutive days and from five individuals for the same time span, or in some cases longer with the ultimate goal of determining how or if the diet affected the characteristic Maya high metabolism (Benedict and Steggerda 1936:157).

In their report Benedict and Steggerda list 60 items as part of the modern Maya diet and classify these foods under several major headings: maize products, vegetables, non-vegetables, fruits, breads, crackers and miscellaneous items (Table 1). Their study clearly differentiates the imported foods from those produced locally, and designate the Spanish imports as non-essentials, even today (Benedict and Steggerda 1936:168).

In their analysis, Benedict and Steggerda (1936:186) discovered, that on the average, modern daily consumption per individual amounted to 2565 calories. Seventy-five percent of this caloric intake was derived from carbohydrates, specifically maize, equaling 1.26 to

Table 1. Items in the diet of the Maya Indian (modified after Benedict and Steggerda 1936:162 - 163, Table 1).

Name		
English	Scientific	Spanish
Maize products--		
White maize	Zea mays L.	Maiz blanco
Yellow maize	" " "	Maiz amarillo
Boiled white maize	" " "	Nixtamal
Dough	" " "	Masa
Corn cakes	" " "	Tortillas
Dough	" " "	Pozole
Vegetables--		
Black beans	Phaseolus vulgaris L.	Frijoles
Lima beans	Phaseolus lunatus L.	Frijoles
Brown beans	Phascolus sp. (?)	Frijoles
Beans and pork		Frijol con puerco
Squash	Cucurbita moschata Duch.	Calabaza fresca
Squash	Cucurbita moschata Duch., or	Calabaza
Squash seeds	C. pepo L.	Pepetas de calabaza
Tuber (yam)	Dioscorea alata L.	Macal
Tuber (yam)	" " "	Macal
Tuber (yam)	" " "	Macal
Sweet potato	Ipomcea batatas L.	Camote
Tuber	Pachyrrhizus erosus L.	Jicama
Pith of tree and maize	Leucopremna mexicana A. DC.,	Bonete
Pith of tree and maize	or Pileus Mexicanus.	Bonete
Green leaves (spinach)	Jatropha aconitifolia	Chaya
Chayote	Sechium edule	Chayote
Tomato	Lycopersicum esculentum (?)	Tomate grande
Rice	Oryza sativa L.	Arroz

Table 1 continued

Name		
English	Scientific	Spanish
Chile	Capsicum annuum L.	Chile
Meats and non-vegetables--		
Venison	Odocoileus toltecus	Venado
Peccary	Pecari angulatus yucatanensis	Puerco del monte
Wild turkey	Agriocharis ocellata	Pavo del monte
Agouti	Dasyprocta punctata yucatana	Tepezcuintle
Beef*	Bos taurus	Carne
Chicken soup*	Gallus sp.	Pollo
Lard*	. . . . .	Manteca
Fried eggs	. . . . .	Huevos fritos
Pork and banana	. . . . .	Puerco y platano
Fruit--		
Oranges (sweet)*	Citrus sinensis	Naranja
Hybrid oranges*	Citrus sp. (?)	Cajera
Oranges (sour)*	Citrus aurantium L.	Naranja
Yucatan plum	Spondias mombin or S. lutea	Ciruela
Custard apple	Annona reticulata L.	Anona
Sapote	Achras zapota L.	Zapote
Wild pineapple	Ananas sp. (?)	Pinuela
Seeds of palm tree	Acrocomia mexicana	Cocyol
Mamey	Calocarpum mammosum L.	Mamey
Papaya	Carica papaya L.	Papaya
Banana*	Musa sapientum L.	Platano
Sour sop	Annona muricata L.	Guanabana
Bread and crackers--		
Sweetened bread*		Pan dulce
White bread*		Pan frances
Soda crackers*		Galleta
Yucatan crackers*		Galletas de chicos
Miscellaneous--		
White sugar*		Azucar blanco
Brown sugar		Panela
Honey		Miel
Salt		Sal

Table 1 continued

Name		
English	Scientific	Spanish
Seasoning.	Capsicum annum L.	Chile
	Bixa orellana L.	Achiote
	Allium sativum L.	Ajo
Chocolate*	Theobroma cacao L.	Chocolate
Coffee*	Coffea arabica L.	
Alcoholic drinks		Anise
		Habanero
		Xtabentum

* Imported; not native.

1.47 pounds per person daily. They have stressed that this caloric consumption is quite low for a laborer since by modern standards an average laborer involved in moderate muscular work would require closer to 3500 calories. Further breakdown of the diet indicates that 17 percent of the calories are derived from protein and approximately 13 percent from fat. Here again, Benedict and Steggerda (1936:188) stress a low protein intake, at 74 grams daily.

A dietary study conducted by Williams (1973:52) in south-central Mexico, shows similar type data on food practices. The general observations included a high consumption of corn products and vegetable protein as opposed to a low intake of animal protein for 130 individuals with a total daily consumption of 1450 calories. Though Williams' data for total caloric consumption is quite low, maize consumption is relatively high and protein intake considerably low.

