Prehistoric Intensive Agriculture in the Mayan Lowlands

Examination of relic terraces and raised fields indicates that the Río Bec Maya were sophisticated cultivators.

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The ancient lowland Maya have been traditionally portrayed as swidden (shifting cultivation) agriculturalists (*1*). The persistence of the swidden concept has inhibited field inquiry of past modes of lowland subsistence, often preserving what may be an unfounded bias concerning the cultivation techniques employed by the Maya. Moreover, the absence of adequate subsistence research has, in effect, supported traditional views regarding such issues as prehistoric population size (*2*) and the collapse of the Classic Maya civilization (*3*).

The last few years have witnessed increased opposition to the swidden concept (*4*). Antagonists have been stimulated by the discovery of ancient forms of intensive cultivation (*5*) in various parts of the New World tropics which have hitherto been considered sparsely utilized (*6*) and by the introduction of revamped theories of the development of agriculture (*7, 8*). Boserup's (*7*) contention that the growth of agriculture from extensive swidden to intensive multicrop cultivation is a direct response to population pressures has been particularly significant, encouraging reexamination of Mayan subsistence (*9*).

The theories of agricultural development set forth by Boserup and modified by Brookfield (*8*) are especially important to the question of Mayan subsistence in light of lowland demographic evidence. Studies by Willey *et al.* (*10*, p. 576), Bullard (*11*), Haviland (*12*), and others suggest that specific Mayan regions once supported large numbers of people. Although prehistoric population estimates must be viewed in relative terms, indications are that several lowland groups exceeded the supportive limits of forest- or bush-fallow systems of swidden cultivation (*2, 13*). It is plausible to assume that, in instances of demographic pressure, more intensive forms of cultivation were adopted or developed by the Maya, a position accepted by a seminar on the collapse of the Classic Maya civilization (*14*).

Based on research in 1973 within the Río Bec region of southern Campeche and Quintana Roo, Mexico (Figs. 1 and 2), this article examines new evidence of intensive Mayan agriculture, in the form of terraces and raised fields. These prehistoric techniques of lowland cultivation are described and their significance discussed (*15*).

Previous Indications of Intensive Agriculture

Evidence of intensive agriculture within the Mayan lowlands is not absent in the literature. Historical accounts describe the existence of irrigation networks along the Motagua and Ulua rivers of Guatemala and Honduras respectively (*16*). Lundell (*17*, p. 73) has recorded stone markers on the forest floor of southern Campeche near Tuxpeña and suggests that these features are relics of intensive agricultural activities by the ancient Maya. Check dams, or *terraplenes agrícolas*, are reported in various sectors of the Río Bec region of Campeche by Ruppert and Denison (*18*, pp. 13 and 50) and in Belize and the Petén district of Guatemala by Blom (*19*). Although long noted, these features have received minor attention.

The presence of relic terraces in the Maya Mountains of Belize are well documented. These structures were noted in 1927 by Ower (*20*, pp. 383–384) and have since been described by several scholars (*21*, pp. 228–229; *22, 23*). Despite the proximity of the Belize terraces to such lowland population centers as Tikal and the Belize–Mopan River valley, their significance to Mayan subsistence is almost totally ignored by proponents of a swidden-based Mayan civilization.

Relic raised fields have been recently uncovered in the poorly drained floodplains of the Candelaria River in southwestern Campeche and in northern Belize by Siemens and Puleston (*24*). These discoveries add a new dimension to lowland Mayan agriculture, illuminating past adaptation and utilization of riverine environments.

Río Bec

The Mayan cultural region of Río Bec is located in the southeastern corner of Campeche and adjacent portion of Quintana Roo. The region contains a large number of rural housemounds and several large ruins, including the fortified site of Becan. This large center and the region surrounding it have received considerable examination by field projects of the Middle American Research Institute, Tulane University (*25*).

The physical setting of the Río Bec area offers a variety of local environments to which past cultivators adapted. Local relief is dominated by limestone hills 20 to 60 meters high with varying slopes up to, but rarely exceeding, 50°. The uplands contain relatively well-drained but shallow soils which are highly vulnerable to erosion when exposed to the torrential rains of the wet season. Level terrain is generally restricted to depressions, either large wooded *bajos* (low areas) or small savannas, where drainage is retarded by thick deposits of subsurface gray clays. Seasonal inundation of the lowlands creates soil conditions which are too wet and sticky for swidden agriculture. Permanent cropping of either type of terrain, upland or lowland, necessitates one of two specific cultivation measures: minimization of soil erosion or drainage.

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Terraces and Associated Features

Tens of thousands of relic terraces crisscross the hillsides of southern Campeche and Quintana Roo, encompassing an area exceeding 10,000 square kilometers. Río Bec terracing was recorded radiating north from Xpujil, Campeche, 62.5 km; south, 13.8 km; east, 77.7 km; and west, 96.2 km (*26*, *27*). The frequency of terracing varies throughout the region. By far the greatest number of terraced slopes are located along an east-west axis from Nicolás Bravo, Quintana Roo, to Xpujil.

According to the classification developed by Spencer and Hale (*28*, p. 6), the Río Bec terraces are predominantly the linear sloping, dry field variety that include: the "rock-embanked but non-contoured terrace with a sloping field laid across slope, without facilities for artificial water, dependent upon natural precipitation for soil water." Figure 3 illustrates a hillside profile of this type of terracing. The slope is broken by embankments which collect eroding soils, creating small, level (or near-level) sections of land which extend 1 to 5 m behind the terrace wall. Each terraced area, then, is sloping, with thinner soils immediately in front of a terrace wall and thicker soils behind. Although individual terraces may run somewhat diagonally across the slope, they more commonly display a contoured pattern. As a rule, terraces conform better to hillside contours as the degree of slope steepens.

