Aboriginal Drained-Field Cultivation in the Americas

Pre-Columbian reclamation of wet lands was widespread in the savannas and highlands of Latin America

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Where population growth begins to exceed the existing carrying capacity, self-sufficient aboriginal farmers may either migrate or increase production through higher yields, more frequent cropping, or the utilization of land which is marginal because of poor soil, steep slopes, lack of water, or excessive water. The denser populations and greater cultural achievements in the pre-Columbian New World have been mainly associated with agricultural expansion by means of irrigation and terracing, and, accordingly, these reclamation methods have received considerable attention. In contrast, cultivation of land having excessive water has been almost ignored, mainly because such agriculture seldom survived into the European period, except in Mexico.

In recent years, extensive ridged-field remains have been found in seasonally flooded plains in widespread parts of lowland and highland South America (*1*). While much remains to be learned, a review of what is known about drained-field agriculture in the New World, and some of the implications, seems worthwhile at this time.

There are different types of poorly drained ground, each presenting different problems, as well as advantages, for reclamation and subsequent cultivation. Most obvious are the large river floodplains which are inundated during periods of high water. Because of the rich alluvial soils, population and cultivation are often concentrated in floodplains, with or without drainage control. However, some of the most extensive areas of inundation are large plains with broad, shallow depressions which fill with rain water, and here soils may be quite poor, especially in the tropics.

Flooding is also characteristic of the immediate margins of lakes, rivers, and swamps, which fluctuate in coverage both seasonally and from year to year. In addition, there are sites covered by permanent, but shallow, bodies of water which can be cultivated following diking or draining, or through building soil islands. The least severe type of poor drainage is soil waterlogging, with little or no standing surface water, which can occur on sloping land as well as on flatland. Most crop root systems do poorly if waterlogging lasts more than a few weeks. But waterlogged soil can be readily reclaimed by ditching or by building up low crop ridges, if fertility warrants it, or cultivation can be concentrated during the dry periods, as long as there is adequate moisture.

An excess of water is obviously a great handicap to cultivation; however, this is frequently offset, in part, by high-quality soils, level surfaces, the availability of irrigation water, and the richness of aquatic wildlife resources. On the other hand, the labor requirements for constructing and maintaining drainage systems are high, and it is unlikely that drainage would be undertaken so long as other, more easily cultivable land was available.

The following types of wet-land cultivation can be differentiated: (i) soil platforms built up in permanent water bodies; (ii) ridged, platformed, or mounded fields on seasonally flooded or waterlogged terrain; (iii) lazybeds or low, narrow ridges on slopes and flats subject to waterlogging; (iv) ditched fields, mainly for subsoil drainage; (v) fields on naturally drained land, including sandbars, river banks, and lake margins; (vi) fields diked or embanked to keep water out; and (vii) aquatic cultivation, in which complete drainage is not attempted and plants are grown in water. An agricultural system may employ more than one of these methods. Also, some techniques may serve functions other than drainage alone, such as irrigation, soil aeration, and improvement in the fertility of the soil. All these methods, with the exception of aquatic cultivation, were practiced by aboriginal people in the Americas. Brief descriptions of the major known examples follow. There was nothing comparable to Asian wet rice cultivation, although some wild aquatic plants, such as wild rice and the camus bulb, were harvested.

Chinampas

The one form of pre-Columbian drainage that has long been known and well studied is the *chinampa* system of the Valley of Mexico (*2*). *Chinampas* are rectangular garden plots built up above the water level of shallow lakes. These fields are characterized by the use of seed beds, fertilization with mulches of aquatic plants and bottom muds, and year-round irrigation by means of seepage and with water scooped from the bordering canals. The result is a continuous succession of crops—one of the most intensive systems of agriculture, past or present, in the Western Hemisphere, in terms of total annual production per unit of land. The *chinampas*, which played a major role in feeding the Aztec capital of Tenochitlan, were concentrated in lakes Zumpango, Xaltocan, Texcoco, Xochimilco, and Chalco. They are still being created and cultivated in the southern portions of Chalco and Xochimilco, and these modern survivals provide clues not only to ancient *chinampa* agriculture but also to the functions and technology of other types of drained fields no longer in use.

The first *chinampas* may date back as much as 2000 years (*3*). Pedro Armillas has attempted to measure the former distribution of *chinampas* on the basis of fossil remnants (*tlateles*) in drained portions of former lakes and suggests a preliminary total of 10,000

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hectares for just lakes Chalco and Xochimilco (*4*). While modern *chinampas* are quite broad (5 to 15 meters), the fossil fields are often much narrower, suggesting that the present system is not necessarily "virtually unchanged" from the time of Cortes (*5*). The narrow fossil fields are closer in form to the ridged fields of South America; also, many of them are found on former lake margins on relatively high ground where flooding was not permanent but was seasonal, as is the case with the South American ridged fields.