Based on their study, Benedict and Steggerda have classified maize, beans and squash as the essential food items, which combined with a meat source from the forest adequately supply the Maya with their necessary protein and energy requirements. It is important to stress that the factors leading to the domestication and present day cultivation of these particular plants are not accidental (Kaplan 1973:77 - 78). The reasons for this dietary evolution are probably the result of repeated sampling of available plant resources with a gradual trend towards selection of the best nutritional combinations. In areas where maize consumption is high, the amino acid lacking in the diet is lysine. This amino acid must be obtained from another available food source. Beans, with a high lysine content adequately supplement the diet with this lacking element, and a valuable nutritional combination is achieved (Kaplan 1973:75 - 76).

Another consideration that deserves mention is the role of food processing in improving the nutritional quality of maize. Generally, maize is deficient in the important amino acids, lysine, trytophan and niacin, a member of the vitamin B complex. Bressani and Scrimshaw (1958 cited in Katz, Heideger and Valleroy 1974:767) discovered that in Mexico and Central America, where maize is pre-treated in a lime water solution the nutritional quality of maize is markedly enhanced. The experiment they conducted showed that, while the lime cooking process decreased the overall nutrient content of maize, the relative amounts of lysine and tryptophan increased. The ratio of isoleucine to leucine was also observed to have increased, important because the condition favors the conversion of tryptophan to niacin, an essential vitamin.

So, based on the dietary studies of the past 30 years, Benedict and Steggerda's observations of the Maya achieving an adequate diet appear to be correct. The Maya diet is balanced, provided sufficient quantities of beans are consumed, since bean protein, similar to meat or fish protein, adequately supplements the missing elements in maize (Food and Agricultural Organization of the United Nations 1953:51).

To summarize the important points, what appears evident based on the MacNeish investigations and the Spanish ethnographic reports, maize has formed a part of the Maya diet since prehistory. Today, the modern Maya still maintain the food practices of their ancestors and have been basically uneffected by the Spanish food imports. Recognizing the incomplete nutritional value of maize the population gradually selected for food combinations that could adequately meet their dietary requirements. The corn, beans and squash diet developed as a result of this selection and, it is now known, based on recent food studies, the combination is of high nutritional value provided sufficient quantities of beans are consumed to supplement the lacking elements in maize. Additionally, processing maize with lime water has proved to selectively enhance its nutritional quality, achieving a favorable balance of amino acids and vitamins.

As part of their analysis, Benedict and Steggerda broke down the modern Maya diet into its three basic components: carbohydrates, proteins and fats. The greater part of the diet is in the form of carbohydrates equaling 75% of the total calories, proteins form 17% of the consumed calories and fats approximately 13%.. In general the total caloric consumption as well as the total protein intake are considered quite low. Maize, on the other hand, a carbohydrate, is obviously extremely important judging from its high content in the diet. Because of its importance in today's diet it has been assumed that maize was just as essential in the prehistoric diet. So, using the general dietary information outlined in this section, and in particular, a study conducted by Cowgill (1961) in the Peten dealing with maize production using slash and burn agriculture, a test was devised to determine whether the maize production at Tikal could adequately support the population that constituted the center.

7. SIMULATION OF AGRICULTURAL PRODUCTION AND POPULATION AT PREHISTORIC TIKAL

Though a general study of slash and burn farming, the modern Maya diet and population estimates of Tikal have been fundamental to this research, more precise information, empirical data from the field, was required for the simulation of Tikal's prehistoric agricultural production and thus population size. To test Tikal's agricultural self-sufficiency based on maize cultivation three basic questions needed to be answered. How large was Tikal's sustaining area? How many acres did each individual require annually for subsistence? What was the average length of the slash and burn agricultural cycle? If answers to these questions were possible, the figures could be formalized in a mathematical model and a hypothetical population size for Tikal calculated in terms of Tikal's actual physical limits.

The first problem was the determination of Tikal's sustaining area, that is, defining the area available for cultivation. Haviland (1969:430) assumes this area was roughly circular and coterminous with earthwork constructions to the north and south of the site as well as two large bajo regions to the east and west. His estimate, approximating 162.78 square kilometers or roughly 40,000 acres includes the bajo lands that intrude into Tikal's sustaining area. Haviland's site limits correspond to a decreasing number of house structures as one increases the distance from Tikal proper. However this fact alone does not provide sufficient evidence that Tikal's sustaining area stopped abruptly at the point delineated by Haviland. Still, using his 40,000 acre figure, Tikal is given a limit and a population estimate possible at least for this area. Though once Tikal's limits are set, it is possible to extrapolate the test results to a larger area. Another estimate of Tikal's sustaining area has been proposed by Puleston (1974:303). Excluding bajo portions of land as well as the space occupied by architectural structures, Puleston has offered an estimate of 120 square kilometers.

For purposes of this study, a half-way point between both figures was accepted. Haviland's 40,000 acre estimate was used, less 14% composed of terrain unsuitable for cultivation or covered with masonry (Sanders 1973:358). The final estimate of Tikal's sustaining area was calculated at 130 square kilometers or 35,000 acres.