The check dam type of terrace reported by Ruppert and Denison (*18*) occurs less frequently than the linear sloping variety. Found in hillside ravines, check dams appear to closely resemble the channel bottom weir terraces (*28*) which have been noted in various sectors of the Mayan lowlands (*19*). Weir terraces are laid across drainage channels and capture silt-laden runoff. As such, they create nearly level areas of soil behind each terrace.

Two distinct constructional forms of terrace embankments have been uncovered. Eastward from Becan, embankments consist of cut limestone walls and rubble fill (Fig. 4). Fronting walls are constructed of small, dry-laid limestone slabs, creating an embankment 80 to 140 centimeters in height. Behind this, a rubble fill of rocks is deposited, similar to some of the ancient terraces of the Andes (*29*, p. 494; *30*, p. 211). The entire embankment, wall and fill, is

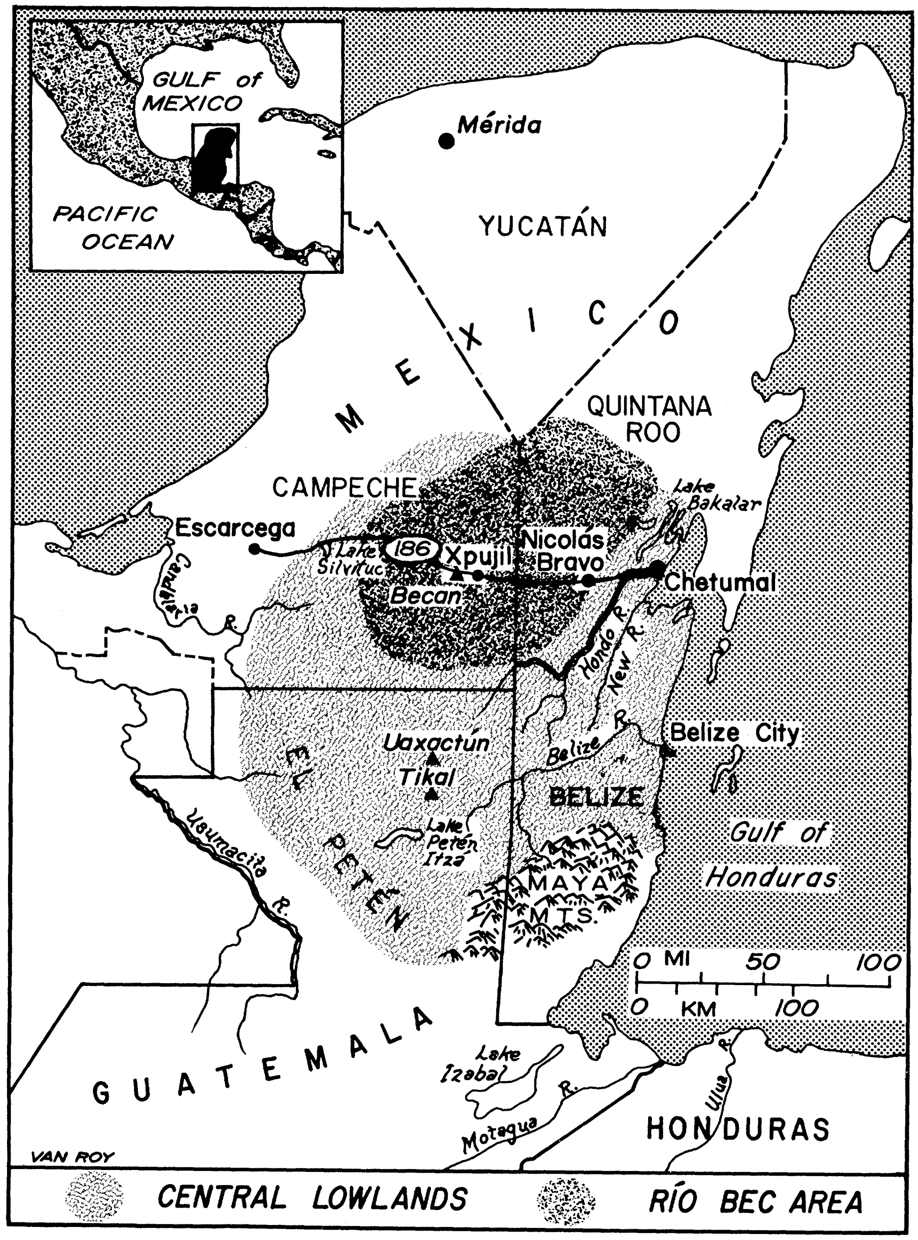

Fig. 1. Map of the central Mayan lowlands and the Río Bec region.

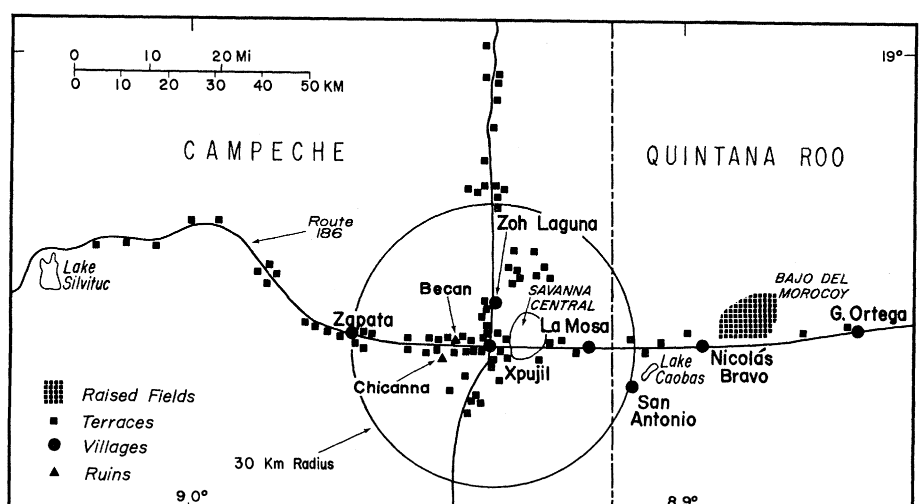

Fig. 2. Map of the Río Bec study area showing the locations of identified terraces and raised fields. Terrace locations are only those surveyed from the ground and, thus, reflect those areas currently cleared for agricultural use. Aerial reconnaisance revealed large zones of terracing north and south of Route 186, particularly between Becan-Xpujil and Nicolás Bravo.