Ridged Fields of the Wet Savannas

There is no need to elaborate here on the *chinampas* and their important role in Mexican culture history. However, they are not as unique in the Americas as they were once believed to be. Since 1962, numerous remnants of large raised planting surfaces have been found in South America in both lowland tropical savannas and highland basins on terrain subject to seasonal inundation. These features have usually been referred to as "ridged fields," less often as "raised fields" or as *camellones*.

There are at least 170,000 hectares (1700 square kilometers) of ridged field remnants in Surinam, Venezuela, Colombia, Ecuador, Peru, and Bolivia (Fig. 1). Some are isolated, but others are near modern settlements and roads. In view of their size and number, the fact that they have been ignored until recently is a puzzle. However, the ridges are not conspicuous on the ground, often being severely eroded or partly buried in sediment (Fig. 2). From the air, on the other hand, the ridges form distinctive and obviously man-made patterns (Fig. 3), especially at times of the year when contrasting grass tones between ridges and ditches stand out, or when the ridges rise above flood waters. Also, there has been a general lack of awareness, by both local people and scholars, of what long rows of linear soil features in swamplands might mean. In studying and mapping the ridged fields, aerial photographs have been essential, and these have only recently become available for much of South America.

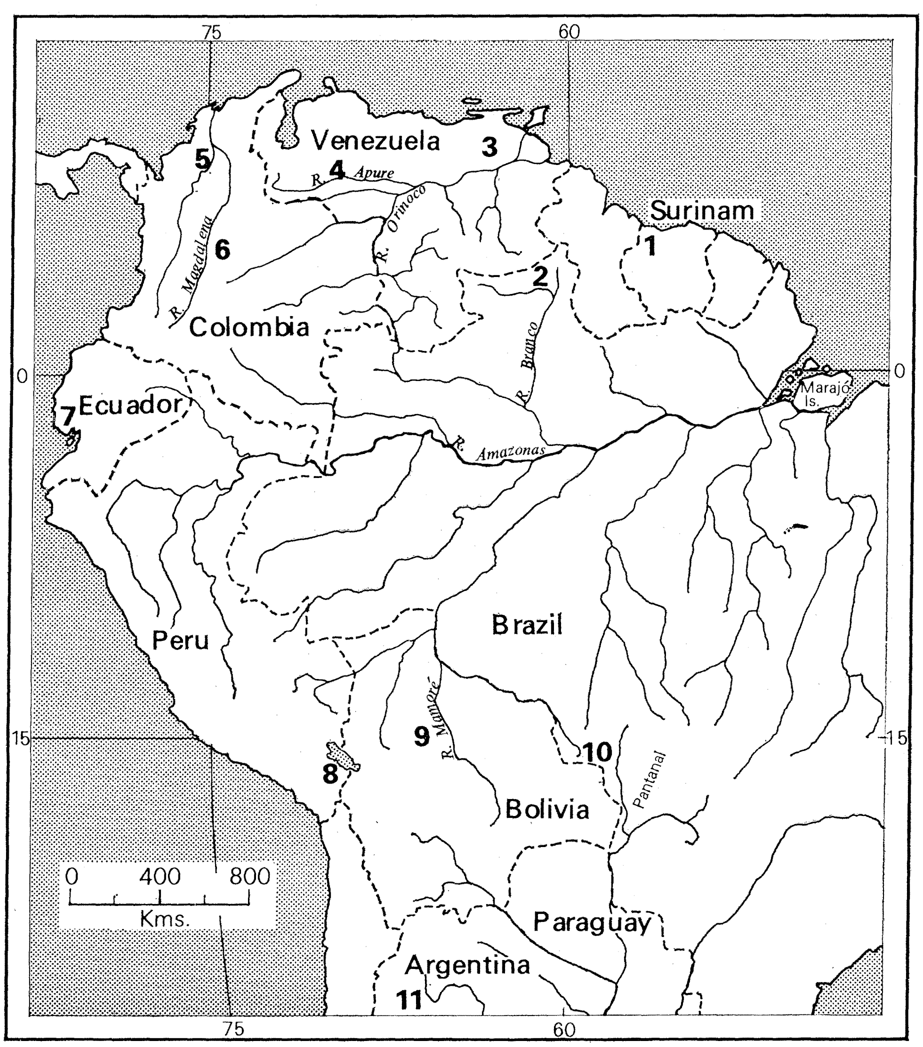

Fig. 1. Map of the drained-field areas in South America mentioned in the text. 1, Hertenrits; 2, Makuxí; 3, Karinya; 4, Caño Guanaparo; 5, San Jorge; 6, Sabana de Bogotá; 7, Guayas; 8, Lake Titicaca; 9, Llanos de Mojos; 10, Guato; 11, Lerma Valley.

Except for two very brief reports of obvious ridged fields in unidentified parts of the Orinoco Llanos in the 16th and 18th centuries (*6*), there apparently is no mention of such farming in the literature either of the conquest or of the colonial period. Presumably, the system was given up before the Spaniards arrived or very soon thereafter. In 1916 Nordenskiöld mentioned drainage works in the Llanos de Mojos of Bolivia, but he seems to have missed the largest concentrations and apparently was not impressed (*7*). The Reichel-Dolmatoffs mentioned drained fields in the San Jorge area of Colombia in 1953 but gave few details (*8*). Otherwise, the discoveries and descriptions of ridged fields have come only in the last few years.