Agricultural Data from Lake Peten

The study at Lake Peten conducted by Cowgill (1961) has proven helpful in answering the last of the key questions in this research. Her interview with 40 milperos provided information regarding the length of the slash and burn farm cycle and the amount of land required per individual for subsistence. The reader will recall that, when practicing slash and burn agriculture the farmer is required to abandon his land and allow an appropriate fallow period so that lost soil nutrients are replenished and soil damage prevented. The length of this farm cycle, both productive and fallow years is crucial information since it determines the amount of land available per person and affects the farmed land's productivity. Cowgill (1962:276) discovered that when Peten milperos were asked how much fallow they felt necessary after a single crop, three-fifths answered a two year rest, one fifth recommended a three year fallow while the remainder suggested anywhere from two to six years. However, the data collected on fields used in 1959, showed that the fallow periods were much longer than indicated by the local theory. Cowgill suspects that the variation between the farmer's suggestions and the actual data is due to the present low population density in the Peten. This situation would allow the milpero to change land more frequently than if land were a scarce commodity. But if the population density were to rise, the milperos could probably farm the land without damage following the length cycle they have proposed. Cowgill has concluded that a conservative farm cycle can be maintained on the basis of a four year fallow for every single year of cultivation or six years fallow for two consecutive years of farming.

In her Peten study Cowgill (1962:277) determined the land required annually per person by means of two formulas (see Fig. 7-1). Using the two sets of data gathered on fallow periods, two different sets of results were obtained. Based on the information collected from the Peten milperos on fallow periods, an average 2.4 acres per person were calculated if only one crop was grown. When two consecutive crops were cultivated this figure rose to three acres per person. With the actual 1959 data, results showed that 4.15 acres were needed per person after a single crop, though after two consective crops

[for one year of cultivation]

$$\text{land needed per person annually} = \frac{\text{average yield of first year crop}}{\text{years fallow} + 1}$$

[for two consecutive years of cultivation]

$$\text{land needed per person annually} = \frac{\text{average yield of first year crop} + \text{second year crop}}{\text{years fallow} + 2}$$

Fig. 7-1. Formulas determining the acreage required per individual annually (after Cowgill 1961:38 - 39).

3.25 acres per person were required. Confirming Cowgill's results are those from the Reina (1967:12) study also conducted near Lake Peten. Reina estimated 10 cuerdas or two acres were necessary to support one person for a year, since an average crop yield per cuerda was around 78 pounds and one individual requires approximately 636 pounds of maize annually. He has emphasized, however, that many times a milpero has more land in his possession than needed just to insure a sufficient food supply (Reina 1967:12 - 13).

Mathematical Models Calculating Population Size

With the agricultural data quantified, it was believed that Tikal's population could be estimated using the mathematical expression proposed by Conklin (1959:63) as a general formula determining critical population size of a given area (see Fig. 7-2). On closer examination it was recognized that, if used, Conklin's formula would give erroneous population estimates. Continuous cropping of the same plot of land gradually depletes soil nutrients and reduces productivity. Conklin's formula ignores the fact that each year the crop yield of a plot decreases if no fallow period is allowed (Cowgill 1962:276 - 277). If in fact continuous cropping were the case, the population size of any area would decrease since food production would drop. It is evident, then, that Conklin's formula would give false population estimates since a small value for T, analogous to a short agricultural cycle, would result in a large value for CS population size, a situation which in the long run would not hold true.

$$CS = \frac{L}{A \cdot T}$$

where

CS critical population size

L total land available for cultivation in square units

T length of an agricultural cycle in years

A land required per person annually in square units

Fig. 7-2. Mathematical model determing Criticial population size (Conklin 1959:63).

For this reason another mathematical expression is proposed (see Fig. 7-3) in this study, which, although similar to Conkin's, includes two important changes. First, the length of the agricultural cycle (T) is decomposed into two terms, P, the number of productive years in the cycle and, F, the number of fallow years in the cycle. Second, a usage factor, U, is introduced which is a means of correcting decreasing fertility with each crop. In this study U is defined as 1/P, but a more sophisticated production decreasing function could be used. The ultimate form of, U, however, must be validated with data from the field.

This test, through simulation, has determined Tikal's population size according to an agricultural potential based on a sustaining area of 35,000 acres (L). The acreage required per person ranges from 2.0 to 4.0 acres. The time length of an agricultural cycle has been split up into productive years, with values from one to three, and fallow years, assigned values from one to six. Using these figures, the highest possible population estimate for Tikal has been a mere 8,750 people based on 2.0 acres per person, one single year of cultivation and one year fallow (Appendix A).

The original Tikal sustaining area estimate as calculated by Haviland was 40,000. Fourteen percent of this figure was subtracted from the total since this area was designated as "uncultivable" (Sanders 1973:358). When the 14% is added to the 35,000 acres, for there is reason to believe this "uncultivable" bajo land was in fact used for a dry season crop (Cowgill 1961:14), and the acreage

$$CS = \frac{L}{A(P + F)} \cdot U$$

where

CS	critical population size
L	total land available for cultivation in square units
P	productive years in the agricultural cycle
F	fallow years in the agricultural cycle
A	land required per person annually in square units
U	usage factor

Fig. 7-3. Revised mathematical model determining critical population size.

needed per person reduced to 2.0 acres, the highest possible population estimate using one year cultivation to one year fallow would only be 10,000.