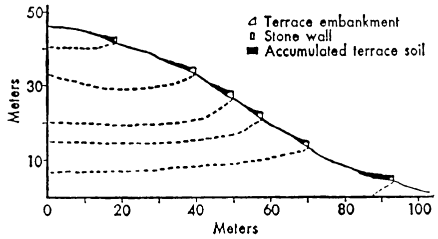

Fig. 3. Hillside profile of linear sloping terraces 18 km east of Xpujil.

80 to 300 cm wide at the base.

To the west of Becan, terrace embankments are generally smaller and lack a well-defined section of rubble fill. Embankments are composed of either dry-laid limestone walls, or rows of upright rock slabs. The slab-type terrace is built of large cut stones sunk approximately 20 cm into the ground. These embankments rarely exceed 40 cm in height and their basal width fluctuates from 60 to 80 cm. This constructional form displays a striking similarity, particularly in a decayed state, to the "linear border" type of relic terrace common to regions of the southwestern United States (*31*).

Terraces occur on hillsides varying in slope from 4° to 47°. In most instances, slopes exceeding 50° are void of terracing. As expected, the distance between embankments is directly related to the degree of slope and, with minor exceptions, decreases as the slope increases. The following distances between terrace embankments have been recorded: 42.24 m at slope angles of from 4° to 14°; 24.10 m at 15° to 29°; and 19.00 m at 30° to 47°.

Linear ridges running up- and downslope are common in the eastern sector of the study area. Such ridges are composed of parallel, dry-laid limestone walls separated by rubble fill. The heights of the ridge vary from 80 to 130 cm, while basal widths range from 200 to 400 cm. These structures are connected to larger terrace embankments, creating a network of walkways similar to those described in the terraced regions of the Andean *lomas* (*32*). When walkways are frequent on long, gentle slopes, terraced areas display a deceptive lattice pattern from the air (Fig. 5).

Other terrace-associated features include small rock walls laid diagonally across the slope, stone platforms, and housemounds of various sizes. The latter features are particularly frequent, with an average of one housemound for every 0.75 hectare of terraced hillside. Common in the immediate vicinity of Becan are linear stone and dirt ridges. Apparently nonagricultural in function, these structures are restricted to sections of level, noninundated terrain. More detailed descriptions of these ridges are forthcoming and, thus, will not be treated in this article (*33*).

Functions

The relic terraces of southern Campeche and Quintana Roo were probably constructed as impediments to the erosion of the very shallow (5 to 45 cm) topsoils common to the region. The continual clearance and exposure of slope soils to annual extremities in precipitation created physical conditions highly susceptible to soil erosion. To counteract the erosive force of rainfall and to maintain fertile hillside soils, the Río Bec Maya built rock and rubble embankments, or soil-trap terraces (*34, 35*). Each embankment captured the earth washed downslope, creating soil deposits of 25 to 45 cm in depth. The manner in which the trapped soil was utilized has not been determined, although several possibilities exist: (i) it served as a superior cultivation medium for a dominant crop, perhaps maize, which was probably also planted throughout the entire terraced section; (ii) it provided an adequate soil depth for the cultivation of root crops, maize having been planted on the thinner upslope soils; (iii) it was carried upslope and deposited uniformly over each terraced section. In any case, the soils were maintained and used on hillsides, not washed away.

Drainage was undoubtedly an important function of both terraces and associated features. The concentration of runoff behind terrace embankments, particularly during the daily showers of the rainy season, inundated surrounding soils and damaged the terrace wall. To combat these hazards, at least three drainage techniques were employed: guide walls, seepage outlets, and laterally sloping embankments.

Walkways and small stone walls acted as devices to control the distribution of runoff water. These structures divided terraced slopes into quadrilateral compartments in which precipitation was contained, maintaining a balance of water over the hillsides. To prevent constructional damage within each terrace compartment, embankments were built so as to facilitate drainage. A rubble fill was deposited

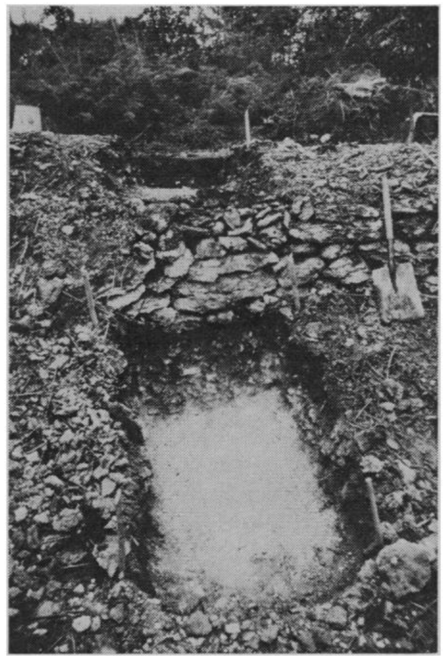

Fig. 4. The downslope face of a Río Bec terrace. Note the rubble-fill drainage system immediately behind and below the terrace wall.

behind and below each terrace wall to provide a medium for the seepage of rainwater under the embankment and downslope (Fig. 4). A similar drainage technique was apparently utilized by the Incas as well (*30*, p. 211). Furthermore, terrace embankments were constructed with a slight lateral slope, which allowed excessive runoff water to flow along the embankment to collection points. Whether the collected water was drained downslope is undetermined.