A large portion of the vast tropical savannas of South America are subject to seasonal flooding for periods lasting up to several months. With their generally low soil fertility and their excessive water during the growing season, it is not surprising that these "wet" savannas are considered marginal for farming. The tribes of these savannas were agricultural, but they ordinarily confined this activity to the gallery forests and forest islands within the savannas. Some of these tribes, such as the Yaruro in the Orinoco savannas and the Siriono in the eastern Mojos savannas, are now seminomadic hunters and gatherers for whom agriculture is of secondary importance (*9*). Thus, it is of some significance that evidence of drained-field cultivation has been found in several savannas.

In 1961, oil exploration geologists in the Mojos savannas of the Department of the Beni in eastern Bolivia came upon large numbers of low, parallel ridges which could only have been made by man (*10*). Independent field study analysis of aerial photographs, and aerial reconnaissance the following year provided a good idea of the nature, number, distribution, ecological situation, and probable function of the relic ridges, as well as revealing other, associated earthworks, including mounds, causeways, and canals (*11*).

The Llanos de Mojos cover some 180,000 square kilometers in the Beni Basin between the Andes and the western hills of the Brazilian Highlands (*12*). During high water, the Beni, Mamoré, and Guaporé rivers and their tributaries overflow the llanos, and as much as 80 percent may be under a few centimeters to a meter or so of water for as long as 6 months. The climate is humid tropical, but the vegetation is open savanna with scattered forests on the higher, better drained ground. Soils are mostly high in clays and low in organic content, so it is not surprising that agriculture today is confined to the better and dryer soils of the forests, while the savannas are used for cattle raising. Nevertheless, there is mute evidence of former intensive savanna cultivation in the form of tens of thousands of raised field remnants which, together with intervening ditches, cover at least 20,000 hectares.

West of the town of Trinidad, the old fields consist of narrow, closely spaced ridges or simply of shallow ditches (Fig. 3), but to the north, near Lago Rogoaguado, the fields are actually rectangular platforms as much as 25 meters wide and 400 meters long (Fig. 3). Elsewhere there are rows of small circular mounds, about 2 meters across, similar to the *montones* reported in Hispaniola in the 16th century (*13*). Most of the fields are 15 to 50 centimeters high, which is enough to place them above the level of average floods.

The Spanish explorers and the Jesuits found relatively sophisticated tribes in Mojos (the Arawaken Mojo and Baure) with large villages characterized by plazas, palisades, and moats and containing as many as 3000 people, but they made no mention of drained fields. However, the region was not settled and fully explored until the 1680's, by which time the savanna tribes already had been decimated by European diseases, and their cultures disrupted by the direct and indirect effects of initial Spanish contacts. Nevertheless, Jesuit accounts indicate that at least 100,000 Indians still remained in Mojos in the 1690's (*14*). There has been little archeology in the region, so the antiquity of the various earthworks is not known, but at the time of first contact in 1580 the Mojos tribes may still have been constructing them in order to provide artificial high ground for agriculture, transportation, and settlement.

The Mojos finds alerted scholars to the possibility of other relic drained

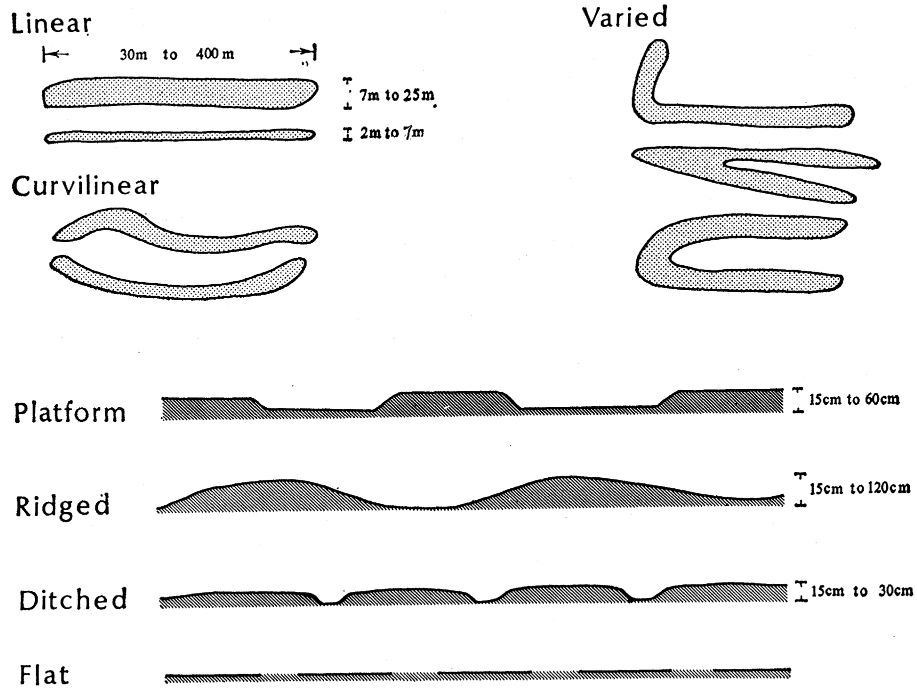

Fig. 2. Sketches of ridged-field shapes (above) and profiles (below) in South America. The "flat" profile is one where ridge and ditch relief has been leveled by plowing or sedimentation, but with soil differences persisting.