8. CONCLUSIONS

The test results indicate that cultivating maize, the archaeological site of Tikal with a population close to 49,000 had the capacity to feed only one-fourth of its population or 10,000 people. To support a milpa-based population the size Haviland proposes, Tikal's sustaining area need be four times the originally predicted size. Without a doubt, the simulation of Tikal's prehistoric population and agricultural production tend to call into question Haviland's results. In fact, what appears to be considerable overestimation on Haviland's part only emphasizes the need for a more meticulous population study. Undoubtedly Tikal's size was large considering the density of house structures and concentration of ceremonial architecture and this certainly poses a problem with respect to their ability to produce food, but based on what is known about milpa agriculture and Maya diet, Tikal as Haviland predicts could not have possibly subsisted. Very simply, the physical limits of Tikal placed a low ceiling on the carrying capacity of a site cultivating maize with the slash and burn farming technique.

Until this point we have assumed that Tikal used the milpa farming system and cultivated maize as their major staple. However considering the description of Tikal, its importance and sophistication, it does seem unlikely that such a center be limited to one major staple using a single form of cultivation. Instead the Maya may have had a variety of alternatives from which to choose, thus solving their subsistence problem.

The first of these alternatives is expansion of Tikal's territory to meet the needs of its inhabitants. Though this possibility is an unlikely one since an extension of Tikal might interfere with neighboring sites, the area is open to investigation and a study of intersite regions would probably offer insight into the Tikal subsistence problem (Puleston 1974:310).

A second solution to Tikal's problem is through exploitation of the numerous food resources available to the Maya. Rather than being the most important staple, maize could have been one of many major food sources. Bronson (1966) discusses the value root crops may have had for the Maya. The fact that root crops are cultivated today and are mentioned in early Spanish literature is pointed out. The economics of root crop cultivation is explained as well as the nutritional value which is similar to maize (Bronson 1966:268 - 269). Puleston (1968) offers an alternative food source in the way of the ramon nut. He stresses the nutrional composition of this nut and its obvious presence in all the Maya sites. Puleston emphasizes the little care necessary for ramon nut cultivation, the simplicity of harvest and conveniency of storage. As a supplement to a maize and bean diet the use of the ramon nut might adequately solve the Tikal subsistence problem, however the fact that the modern Maya employ this food source in emergency situations only suggests that perhaps the prehistoric Maya also lacked a taste for the ramon nut, and used it in times of emergency food shortages. Lange (1971) proposes marine resources as a likely supplement to the Tikal diet. and judging from the amount of marine material uncovered during excavation, this food alternative seems to have been an important one.

The Maya not only had a number of food sources from which to choose, they may well have had several agricultural techniques at their disposal. More intensive forms of cultivation could have been employed such as irrigation, chinampa farming, intensive gardening in addition to the traditional milpa farming. Wilken (1971:436, 439, 441) discusses the advantages of all these techniques at length, indicating where in the Maya region there is evidence of their use.

Finally, large scale food imports have been offered as a solution to Tikal's subsistence problem. However the likelihood of a site the size of Tikal depending on an outside food source is slight.

Rather, in the final analysis it seems clear that Tikal's population was certainly far less than Haviland predicts, but yet they were probably faced with a subsistence problem that milpa farming simply could not resolve. Alternative food sources as well as farming techniques were probably available to the Maya, however extensive study of this with good evidence is still lacking.

BIBLIOGRAPHY

Adams, Richard E.
1973 The collapse of Maya civilization. In _The Classic Maya Collapse_, edited by T. Patrick Culbert, pp. 21 - 34. University of New Mexico Press.

Andrews, George F.
1975 _Maya cities_. University of Oklahoma Press, Norman.

Benedict, F.G. and Morris Steggerda
1937 The food of the present day Maya. Contributions to American Archaeology, Carnegie Institution of Washington Publication 456:157 - 188.

Benson, Elizabeth
1967 _The Maya world_. Crowell, New York.

Bronson, Bennet
1966 Roots and subsistence of the ancient Maya. _Southwestern Journal of Anthropology_ 22:251 - 279.

Carr, Robert F., and James Hazard
1961 Map of the ruins of Tikal, El Peten, Guatemala. _Tikal Reports_, No. 11, Museum Monographs. Philadelphia.

Clarke, William
1966 From extensive to intensive shifting cultivation: a succession from New Guinea. _Ethnology_ 5:347 - 359.

Coe, W.R.
1962 A summary of excavation and research at Tikal, Guatemala: 1956 - 61. _American Antiquity_ 27:479 - 507.

1963 A summary of excavation and research at Tikal, Guatemala: 1962. _Estudios de Cultura Maya_ 3: 41 - 64.

1967 _Tikal: a handbook of ancient Maya Ruins_. The University Museum, Philadelphia.