The connective system of terraces and walkways functioned as a transportation network. Terraces joined by walkways were generally larger than other terraces, offering pathways of widths exceeding 100 cm. Such an elevated transportation network maintained three distinct advantages over ground-level pathways. It (i) kept traffic away from cultivated fields where crop damage might have occurred, (ii) eased walking conditions over terrace embankments; and (iii) facilitated movement over muddy terrain during the long wet season.

Other possible terrace functions include the creation of a level planting surface and field clearance. The establishment and maintenance of a level planting surface was either an explicit or implicit function of the terraces. Trapped soils created level surfaces extending 1 to 5 m behind each embankment, depending on the degree of slope. The significance of these level sectors to Mayan cultivation has not been determined.

Terrace embankments might well have functioned as receptacles for rock and other field debris. This material, collected from cropping surfaces to facilitate cultivation, may constitute the rubble-fill segment of the terraces. Indeed, incipient terracing might have resulted from the collection and deposition of such field debris.

Raised Fields

Raised fields, often called ridged or drained fields, "include any prepared land involving the transfer and elevation of soil above the natural surface of the earth in order to improve cultivating conditions" (*36, 37*). This agricultural technique is widely distributed among indigenous tropical cultivators (*36*) and was important to numerous pre-Columbian Amerinds (*6*). Remnants of raised fields have tentatively been identified in the Bajo del Morocoy, a large, wooded, lowland area northeast of Nicolás Bravo (Fig. 2). Aerial reconnaissance and photographs reveal a checkerboard pattern of elevated platforms covering an area in excess of 120 km^2. Because of the thickness of *bajo* vegetation, a thorough examination of these earthworks will necessitate considerable clearing. Unfortunately, the raised fields that were discovered lay immediately outside the research permit zone, prohibiting land clearance as well as archeological investigation (*38*).

Mayan raised-field cultivation was conducted in seasonally inundated lowlands where soils were often highly fertile but poorly drained (*34*). Prolonged inundation, often 4 to 5 months in duration, created waterlogged soils not suitable for cropping. To provide a medium for cultivation, the Maya constructed raised, dirt platforms and an associated network of drainage canals. This system of platforms and canals facilitated drainage, establishing a drier cropping surface above the level of standing water.

Tropical cultivators maintain an acute awareness of the varying agricultural functions provided by raised fields. Other than drainage, "these include the enhancement of soil fertility through pulverization and through the concentration of organic matter and top soil, modification of micro-climate, control of weeds, control of erosion, and facilitation of harvesting" (*36*). Comparisons with contemporary data on tropical cultivation suggest that the Maya possessed methods of increasing and maintaining soil fertility, such as mulching, which were applied to terraced as well as raised fields. Further, the dominance of root crops within tropical raised-field agriculture (*36*) lends support to the contention that these cultigens were important to Mayan subsistence (*39*).

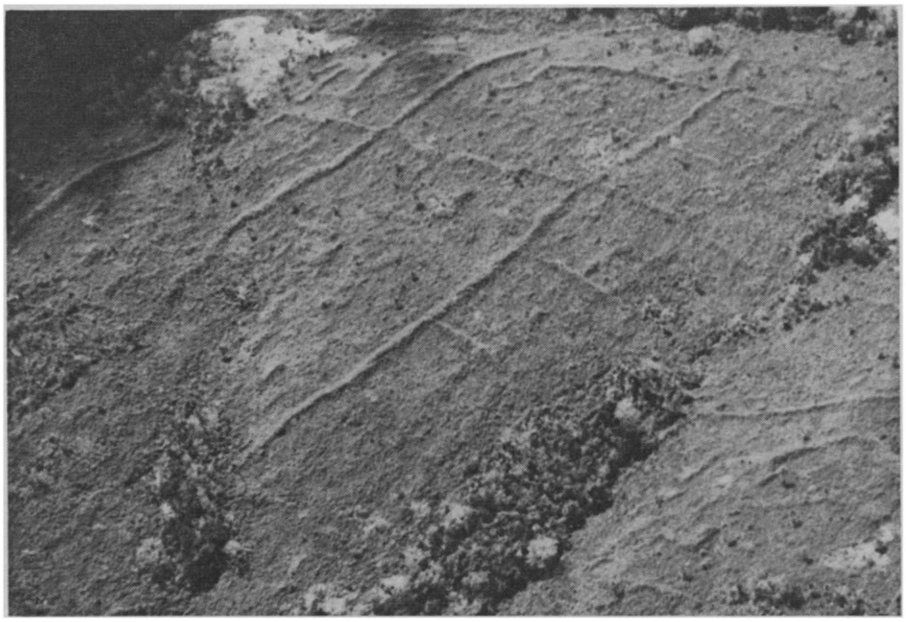

Fig. 5. Aerial photograph of a terrace system near Nicolás Bravo. When walkways are frequent on long, gentle slopes, terraced areas display a deceptive lattice pattern.

Reconstruction of the Agricultural Sequence

The relic terraces and raised fields of and near the Río Bec region are testimonials to past intensive agriculture in the Mayan lowlands. These features were constructed to facilitate annual or near-annual cultivation. In this manner, the frequency of cultivation, or intensity of agriculture, was vastly increased. That these features were utilized for a system of long-fallow cultivation seems highly improbable. The time and labor expended to construct and maintain the structures were too great to justify lengthy fallow periods. It should be noted that the use of stone terraces and raised fields in other regions of the world is associated with agricultural systems in which the frequency of cultivation exceeds the frequency of fallowing.