fields in South America, and a number of such features have now been described. Particularly spectacular fields were found and photographed in 1965 by Parsons and Bowen in the San Jorge River floodplain, a part of the vast aquatic landscape of the lower Magdalena in northern Colombia (*15*). The mapped fields, covering at least 64,000 hectares of ditch and raised surface, consist of (i) ridges on, and perpendicular to, the back slopes of natural levees of stream channels (caño pattern, Fig. 3), (ii) short ridges arranged in checkerboard patterns (Fig. 4), and (iii) parallel but unoriented ridges. The ridges are as much as 2 meters high, 7 meters wide on the average, and up to 1½ kilometers long.

In Surinam, prehistoric ridged fields have been reported in the coastal savannas. The main concentration is associated with a large artificial mound called Hertenrits, built about A.D. 700, near Caroni in an uninhabited wet savanna now being reclaimed as part of a rice project (*16*). Here the ridges are short and narrow, with no regular arrangement.

In the Guayas River floodplain in Ecuador there are at least 4000 hectares of old ridges and platforms (*17*). It is especially surprising that they have been ignored, since they are very close to the city of Guayaquil and since there has been archeological research in the region (*18*). The field remnants are associated with *tolas*, artificial burial and house mounds built by the gold-working Milagro culture, which occupied the floodplain from about A.D. 500 to the arrival of the Spaniards. While ridges are no longer being constructed, some of the old ones are again being cultivated, with rice in the ditches and maize and other crops on the raised surfaces.

The fifth area of relic ridged fields in lowland South America is the Orinoco Llanos of Venezuela. This is one savanna for which there are historical accounts of ridged-field construction (with *macanas*), fertilization (grass mulch), and use (maize, manioc, and peppers) (*6*). No locations were given, but the Llanos seemed a likely place to search for ridged-field remnants because of the region's possible role as a major cultural hearth in prehistoric times (*19*), environmental conditions similar to those of the other ridged-field areas, and the known presence of other earthworks (mounds and causeways) probably built for adaptation to floods (*20*). Reports of ridges in the Tame-El Yopal area of the Colombian portion of the Llanos have not been verified and may result from confusion with wind-oriented fire scars. However, aerial photographs show an apparent cluster of ridged-field remnants along the Caño Guanaparo in southern Barinas, about 15 kilometers north of the Río Apure and from 125

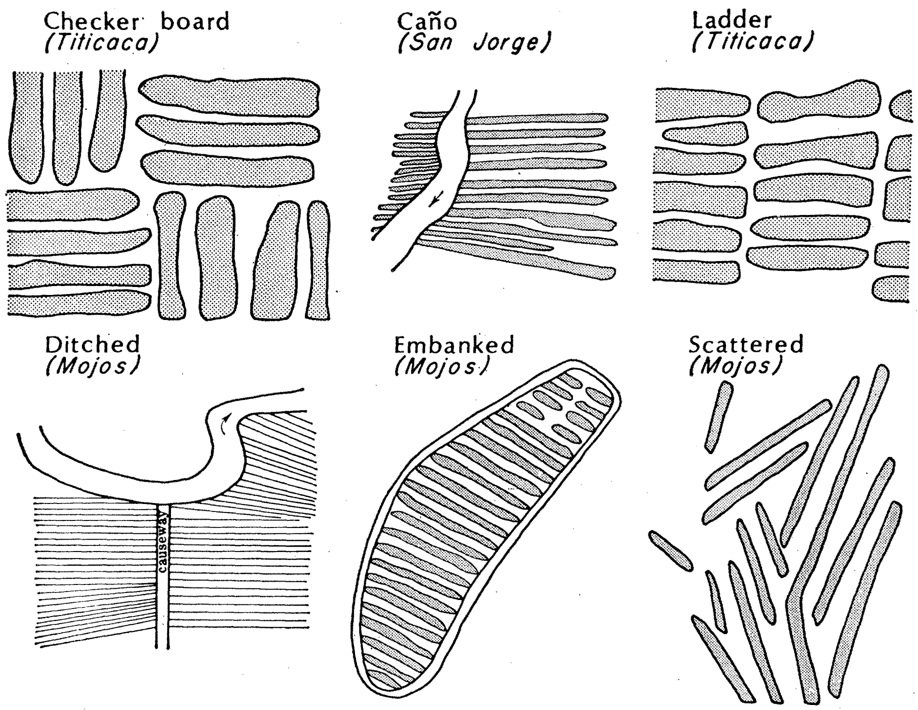

Fig. 3. Sketches of ridged-field patterns in South America.

to 160 kilometers west of San Fernando de Apure (*21*). The ground stripes are at right angles to old stream meander scars, similar to some of the San Jorge patterns, and are fairly narrow and as much as 700 meters long (Fig. 5). The Orinoco Llanos seems to be undergoing very rapid sedimentation, so it is possible that many old fields have been buried.