1975 Resurrecting the grandeur of Tikal. _National Geographic_ 148 (6):792 - 795.

Conklin, Harold C.
1959 Population-land balance under systems of tropical forest

agriculture. Paper presented at the 1957 Meeting of the Ninth Pacific Congress, vol. 7, p. 63, Bangkok.

Cowgill, Ursula
1961 Soil fertility and the ancient Maya. Connecticut Academy of Arts and Sciences, Transactions 42:1 - 56.

1962 An agricultural study of the Southern Maya Lowlands. American Anthropologist 64:273 - 286.

Culbert, T.P.
1973 The Maya downfall at Tikal. In The Classic Maya collapse, edited by T. Patrick Culbert, pp. 63 - 92. University of New Mexico Press.

1974 The lost civilization: the story of the Classic Maya. Harper and Row, New York.

Dumond, D.E.
1961 Swidden agriculture and the rise of Maya Civilization. Southwestern Journal of Anthropology 17:301 - 316.

Ferdon, Edwin N.
1959 Agricultural potential and the development of cultures. Southwestern Journal of Anthropology 15:1 - 19.

United Nations
1953 Maize and maize diets. Food and Agricultural Organization, Nutrition Division: No. 9.

Geertz, Clifford
1966 Agricultural involution. University of California Press, Berkeley.

Haviland, William
1969 A new population estimate for Tikal, Guatemala. American Antiquity 34:429 - 433.

Hunter, Bruce C.
1974 A guide to the ancient Mayan ruins. University of Oklahoma Press, Norman.

Kaplan, Lawrence
1973 Ethnobotanical and nutritional factors in the domestication of American beans. Paper presented at the 1969 International Botanical Congress, Seattle.

Katz, S.H., M.L. Hediger and L.A. Valleroy
1974 Traditional maize processing techniques in the New World. Science 184:765 - 773.

Lafay, Howard
1975 The Maya, children of time. National Geographic 148 (6):729 - 767.

MacNeish, Richard S.
1964 The origins of New World Civilization. Scientific American 211 (22):29 - 37.

Means, P.A.
1917 History of the Spanish conquest of Yucatan and of the Itzas. Peabody Museum, Harvard, Papers 7.

Muller, Robert and R. Kolenkow
1974 Physical geography today. Ziff-Davis Publishing Co., Del Mar.

Morley, Sylvanus
1956 The ancient Maya. Stanford University Press, Stanford.

Naroll, Raoul
1962 Floor area and settlement population. American Antiquity 27:587 - 589.

Palerm, Angel
1955 The agricultural basis of urban civilization in Mesoamerica. In: J.H. Steward Irrigation civilizations: a comparative study. Pan American Union, Social Science 1:28 - 42.

Puleston, Dennis E.
1974 Intersite areas in the vicinity of Tikal and Uaxactun. In Mesoamerican Archaeology, edited by Norman Hammond, pp. 303 - 311. University of Texas Press.

Reina, Ruben
1967 Milpas and milperos: implications for prehistoric times. American Anthropologist 69:1 - 20.

Robicsek, Francis
1972 Copan home of the Mayan gods. Museum of the American Indian Heye Foundation, New York.

Sanders, William
1973 The cultural ecology of the Lowland Maya. In The Classic Maya collapse, edited by T. Patrick Culbert, pp. 325 - 365. University of New Mexico Press.

Shook, Edwin M., W. Coe, V. Broman, L. Satterthwaite
1958 Tikal Reports, No. 1 - 4. University Museum Monographs, Philadelphia.

West, Robert
1964 Natural environment and cultures. In _Handbook of Middle American Indians_, edited by Robert Wauchope, pp. 446 - 500. University of Texas Press.

Wilken, Gene
1971 Food producing systems available to the ancient Maya. _American Antiquity_ 36:432 - 448.

Willey, Gordon
1966 _An introduction to American archaeology_, Vol. 1: Prentice-Hall, Englewood Cliffs.

Williams, A.W.
1973 Dietary patterns in three Mexican villages. Paper presented at the 1969 International Botanical Congress, Seattle.

APPENDIX A

This appendix includes a list of values for the critical population size (CS) obtained using the formula proposed in this research for different values of the dependent variables, total land (L), acreage (A), productive years (P), fallow years (F) and usage factor (U).

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
35000.	2.0	1	1	1	8750.
35000.	2.0	2	1	1	5833.
35000.	2.0	2	1	2	2917.
35000.	2.0	3	1	1	4375.
35000.	2.0	3	1	2	2188.
35000.	2.0	3	1	3	1458.
35000.	2.0	1	2	1	5833.
35000.	2.0	2	2	1	4375.
35000.	2.0	2	2	2	2188.
35000.	2.0	3	2	1	3500.
35000.	2.0	3	2	2	1750.
35000.	2.0	3	2	3	1167.
35000.	2.0	1	3	1	4375.
35000.	2.0	2	3	1	3500.
35000.	2.0	2	3	2	1750.
35000.	2.0	3	3	1	2917.
35000.	2.0	3	3	2	1458.
35000.	2.0	3	3	3	972.
35000.	2.0	1	4	1	3500.
35000.	2.0	2	4	1	2917.
35000.	2.0	2	4	2	1458.
35000.	2.0	3	4	1	2500.
35000.	2.0	3	4	2	1250.
35000.	2.0	3	4	3	833.
35000.	2.0	1	5	1	2917.
35000.	2.0	2	5	1	2500.
35000.	2.0	2	5	2	1250.
35000.	2.0	3	5	1	2188.
35000.	2.0	3	5	2	1094.
35000.	2.0	3	5	3	729.
35000.	2.0	1	6	1	2500.
35000.	2.0	2	6	1	2188.
35000.	2.0	2	6	2	1094.
35000.	2.0	3	6	1	1944.
35000.	2.0	3	6	2	972.
35000.	2.0	3	6	3	648.