Terraces and raised fields represent forms of land reclamation necessitated by the demand for increased agricultural production. In the Río Bec region this demand was most likely stimulated by enlarging populations during the Bejuco (Late Classic) period, about A.D. 600–730 (*40, 41*). The incipient stages of intensive cultivation, however, began at an earlier date.

The sequence of agricultural development within the Río Bec region, then, quite conceivably followed the stages of growth delimited by Boserup (*7*). Initial cultivators in the area pursued a forest-fallow method of swidden agriculture wherein a forest plot was cleared and planted for several years until decreased soil fertility and weed invasion lowered yields. The plot was then left to fallow until some measure of fertility was regained.

Population pressures and, hence, production demands increased during the Pakluum (about 200 B.C.–A.D. 250) and Chacsik (about A.D. 250–500) phases of Río Bec occupation. To combat rising demands, the length of the fallow periods was shortened, allowing more land to be simultaneously cultivated. With each appreciable cut in the fallow period, measures to maintain adequate soil depth and fertility and to control weeds were necessarily adopted or developed. Cultivation may have reached the grass-fallow stages during the latter Chacsik phase (*2*, p. 344).

Analysis of ceramics taken from terrace fill and associated housemounds indicates that initial terrace construction began during the Sabucan phase (about A.D. 500–600) (*42*). Large-scale construction of terraces and, perhaps, raised fields during the Bejuco period paralleled a marked increase in the population of the region. Interestingly, in this period there was a probable influx of groups from southern Quintana Roo and Belize (*40*). Whether these groups brought raised-field agriculture with them is not known.

Intensive agriculture was apparently maintained into the Chintok period (about A.D. 730–830). As population pressures and production demands began to dwindle during the Xcocom phases (about A.D. 830–1050), agriculture regressed through various stages of less intensity until such a time that extensive, swidden systems of cultivation could sustain the populace. Swidden cultivation, ranging from forest-fallow to bush-fallow systems, has remained dominant to this day.

The temporal sequence of agricultural activities within the Río Bec region is, no doubt, the result of a more complex set of circumstances than a simple association between population and agricultural demand (*8*). Environmental factors, foreign intervention, and time lags between increases in demand and the intensity of cultivation are variables which may have altered the sequence somewhat. However, the basic outline presented should remain little changed: (i) a gradual increase with minor fluctuations in the intensity of agriculture up to and during the Bejuco and Chintok periods, followed by (ii) a decrease in such intensity lasting to modern times. With revisions of time and place, this temporal sequence should be applicable throughout the central Mayan lowlands.

Population Implications

Demographic reconstructions of prehistoric Mayan populations must be viewed with caution, as they are contingent upon assumptions and interpretations. Exemplary are attempts to assess the agricultural potential, or carrying capacity, of the lowlands as a measure of potential population limits. Such reconstructions are characterized by the application of contemporary swidden cultivation data to the past. This necessitates numerous interpretations, often conflicting, regarding the length of the swidden cycle, crops and productivity, and the availability of cultivable land (*43, 44*).

The presence of relic terraces and raised fields adds a new perspective to assessments of the carrying capacity of the central lowlands. These agricultural structures are indicative of annual or near-annual cropping and increased productivity, if weeding and mulching or other fertility measures were conducted. Further, the intensive techniques considerably increased the availability of cultivable land. Raised fields are particularly significant, as their construction made possible the cultivation of inundated regions in the central lowlands. Examples illustrate the increased population limits established by the potential production of intensive agriculture.

Vogeler (*45*) estimates a population ceiling of 28 to 85 persons per square kilometer (73 to 220 per square mile) for a zone in the center of the Río Bec area. This estimate is based on contemporary data on swidden cultivation applied to Conklin's (*46*, p. 63) measure of critical population size (carrying capacity) of the land. An extraordinary 7-year swidden cycle (3 years of crops, 4 years of fallow) is operative in which 0.5 ha of land can sustain one individual for 1 year. The ceiling variance results from the estimate of cultivable land, either 25 or 75 percent of the total area considered.

If the contemporary subsistence figure of 0.5 ha is applied to a 1-year, intensive-agriculture cycle, an estimate of the potential population size is greatly increased. If 75 percent of the land was cropped, the potential population ceiling is raised to 150 persons per square kilometer (*47*), a figure in line with Sanders' (*2*, p. 332) estimate of peak lowland population densities. In light of the agricultural techniques utilized by the Río Bec Maya, an estimate of 75 percent for the potential cultivable land area is not excessive.

Housemound studies suggest that in certain Mayan areas populations were maintained in excess of the demographic limits estimated from contemporary investigations of the potential of swidden cultivation. Housemound counts from the Petén region indicate possible rural-like population densities ranging from 40 to 200 people per square kilometer (*10*, p. 577; *11*, p. 366) and urban-like centers maintaining 600 to 700 inhabitants per square kilometer (*12*). The increased estimates of critical population size derived from evidence of intensive cultivation of the central lowlands lend credibility to the housemound studies, illuminating the possibility of large and densely populated Mayan groups.

Agricultural Methods and the Mayan Collapse

Numerous theories, ranging from internal peasant revolt to climatic change, have been offered as explanations of the collapse of the Classic Maya civilization (*48*). Although currently in disfavor, theories connecting the collapse to Mayan agricultural pursuits have persisted. Such explanations suggest that the continual and unaltered reliance on swidden methods of cultivation ultimately created cropping conditions with which the Maya could not cope.