Undoubtedly more ridged-field remnants will be found in tropical America. The seasonally flooded Brazilian savannas, especially on Marajó Island and in the Pantanal of Mato Grosso, are likely areas. The finding, by Siemans (*22*), of a group of apparently pre-Columbian ridged fields in 1969 in the Candelaria area of the western Yucatán peninsula may be one indication of intensive cultivation by the lowland Maya.

Highland Drained Fields

Drained-field systems, relic and contemporary, are most common in the highlands of the Andes and Mexico. They are less of a surprise there than in the lowlands, since the highlands contained sophisticated civilizations with other forms of agricultural earthworks. Nevertheless, newly found highland fields add support to the arguments for very dense populations in the Lake Titicaca (*23*) and Bogotá basins, in the same way that the *chinampa* system supports similar arguments for the Valley of Mexico.

The prehistoric Titicaca and Bogotá ridged fields resemble those in the lowlands more than they do *chinampas*, since they were built for reclaiming seasonally flooded terrain. The Titicaca fields are the most extensive of all, covering a measured 82,056 hectares (*24*). Nevertheless, they were overlooked until 1966—even by me when I drove through them between Puno and Juliaca in 1965. They are arranged in a variety of patterns and sizes, but some are as much as 2 meters high and 25 meters wide and appear as islands along the lake edge during high water (cover, and Fig. 6). Most are located on the western lake plain in both Peru and Bolivia at elevations of 3800 to 3850 meters. Crops of potatoes, quinoa, *cañihua*, and barley are grown here today, but mainly on hill slopes. Because of high alkalinity, poor drainage, and night frosts, but also for historical reasons, most of the lake plain has been used for ranching since the conquest, rather than for farming. Ancient fields have thus been preserved, although encroaching plow cultivation in some sectors is destroying what remains.

The Sabana de Bogotá in Colombia is a broad mountain basin, at an elevation of 2600 meters, containing seasonally flooded and waterlogged land. With good soil and a temperate climate, the Sabana has been a grain-producing area since at least the 16th century, with the aid of subsoil drainage by way of elaborate ditch and drain-off canal systems. Narrow garden beds (*camellones*) are made today by farmers without plows to improve drainage and to handle the heavy clay soils, and such beds are possibly aboriginal in origin (*25*). They do not compare in size with the ridged fields of Titicaca and the lowlands. However, Broadbent has recently discovered the remains of large, ancient drained fields, mostly in the area of Suba, some 20 kilometers north of Bogotá (*26*). Many of these are in zones covered until recently by forest and probably owe their preservation to the fact that they, in contrast to most of the Sabana, have not been plowed over for four centuries. In aerial photographs, dated 1940, of Hacienda La Conejera, the former field patterns show up clearly within modern fields recently cleared from forest. On photographs taken of the same site in 1968, after only 28 more years of plowing, the old fields are much less distinct. As seen from the ground, the old fields showed no greater relief than the surrounding land. They are discernible only because of differences in the soil which have persisted, despite the leveling of the ridges and filling of the ditches, so that there is now a differential growth of maize and wheat crops which is expressed in rectangular block form. It seems reasonable to speculate that much of the Sabana de Bogotá was covered by ridged and also ditched fields prior to the arrival of the Spaniards, and that these fields were related to the population density and to the cultural achievements of the great Chibcha chiefdom of the Sabana.

Large ridged fields have not been found in the smaller, poorly drained basins in the Andes. However, in Peru I have seen deeply ditched fields in use today (as they have probably been for a long time past) in the Pampa de Anta near Cuzco, the Taraco and Pomata areas of Lake Titicaca, and elsewhere. They are similar to the present Bogotá ditch systems, although smaller and less systematic. Rather than creating raised surfaces, they serve to reclaim waterlogged soils by providing subsoil drainage and by channeling excess water away from crops. The present Sibundoy Indians near Pasto in the Colombian Andes also drain their fields by this means (*27*).

There is another form of drained field which is very common in the Andes today and is clearly of aboriginal origin.

This is the lazybed system, locally referred to as *huachos* or *eras*, which is found from Colombia to Bolivia (*28*). Potatoes are the main crop, along with *cañihua*, barley, and arracacha. These fields are commonly made with the Andean foot plow (*chaqui taclla*—similar to the Scottish *cashcrom*), which is used to break and turn heavy grass sods where larger plows are not available or usable, especially on steep slopes. However, lazybeds are also made on poorly drained flat terrain and waterlogged lower slopes in order to improve drainage. Usually they are about 1 meter wide and 30 to 60 centimeters high. Some of the Titicaca ridged fields have been or are being destroyed by lazybeds built on top of them.