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
35000.	2.5	1	1	1	7000.
35000.	2.5	2	1	1	4667.
35000.	2.5	2	1	2	2333.
35000.	2.5	3	1	1	3500.
35000.	2.5	3	1	2	1750.
35000.	2.5	3	1	3	1167.
35000.	2.5	1	2	1	4667.
35000.	2.5	2	2	1	3500.
35000.	2.5	2	2	2	1750.
35000.	2.5	3	2	1	2800.
35000.	2.5	3	2	2	1400.
35000.	2.5	3	2	3	933.
35000.	2.5	1	3	1	3500.
35000.	2.5	2	3	1	2800.
35000.	2.5	2	3	2	1400.
35000.	2.5	3	3	1	2333.
35000.	2.5	3	3	2	1167.
35000.	2.5	3	3	3	778.
35000.	2.5	1	4	1	2800.
35000.	2.5	2	4	1	2333.
35000.	2.5	2	4	2	1167.
35000.	2.5	3	4	1	2000.
35000.	2.5	3	4	2	1000.
35000.	2.5	3	4	3	667.
35000.	2.5	1	5	1	2333.
35000.	2.5	2	5	1	2000.
35000.	2.5	2	5	2	1000.
35000.	2.5	3	5	1	1750.
35000.	2.5	3	5	2	875.
35000.	2.5	3	5	3	583.
35000.	2.5	1	6	1	2000.
35000.	2.5	2	6	1	1750.
35000.	2.5	2	6	2	875.
35000.	2.5	3	6	1	1556.
35000.	2.5	3	6	2	778.
35000.	2.5	3	6	3	519.

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
35000.	3.0	1	1	1	5833.
35000.	3.0	2	1	1	3889.
35000.	3.0	2	1	2	1944.
35000.	3.0	3	1	1	2917.
35000.	3.0	3	1	2	1458.
35000.	3.0	3	1	3	972.
35000.	3.0	1	2	1	3889.
35000.	3.0	2	2	1	2917.
35000.	3.0	2	2	2	1458.
35000.	3.0	3	2	1	2333.
35000.	3.0	3	2	2	1167.
35000.	3.0	3	2	3	778.
35000.	3.0	1	3	1	2917.
35000.	3.0	2	3	1	2333.
35000.	3.0	2	3	2	1167.
35000.	3.0	3	3	1	1944.
35000.	3.0	3	3	2	972.
35000.	3.0	3	3	3	648.
35000.	3.0	1	4	1	2333.
35000.	3.0	2	4	1	1944.
35000.	3.0	2	4	2	972.
35000.	3.0	3	4	1	1667.
35000.	3.0	3	4	2	833.
35000.	3.0	3	4	3	556.
35000.	3.0	1	5	1	1944.
35000.	3.0	2	5	1	1667.
35000.	3.0	2	5	2	833.
35000.	3.0	3	5	1	1458.
35000.	3.0	3	5	2	729.
35000.	3.0	3	5	3	486.
35000.	3.0	1	6	1	1667.
35000.	3.0	2	6	1	1458.
35000.	3.0	2	6	2	729.
35000.	3.0	3	6	1	1296.
35000.	3.0	3	6	2	648.
35000.	3.0	3	6	3	432.

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
35000.	3.5	1	1	1	5000.
35000.	3.5	2	1	1	3333.
35000.	3.5	2	1	2	1667.
35000.	3.5	3	1	1	2500.
35000.	3.5	3	1	2	1250.
35000.	3.5	3	1	3	833.
35000.	3.5	1	2	1	3333.
35000.	3.5	2	2	1	2500.
35000.	3.5	2	2	2	1250.
35000.	3.5	3	2	1	2000.
35000.	3.5	3	2	2	1000.
35000.	3.5	3	2	3	667.
35000.	3.5	1	3	1	2500.
35000.	3.5	2	3	1	2000.
35000.	3.5	2	3	2	1000.
35000.	3.5	3	3	1	1667.
35000.	3.5	3	3	2	833.
35000.	3.5	3	3	3	556.
35000.	3.5	1	4	1	2000.
35000.	3.5	2	4	1	1667.
35000.	3.5	2	4	2	833.
35000.	3.5	3	4	1	1429.
35000.	3.5	3	4	2	714.
35000.	3.5	3	4	3	476.
35000.	3.5	1	5	1	1667.
35000.	3.5	2	5	1	1429.
35000.	3.5	2	5	2	714.
35000.	3.5	3	5	1	1250.
35000.	3.5	3	5	2	625.
35000.	3.5	3	5	3	417.
35000.	3.5	1	6	1	1429.
35000.	3.5	2	6	1	1250.
35000.	3.5	2	6	2	625.
35000.	3.5	3	6	1	1111.
35000.	3.5	3	6	2	556.
35000.	3.5	3	6	3	370.