Specifically, agricultural-collapse theories contend that increased demand for agricultural produce necessitated reductions in the length of the swidden fallow periods. This impeded the return flow of nutrients to swidden plots, creating exhausted soils unable to sustain an adequate production level (*49*). Alternatively, it is suggested that the extensive cutting and burning required by swidden cultivation converted the lowland forests into grasslands which the Maya, lacking the proper technology, were unable to crop (*50*). Also, it has been suggested that, if no preventive measures were taken, soil erosion may have played a contributing role in the collapse (*2*, p. 377).

The evidence of intensive agriculture gathered from Campeche and Quintana Roo raises questions about the validity of swidden-collapse theories as applied to the Río Bec Maya. The abundant presence of relic terraces and raised fields imply that Río Bec cultivators were not inhibited by a lack of agricultural know-how. Rather, they devised or adopted numerous methods which allowed a reduction in the fallow period, maintained soil fertility, depth, and drainage, and controlled grass invasion. Such measures were accomplished with nothing more than chert and obsidian cutting tools, digging sticks, and baskets (*51*). Furthermore, if terraces and raised fields prove to be as common throughout the central lowlands as they are in the Río Bec region, the validity of swidden-collapse theories must be questioned in terms of the entire Classic Maya civilization (*52*).

The concept of intensive lowland cultivation lends support to several previously suggested collapse theories, those concerning environmental ramifications and monocropping disasters. According to the former, large sections of the lowlands were stripped of forest vegetation, and drainage patterns were altered. Such physical tampering might have led to short-term, but large-scale, environmental repercussions to which the Mayan farmer did not have sufficient time to adjust. More plausible, however, is the possibility of a monocropping disaster. Throughout the world, intensive cultivation is associated with specialization in crop as well as in cultivation technique. Overemphasis on terrace maize, or raised-field root crop, production might have left the lowlanders' crops vulnerable to diseases and pests and consequent failures, a less severe problem under swidden cultivation wherein fields are widely scattered (*53*).

Perspective

Historic and contemporary theories concerning the subsistence techniques employed by the ancient lowland Maya are largely speculative or based on meager data. The field research on relic agricultural structures presented here demonstrates that this situation need not exist. Remnants of terraces and raised fields are common throughout southern Campeche and Quintana Roo, indicating that the Río Bec region was inhabited by sophisticated, intensive cultivators. Based on other reports (*17, 24*), it seems appropriate to apply this assessment to various other sectors of the Mayan lowlands, including Belize and the Petén region of Guatemala (*54*). In areas where terracing or raised fields do not occur, a less intensive bush- or grass-fallow system of agriculture may have been pursued (*2*). Hence, the contention that the lowland Maya, restricted by a hostile environment, never progressed beyond swidden cultivation is invalid.

Tentative assessment of the collected Río Bec data suggest that Mayan agriculture progressed through various stages of intensity from forest-fallow swidden to annual cultivation. The intensity and extent of cultivation most likely peaked in association with enlarging populations during the Late Classic period. In the Río Bec region, this climax took place during Bejuco and Chintok times (about A.D. 600–830). The ensuing collapse of the lowland civilization was not a result of primitive farming techniques, although agricultural ramifications may have played a contributing role.

Continued research should illuminate past Mayan agricultural pursuits, providing more precise data about farming activities and crops utilized, the areal extent of intensive cultivation, and the temporal sequence of agricultural development. A more accurate and complete description of lowland subsistence will contribute to a more thorough comprehension of Mayan civilization.

References and Notes

1. The list of proponents of swidden Mayan agriculture is lengthy, and at various times it has included most scholars who have devoted attention to Mayan agriculture. Exemplary are G. R. Willey and W. R. Bullard [in *The Handbook of Middle American Indians*, vol. 2, *Archaeology of Southern Mesoamerica*, G. R. Willey, Ed. (Univ. of Texas Press, Austin, 1965), pp. 372–373] and M. D. Coe [*The Maya* (Thames & Hudson, London, 1966), p. 138].
2. W. T. Sanders, in *The Classic Maya Collapse*, T. P. Culbert, Ed. (Univ. of New Mexico Press, Albuquerque, 1973), p. 325.
3. S. G. Morley, *The Ancient Maya* (Stanford Univ. Press, Stanford, Calif., 1946), p. 71.
4. G. Wilken, *Am. Antiquity* **26**, 432 (1971). Although the concept of intensive Mayan agriculture has recently received considerable attention, it is not new, having been suggested as early as 1925 by T. Gann [*Mystery Cities* (Duckworth, London, 1925), p. 22] and later by O. G. and E. B. Ricketson [*Carnegie Inst. Wash. Publ. 477* (1937), p. 12].
5. Intensive agriculture is defined here as any mode of cultivation in which the frequency of cropping per unit of land exceeds the frequency of fallowing. Swidden is an extensive mode of agriculture in that the frequency of fallowing exceeds the frequency of cultivation. Specific cropping techniques, labor, or productivity are not essential to the definitions.
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7. E. Boserup, *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure* (Aldine, Chicago, 1965).
8. H. C. Brookfield, *Pac. Viewpoint* **13**, 30 (1973).
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10. G. R. Willey, W. R. Bullard, J. B. Glass, J. C. Gifford, *Pap. Peabody Mus. Archaeol. Ethnol. Harv. Univ.* **54**, 1 (1965).

→ W. R. Bullard, *Am. Antiquity* **25**, 355 (1960).

12. W. Haviland, *World Archaeol.* **2**, 187 (1970).
13. Specific figures are difficult to calculate, as the production of any mode of swidden cultivation is dependent on varying parameters. However, S. Cook [*Addison-Wesley Modular* (Addison-Wesley, Reading, Mass., 1972, Publ. 16)] offers subsistence data suggesting that swidden agriculture was hard-pressed to support peak Mayan populations.