In the Mexican highlands there are other types of drained fields besides the *chinampas*. The only detailed published descriptions are by Wilken for Tlaxcala (*29*), but similar fields exist elsewhere—for example, in Puebla, Oaxaca, and the State of Mexico—in poorly drained valley and basin bottoms. In southwestern Tlaxcala contemporary drained fields occur on sites ranging from swampland to land watered only by seasonal rain. In all cases waterlogged soil must be drained before cultivation is possible. The main technique is to dig drainage canals several meters wide and deep, but raised garden plots some 10 meters wide may also be built up between the ditches. The ditches are periodically cleaned, and muck and vegetation are spread on the fields to increase fertility.

Fig. 4. Partly inundated pre-Columbian ridged fields in the Río San Jorge floodplain of northern Colombia. [Courtesy J. J. Parsons and W. Bowen]

North American Garden Beds

In North America, remnants of aboriginal raised fields were quite common until most were destroyed by plowing in the 19th century (*30*). These fields, usually referred to as "garden beds," are linear or curved and fairly narrow (1 to 4 meters), and they occur in clusters of several hundred. At least 180 such clusters have been reported in Wisconsin and Michigan, and undoubtedly there were once many more. The primary function of the garden beds may have been to break up grassland sod. However, many if not most of the fields occur in the bottomlands of the Mississippi drainage system; hence they probably also had a drainage purpose. There seem to be no historical descriptions of the garden beds in use. Probably they were a product of the "Mississippian" cultures (about A.D. 700 to 1500), which were characterized by a dependence upon agriculture and by a village orientation to "the major streams with large alluvial floodplains which provided fertile and easily worked soils" (*31*).

The occurrence of ridged fields in the mid-latitudes and subtropics is partly confused by what is called *gilgai* topography. This is a landscape crumpled into a complex microrelief of mounds and ridges and depressions. It is known, in North America, India, Australia, and Africa—regions where there are marked wet and dry seasons—usually in lowland savannas and grasslands. *Gilgai* seems to be the result of the "self plowing" of black, montmorillonite clay soils experiencing severe seasonal swelling and contraction. In some instances the topography may take the form of parallel linear or curved stripes and depressions somewhat similar to garden beds, lazybeds, and ridged fields (*32*). Some features considered man-made ridged fields may actually be *gilgai* soils, and some features labeled *gilgai* may really be ridged fields. Certainly soil scientists and culture historians should be aware of the alternative possibilities.

Other Types of Drained Fields

One of the few contemporary examples of Indian cultivation of wet savannas is in the Río Branco campos of northeastern Brazil, where the Makuxí (Macusi) Indians near Serra do Flechal build large manioc mounds some 50 centimeters high and 1 to 2 meters across (*33*). These are larger than the small hillocks of tropical forest cultivators and may be comparable to the *montones* of Hispaniola and Mojos. Over 1000 small mounds in an orchard pattern were found in the Lerma Valley in Salta, Argentina; they seem to have been used for cropping of poorly drained ground (*34*).

Large burial and settlement mounds of aboriginal origin are common throughout tropical America, and many are located on ground subject to seasonal flooding, as in Mojos and on Marajó Island. Many of these mounds have had farms on them in the past, and still do. One striking example is the Guato Indian mounds reported by Schmidt in 1914 in the savannas between the upper Río Paraguay and the upper Río Guaporé in western Mato Grosso, one of which, 2 meters high, measured 140 by 76 meters (*35*). Groves of acuri palms (*Attalea*) were planted on top.

There are a few instances of embanked or diked fields, in which walls were built to keep water out, in Mojos (Fig. 3) and the Titicaca plain, but ridges, mounds, and ditches are the more common means of coping with poor drainage.

The cultivation of river land (banks, sandbars, low islands) during low water has been a common aboriginal practice in the floodplains of the Amazon, Orinoco, and other large rivers. While little is known about such agriculture, it was apparently common in the past (*36*) and is still practiced by both Indians and settlers today. Crops are planted which have a short growing season and do