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
35000.	4.0	1	1	1	4375.
35000.	4.0	2	1	1	2917.
35000.	4.0	2	1	2	1458.
35000.	4.0	3	1	1	2188.
35000.	4.0	3	1	2	1094.
35000.	4.0	3	1	3	729.
35000.	4.0	1	2	1	2917.
35000.	4.0	2	2	1	2188.
35000.	4.0	2	2	2	1094.
35000.	4.0	3	2	1	1750.
35000.	4.0	3	2	2	875.
35000.	4.0	3	2	3	583.
35000.	4.0	1	3	1	2188.
35000.	4.0	2	3	1	1750.
35000.	4.0	2	3	2	875.
35000.	4.0	3	3	1	1458.
35000.	4.0	3	3	2	729.
35000.	4.0	3	3	3	486.
35000.	4.0	1	4	1	1750.
35000.	4.0	2	4	1	1458.
35000.	4.0	2	4	2	729.
35000.	4.0	3	4	1	1250.
35000.	4.0	3	4	2	625.
35000.	4.0	3	4	3	417.
35000.	4.0	1	5	1	1458.
35000.	4.0	2	5	1	1250.
35000.	4.0	2	5	2	625.
35000.	4.0	3	5	1	1094.
35000.	4.0	3	5	2	547.
35000.	4.0	3	5	3	365.
35000.	4.0	1	6	1	1250.
35000.	4.0	2	6	1	1094.
35000.	4.0	2	6	2	547.
35000.	4.0	3	6	1	972.
35000.	4.0	3	6	2	486.
35000.	4.0	3	6	3	324.

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
40000.	2.0	1	1	1	10000.
40000.	2.0	2	1	1	6667.
40000.	2.0	2	1	2	3333.
40000.	2.0	3	1	1	5000.
40000.	2.0	3	1	2	2500.
40000.	2.0	3	1	3	1667.
40000.	2.0	1	2	1	6667.
40000.	2.0	2	2	1	5000.
40000.	2.0	2	2	2	2500.
40000.	2.0	3	2	1	4000.
40000.	2.0	3	2	2	2000.
40000.	2.0	3	2	3	1333.
40000.	2.0	1	3	1	5000.
40000.	2.0	2	3	1	4000.
40000.	2.0	2	3	2	2000.
40000.	2.0	3	3	1	3333.
40000.	2.0	3	3	2	1667.
40000.	2.0	3	3	3	1111.
40000.	2.0	1	4	1	4000.
40000.	2.0	2	4	1	3333.
40000.	2.0	2	4	2	1667.
40000.	2.0	3	4	1	2857.
40000.	2.0	3	4	2	1429.
40000.	2.0	3	4	3	952.
40000.	2.0	1	5	1	3333.
40000.	2.0	2	5	1	2857.
40000.	2.0	2	5	2	1429.
40000.	2.0	3	5	1	2500.
40000.	2.0	3	5	2	1250.
40000.	2.0	3	5	3	833.
40000.	2.0	1	6	1	2857.
40000.	2.0	2	6	1	2500.
40000.	2.0	2	6	2	1250.
40000.	2.0	3	6	1	2222.
40000.	2.0	3	6	2	1111.
40000.	2.0	3	6	3	741.

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
40000.	2.5	1	1	1	8000.
40000.	2.5	2	1	1	5333.
40000.	2.5	2	1	2	2667.
40000.	2.5	3	1	1	4000.
40000.	2.5	3	1	2	2000.
40000.	2.5	3	1	3	1333.
40000.	2.5	1	2	1	5333.
40000.	2.5	2	2	1	4000.
40000.	2.5	2	2	2	2000.
40000.	2.5	3	2	1	3200.
40000.	2.5	3	2	2	1600.
40000.	2.5	3	2	3	1067.
40000.	2.5	1	3	1	4000.
40000.	2.5	2	3	1	3200.
40000.	2.5	2	3	2	1600.
40000.	2.5	3	3	1	2667.
40000.	2.5	3	3	2	1333.
40000.	2.5	3	3	3	889.
40000.	2.5	1	4	1	3200.
40000.	2.5	2	4	1	2667.
40000.	2.5	2	4	2	1333.
40000.	2.5	3	4	1	2286.
40000.	2.5	3	4	2	1143.
40000.	2.5	3	4	3	762.
40000.	2.5	1	5	1	2667.
40000.	2.5	2	5	1	2286.
40000.	2.5	2	5	2	1143.
40000.	2.5	3	5	1	2000.
40000.	2.5	3	5	2	1000.
40000.	2.5	3	5	3	667.
40000.	2.5	1	6	1	2286.
40000.	2.5	2	6	1	2000.
40000.	2.5	2	6	2	1000.
40000.	2.5	3	6	1	1778.
40000.	2.5	3	6	2	889.
40000.	2.5	3	6	3	593.