→ G. R. Willey and D. Shimkin, *Southwest. J. Anthropol.* **27**, 1 (1971); T. P. Culbert, Ed. *The Classic Maya Collapse* (Univ. of New Mexico Press, Albuquerque, 1973).

15. A more thorough discussion is forthcoming in B. L. Turner II, in preparation.
16. A. Palerm and E. Wolf, *Social Science Monograph No. 3* (Pan American Union, Washington, D.C., 1957), p. 28.
17. C. L. Lundell, *Southwest. Rev.* **19**, 65 (1933).
18. K. Ruppert and J. Denison, *Carnegie Inst. Wash. Publ. 543* (1943).
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→ L. Ower, *Geogr. J.* **70**, 372 (1927).

21. J. E. S. Thompson, *Field Mus. Nat. Hist. Publ. 301, Anthropol. Ser.* **17**, 219 (1931).
22. C. L. Lundell, *Carnegie Inst. Wash. Misc. Pap. 522* (1940), pp. 9–12.
23. A. Wright, D. Romney, R. Arbuckle, V. Vial, *Colonial Research Publication No. 24* (Her Majesty's Stationary Office, London, 1959), pp. 112–113.
24. A. H. Siemens and D. Puleston, *Am. Antiquity* **37**, 288 (1972); Siemans and Puleston are currently examining large raised-field complexes in the Río Hondo floodplain and in the *bajos* of northern Belize (personal communication).
25. See, for example, R. E. W. Adams *et al.*, *Preliminary Reports on Archaeological Investigations in the Río Bec Area, Campeche, Mexico* (Middle American Research Institute, Tulane Univ., New Orleans, La., in press).
26. The areal limits of Río Bec terracing that were recorded are within the areas I examined. J. Eaton, who has also called attention to the relic terraces in the Río Bec region (*27*, p. 54) has noted similar structures further south and east of Xpujil (personal communication).
27. J. Eaton, *Ceram. Cult. Maya* **8**, 42 (1972).
28. J. Spencer and G. Hale, *Pac. Viewpoint* **2**, 1 (1961).
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30. J. Rowe, in *The Handbook of South American Indians*, J. Steward, Ed. (Government Printing Office, Washington, D.C., 1947), vol. 2, p. 183.
31. R. B. Woodbury, *Soc. Am. Archaeol. Mem.* **16**, 1 (1961).
32. F. Engel, *Curr. Anthropol.* **14**, 271 (1973).
33. P. M. Thomas, Jr., in (*25*).
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35. Similar conclusions have been suggested concerning relic terraces in the Maya Mountains by Lundell (*22*, p. 11) and highland Chiapas by L. Guzman [*Rev. Interam. Cienc. Soc.* **1**, 398 (1961)].
36. W. M. Denevan and B. L. Turner II, *J. Trop. Geogr.*, in press.
37. The term "ridges" as applied to the linear walls found in the vicinity of Becan should not be confused with either terraces or raised fields. Eaton's (*27*) use of the term "ridged fields" refers to ridges that were probably nonagricultural in origin.
38. The 1973 Río Bec permit granted to the University of Texas at San Antonio–University of Wisconsin, Madison, research group by the Instituto Nacional de Antropología e Historia allowed archeological examination only within 30 km of Xpujil, Campeche.

→ B. Bronson, *Southwest. J. Anthropol.* **22**, 251 (1966); also see A. Wright *et al.* (*23*, p. 111).

40. The chronological sequence was developed by J. Ball [*Ceram. Cult. Maya* **8**, 34 (1972)].
41. For a more detailed discussion of Río Bec ceramic data and their implications, see J. Ball, thesis, University of Wisconsin, Madison (1973).
42. Ceramics were gathered from terraces and associated housemounds on five different Río Bec hillsides by J. Eaton, J. Taschek, and B. L. Turner. Ceramic analysis was conducted by J. Ball. Although the sample size is small, ceramic data are coherent with Ball's extensive ceramic survey (*41*) of Becan.
43. U. Cowgill [*Am. Anthropol.* **64**, 273 (1962)] generously concludes (p. 277) that swidden agriculture near Lake Petén could support 38 to 77 people per square kilometer (100 to 200 people per square mile).
44. R. Reina [*Am. Anthropol.* **69**, 1 (1967)] provides contradictory evidence to that gathered by Cowgill (*43*) concerning the productivity of Petén cultivation.
45. I. Vogeler, in (*25*). The portion of Campeche investigated by Vogeler has only recently been exposed to cultivation, and a full cycle has not been established. The cycle used to calculate the carrying capacity figures is based on optimistic estimates suggested by immigrant farmers. Furthermore, Vogeler's carrying capacity figures may be in error. My calculations, using the same figures and formula, indicate carrying capacities of 28 to 65 people per square kilometer.
46. H. C. Conklin, *Proc. Ninth Pacific Sci. Assoc. 1957* **7**, 60 (1959). Critical population size, C_s, is equal to L/AT, where L is the maximum cultivable land available, A is the minimum average units of land required for clearing per individual per year, and T is the minimum average duration of the full agricultural cycle.
47. My calculations are based on the entire permit area of 2827.43 square kilometers. If 75