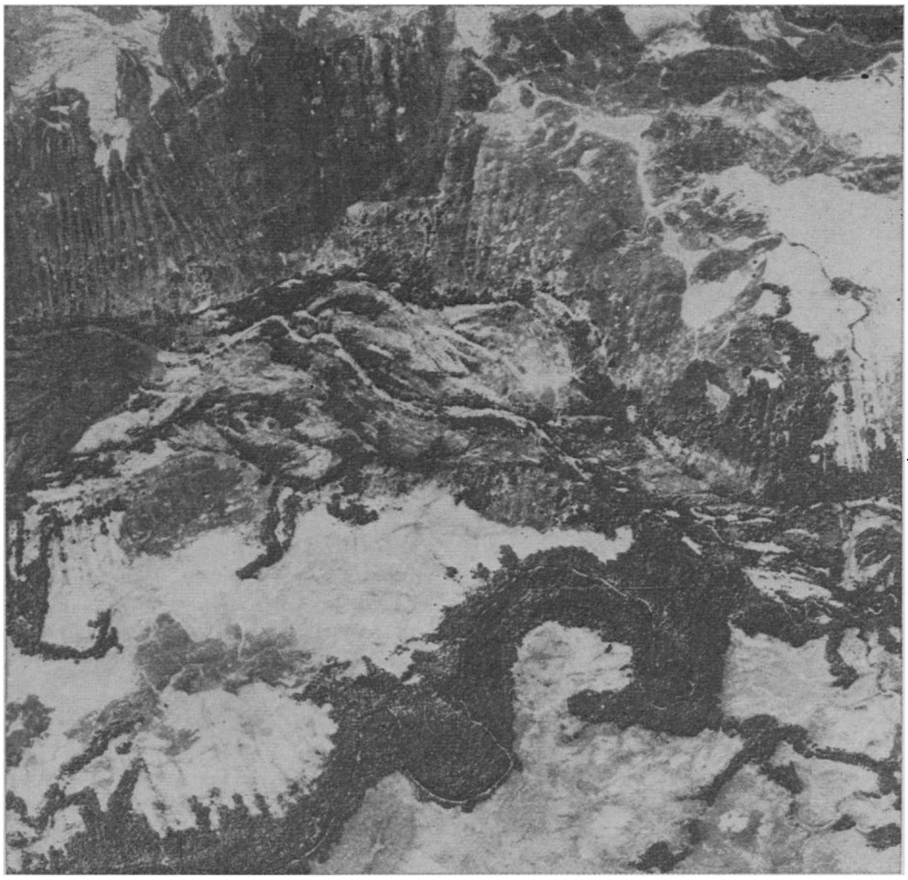

Fig. 5. Ridged-field remnants at right angles to streams near the Caño Guanaparo (at bottom) about 130 kilometers west of San Fernando de Apure in the Orinoco Llanos of Venezuela. (Scale: about 1:37,000.) [Courtesy J. H. Terry]

well in sandy soils—such as peanuts, sweet potatoes, squashes, and some beans.

Seasonally flooded savannas have also been cultivated during the dry season. Padre Gumilla in the 18th century reported that the Otomaco Indians between the Orinoco and Río Apure in Venezuela planted crops on the grassy margins of savanna lagoons as the lagoons dried up (*6*). Today the Karinya in the Orinoco Llanos cultivate moriche palm swamps during the dry season with the aid of surface mulches and ash and, in some places, with drainage ditches dug by communal labor (*37*). Mounding or ridging is minimal, but this system may be a survival of more elaborate earlier practices.

Discussion

There is now evidence, mostly of a reconnaissance nature, of a wide variety of drained-field agricultural systems occurring in a variety of ecological situations in the Americas. However, except for the fields in highland Mexico, we know very little about these systems and the societies responsible for them. The South American field remnants have not been dated or correlated with archeological materials, and there are few descriptions of the fields in use. That the relic ridged fields were agricultural is implicit, there being no other rational explanation for them (*1*). The fields are sufficiently extensive and impressive to warrant detailed archeological and ecological studies. Also, additional areas of field remnants may be discovered through careful examination of conventional aerial photographs or with the aid of infrared and other remote sensing techniques (*38*). Meanwhile, only preliminary conclusions can be drawn concerning causation, techniques, crops, and demographic and cultural implications.

Drained-field agriculture is, of course, common today in the mid-latitudes as increasing efforts are being made to cultivate marginal lands by modern techniques. In Europe, there are classic preindustrial examples, such as the fens of England and the polders of the Netherlands (*39*). But it is to the tropics of the Eastern Hemisphere that we may look for aboriginal drainage techniques that might provide the best clues to pre-Columbian practices in tropical South America. Ridge and mound agriculture is common in the African savannas, but the primary function seems more often to be for aeration, root removal, and concentration of top soil rather than for drainage (*40*). In Melanesia, however, there are excellent contemporary examples of ridged-field agriculture in poorly drained situations. Fields photographed in the Baliem Valley of New Guinea are remarkably similar in pattern and dimensions to some of those in South America (*41*). Sweet potato fields are constructed by teams of men using simple digging sticks and wooden spades to raise long ridges by throwing earth up from drainage ditches. Fertility is maintained by mixing in a mulch of grass and aquatic plants that makes it possible to grow crops continuously for several years before fallowing. The *chinampas* of Mexico are managed somewhat similarly, and the same methods must have been used in South America. It is unlikely that aboriginal people would have developed elaborate drainage systems unless each field could have been cultivated numerous times.

But why attempt to farm poorly drained land in the first place, especially when there is more fertile and more cultivable land locally available? For one thing, seasonally flooded areas generally have rich protein resources in the form of fish and other aquatic life such as various turtles, rodents, and birds. Such resources are especially important in the South American tropical lowlands, where the staple crop is manioc, which has a very low protein content. The same reasoning might apply to the Lake Titicaca plain, where the potato is the staple. Proximity to rivers and river banks is, of course, also important for transportation and for fertile, easily worked soils.