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
40000.	3.0	1	1	1	6667.
40000.	3.0	2	1	1	4444.
40000.	3.0	2	1	2	2222.
40000.	3.0	3	1	1	3333.
40000.	3.0	3	1	2	1667.
40000.	3.0	3	1	3	1111.
40000.	3.0	1	2	1	4444.
40000.	3.0	2	2	1	3333.
40000.	3.0	2	2	2	1667.
40000.	3.0	3	2	1	2667.
40000.	3.0	3	2	2	1333.
40000.	3.0	3	2	3	889.
40000.	3.0	1	3	1	3333.
40000.	3.0	2	3	1	2667.
40000.	3.0	2	3	2	1333.
40000.	3.0	3	3	1	2222.
40000.	3.0	3	3	2	1111.
40000.	3.0	3	3	3	741.
40000.	3.0	1	4	1	2667.
40000.	3.0	2	4	1	2222.
40000.	3.0	2	4	2	1111.
40000.	3.0	3	4	1	1905.
40000.	3.0	3	4	2	952.
40000.	3.0	3	4	3	635.
40000.	3.0	1	5	1	2222.
40000.	3.0	2	5	1	1905.
40000.	3.0	2	5	2	952.
40000.	3.0	3	5	1	1667.
40000.	3.0	3	5	2	833.
40000.	3.0	3	5	3	556.
40000.	3.0	1	6	1	1905.
40000.	3.0	2	6	1	1667.
40000.	3.0	2	6	2	833.
40000.	3.0	3	6	1	1481.
40000.	3.0	3	6	2	741.
40000.	3.0	3	6	3	494.

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
40000.	3.5	1	1	1	5714.
40000.	3.5	2	1	1	3810.
40000.	3.5	2	1	2	1905.
40000.	3.5	3	1	1	2857.
40000.	3.5	3	1	2	1429.
40000.	3.5	3	1	3	952.
40000.	3.5	1	2	1	3810.
40000.	3.5	2	2	1	2857.
40000.	3.5	2	2	2	1429.
40000.	3.5	3	2	1	2286.
40000.	3.5	3	2	2	1143.
40000.	3.5	3	2	3	762.
40000.	3.5	1	3	1	2857.
40000.	3.5	2	3	1	2286.
40000.	3.5	2	3	2	1143.
40000.	3.5	3	3	1	1905.
40000.	3.5	3	3	2	952.
40000.	3.5	3	3	3	635.
40000.	3.5	1	4	1	2286.
40000.	3.5	2	4	1	1905.
40000.	3.5	2	4	2	952.
40000.	3.5	3	4	1	1633.
40000.	3.5	3	4	2	816.
40000.	3.5	3	4	3	544.
40000.	3.5	1	5	1	1905.
40000.	3.5	2	5	1	1633.
40000.	3.5	2	5	2	816.
40000.	3.5	3	5	1	1429.
40000.	3.5	3	5	2	714.
40000.	3.5	3	5	3	476.
40000.	3.5	1	6	1	1633.
40000.	3.5	2	6	1	1429.
40000.	3.5	2	6	2	714.
40000.	3.5	3	6	1	1270.
40000.	3.5	3	6	2	635.
40000.	3.5	3	6	3	423.

LAND (ACRES) (L)	ACREAGE/ PERSON*YEAR (A)	AGRICULTURE-CYCLE PRODUCTIVE (P)	FALLOW (F)	USAGE FACTOR (U)	CRITICAL POP. SIZE (CS)
40000.	4.0	1	1	1	5000.
40000.	4.0	2	1	1	3333.
40000.	4.0	2	1	2	1667.
40000.	4.0	3	1	1	2500.
40000.	4.0	3	1	2	1250.
40000.	4.0	3	1	3	833.
40000.	4.0	1	2	1	3333.
40000.	4.0	2	2	1	2500.
40000.	4.0	2	2	2	1250.
40000.	4.0	3	2	1	2000.
40000.	4.0	3	2	2	1000.
40000.	4.0	3	2	3	667.
40000.	4.0	1	3	1	2500.
40000.	4.0	2	3	1	2000.
40000.	4.0	2	3	2	1000.
40000.	4.0	3	3	1	1667.
40000.	4.0	3	3	2	833.
40000.	4.0	3	3	3	556.
40000.	4.0	1	4	1	2000.
40000.	4.0	2	4	1	1667.
40000.	4.0	2	4	2	833.
40000.	4.0	3	4	1	1429.
40000.	4.0	3	4	2	714.
40000.	4.0	3	4	3	476.
40000.	4.0	1	5	1	1667.
40000.	4.0	2	5	1	1429.
40000.	4.0	2	5	2	714.
40000.	4.0	3	5	1	1250.
40000.	4.0	3	5	2	625.
40000.	4.0	3	5	3	417.
40000.	4.0	1	6	1	1429.
40000.	4.0	2	6	1	1250.
40000.	4.0	2	6	2	625.
40000.	4.0	3	6	1	1111.
40000.	4.0	3	6	2	556.
40000.	4.0	3	6	3	370.