percent of this area is cultivable, then $C_s =$ (2120.57 km²)/(1 × .005 km²), or $C_s = 424,145$ km².
48. The term "collapse" refers to the decline and eventual abandonment of the ceremonial centers in the southern and central lowlands from A.D. 790 to 950 (see *14*).
49. This theory, which is alluded to throughout Mayan literature, was perhaps first discussed by O. F. Cook, *Smithson. Inst. Annu. Rep. 1919* (1921), p. 314.
50. First suggested by biologists from the Department of Agriculture, the grassland theory received considerable attention from S. G. Morley (*3*).
51. Terracing and raised fields are constructed throughout the tropics by "digging stick" farmers. Perhaps most impressive are the raised-field cultivators of highland New Guinea [see K. Heider, *Viking Fund Publ. Anthropol. 49* (1970)].
52. The Petén remains the principal central lowland region in which relics of intensive agriculture have yet to be reported in abundance. This is, perhaps, largely the result of inadequate field research. I noted relic terraces along the main road from Flores to Ciudad Melchor de Mencos (about 35 km southeast of Tikal) on a reconnaissance of the Petén in January 1974. A series of five terraces was constructed across a ravine which was about 30 meters wide. Embankments were composed entirely of stone rubble and dirt. Informants indicated that stone-faced terraces are common on hillsides that are inland from the main road.
53. For similar assessment, see G. R. Willey and D. Shimkin, in *The Classic Maya Collapse*, T. P. Culbert, Ed. (Univ. of New Mexico Press, Albuquerque, 1973).
54. A similar assessment has been adopted by T. P. Culbert [*The Lost Civilization: The Story of the Classic Maya* (Harper & Row, New York, 1974), pp. 46–49].
55. I thank R. E. W. Adams, Donald D. Brand, and William M. Denevan for criticisms and consultation; Joseph Ball for ceramic analysis; and the 1973 National Geographic Society Río Bec Project members for aiding and encouraging this research. I am indebted to Guillermo Bonfíl Batalla, director general of the Instituto Nacional de Antropología e Historia (INAH), Mexico City; Ignacio Marquina, director of the Departamento de Monumentos Prehispánicos, INAH; Miquel Mesmacher, former representative of the INAH in the Yucatán archeological area; and Carlos Sansores Perez, former governor of Campeche, Mexico. Financial aid was provided by the National Science Foundation and the Ibero-American Studies Program of the University of Wisconsin, Madison. Maps were prepared by Bruce Van Roy.

NEWS AND COMMENT

Watergate: 1972 Campaigners Tried to Use R & D Agencies

A report by the staff of the Senate Watergate committee describes in detail a White House plan, in 1972, to manipulate grants, contracts, and appointments throughout the government, including agencies concerned with R & D and education, to the benefit of those who might be friendly to the Nixon campaign. The report, obtained by *Science* in draft form, is a chapter of the committee's final report and is due to be published along with the final report later this month. The committee launched congressional inquiry into the Watergate scandals last year.

The White House plan was known as the "responsiveness program," and its "chief architect" was Frederic V. Malek, then special assistant to the President and now deputy director of the Office of Management and Budget (OMB). Among the agencies to be involved in the responsiveness program were, according to the draft Senate report, the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the Urban Mass Transportation Administration (UMTA), the National Institute for Occupational Safety and Health (NIOSH), and some education jobs. Other research-oriented agencies mentioned in the White House memorandums obtained by the Senate committee are the National Institute of Education (NIE) and the Consumer Product Safety Commission (CPSC). In addition, the Malek subordinates who executed the responsiveness program wanted to have a career employee of the Equal Employment Opportunity Commission (EEOC) fired after he appeared to be sympathetic to Democratic candidate George McGovern. But the employee stayed on, and there is scant evidence in the other instances cited in the report that the Malek team had much success in bending the federal bureacracy to their aims.

Senate Watergate investigators, during the limited time they could give to the responsiveness program inquiry, focused on White House attempts to win the Spanish-speaking vote through use of grants, contracts, and appointments. These findings are the focus of the draft report and have already been reported in the *New York Times*. The committee, to a lesser extent, looked into responsiveness efforts for the black vote, but the attempts to use the research grants and the education appointments receive only passing scrutiny. Although investigators found what looked like evidence of violation of the Hatch Act and other federal laws in the Spanish-speaking campaign, they did not specifically investigate possible criminal activity in these other instances. Said one staffer, "This is an area which obviously deserves further inquiry. . . . This is something which we hope will be investigated further by other committees."

The responsiveness program originated as a result of a feeling by some White House aides that the executive branch was being underused as a source of help in the campaign. Typical of this sentiment was a memo by Jeb S. Magruder, then on the White House staff, who eventually directed the Committee for the Re-Election of the President (CRP). Magruder wrote then–Attorney General John Mitchell in January 1971, according to the Senate report,

> [O]ur administration has not made effective political use of the resources of the Federal government, the RNC [Republican National Committee], the White House, and outside groups and corporations. In developing the structure for the campaign, proper use of these resources should be of preliminary concern at the outset of the planning.

Subsequently, Magruder, according to the Senate report, "at the Attorney General's request began an examination of utilization of federal resources by others in presidential campaigns." Magruder concluded, the report says, that, while President Eisenhower did not, President Johnson and Vice President Humphrey did use their White House staffs for their campaigns. Peter Millspaugh, a White House aide, urged in May 1971 that an inventory be taken of federal resources to be used "with perhaps the federal grants area broken out for priority treatment." And in a 23 June 1971 memo, Millspaugh included the NSF on his list of likely targets.

> "The Basic Types of Patronage"
> 1) Jobs (full time, part time, retainers, consultantships, etc.)
> 2) Revenue
> —Contracts (Federal government as purchaser—GSA [General Services Administration])
> —Grants (do-good programs, EDA [Economic Development Administration], model cities, NSF research, etc.)
> —Subsidies (needy industries—airlines, etc.)
> —Bank Deposits (all Federal accounts)
> —Social Need Programs (direct benefit to citizens, i.e., social security, welfare, etc.)
> —Public Works Projects.