A second possible reason for the great efforts that were, and are, expended on building and maintaining drained fields is demographic. Boserup (*42*) and others have argued that agricultural intensification is a result of, rather than a cause of, increased population, and this does seem to be true for many preindustrial societies. In New Guinea, for example, for groups of essentially the same culture, the ratios of extensive to intensive cultivation vary with local population densities (*43*). An increase in productivity per unit of land is resisted as long as there is adequate land available for more extensive systems, mainly because intensification requires greater inputs of labor, at least initially, in terms of productivity per man-hour. In the South American savannas, population must have been initially concentrated on the more fertile soils of the gallery and island forests. Such forest soils now cover only about 10 to 15 percent of the Llanos de Mojos. Once the forest soils were fully in use, surplus populations might have been motivated to cultivate the savannas despite the greater labor required. Probably, as population increased, more and more savanna was brought into cultivation.

That the ridged-field areas in the lowland savannas were relatively densely settled is suggested by historical documents for Mojos (*14*) and by archeological evidence for San Jorge (*15*) and Guayas (*17*, *18*). The presence of the drained fields provides additional support, if the preceding argument is valid. Estimating population densities from the extent of the drained fields is difficult, however, since it is not known how many fields were cultivated at any given time. For San Jorge, if a conservative 0.8 hectare of land and water surface is allowed per person, and if only 20 percent of the fields were farmed at once, the population density comes to a substantial 25 persons per square kilometer. Locally, all the ridges may have been in cultivation at once, in which case the densities could have been more than 100 persons per square kilometer. Such densities are not unreasonable in view of present populations of up to 400 per square kilometer in the Baliem Valley of New Guinea, where swamp drainage is practiced (*44*).

In the highlands, drained fields were clearly associated with dense populations. These were nuclear areas in terms of population growth and cultural evolution and were apparently characterized by the progressive utilization of new ecologic niches as population increased and new technology was developed (*44*); the most difficult habitats were brought into cultivation last, usually with elaborate reclamation. Presumably when population and production demands were reduced, as they were drastically in the 16th century, the least easily cultivated habitats were abandoned first. Around Lake Titicaca this meant the higher terraced slopes and the drained fields of the lake plain, both

Fig. 6. Ground view (July 1966) of one of the large ridged fields, shown on the cover, at the edge of Lake Titicaca near Requeña, Peru. The pockmarks were made by rooting pigs. Note the eroded edges of the ridge and the alkaline deposits on both sides of the ridge.

of which are still largely uncultivated today. Thus, preconquest populations of the Titicaca area may have been even greater than the present dense populations. Much of the lake plain is hacienda pasture and not available to the Indians. However, where Indians do control such land, as around the town of Huata north of Puno, there is increasing lake plain agriculture, but with the lazybed system rather than construction of large ridges. Most of the areas of drained-field remnants in Latin America probably supported substantially larger populations than they do today.

Summary and Conclusions

The three main types of land reclamation in aboriginal America were irrigation, terracing, and drainage. Of these, drainage techniques have received the least attention, probably because they are no longer important and because the remnants are not conspicuous. Nevertheless, drained-field cultivation was widespread and was practiced in varied environments, including highland basins, tropical savannas, and temperate flood plains. Sites ranged from seasonally waterlogged or flooded areas to permanent lakes. Ridging, mounding, and ditching were emphasized, rather than diking. Tools were simple, crops varied, and fertilization was accomplished mainly by mulching.

The presence of drainage agriculture probably indicates that populations exceeded the carrying capacity of the more easily cultivated land. When populations declined, following the conquest by Europeans, the drained fields were probably given up because of the large amount of labor required to cultivate them. Most of these lands are now used only for cattle, but could undoubtedly be reclaimed again for agriculture (*46*). However, the cost of such reclamation might be prohibitive where populations are sparse, transportation is poor, and distances to markets are long. The *chinampas* of Mexico are an exception, since there is a major urban market close at hand.

The aboriginal cultures responsible for drainage ranged from the seminomadic Guato, to farm villages and chiefdoms, to the high civilizations. The ridged-field farmers of the savannas were capable people but certainly not comparable to the farmers of the efficient and sophisticated states of the Andes and Mexico. Most of the drained-field systems could have been constructed and managed through small-scale family and community cooperation, as in New Guinea, rather than through central political control. On the other hand, there does seem to be a frequent relationship between degree of agricultural intensification, population size, and complexity of social organization (*47*). Unfortunately, not much is known yet about the intensification process for drained-field cultivation or for other reclamation systems.

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NEWS AND COMMENT

Behaviorial Sciences: The View at the Center for Advanced Study

Palo Alto. Early in the morning of 24 April, arsonists set three fires in the buildings of the Center for Advanced Study in the Behavioral Sciences which stand on an isolated hilltop on Stanford University land. Fire displaced 10 of the 50 fellows from their offices, and the heaviest damage to research materials was sustained by a sociologist from New Delhi (see page 657). Cost of reconstruction at the center, most of it covered by insurance, is estimated at $60,000, not counting replacement of furnishings and equipment. But the impact of the fire cannot be reckoned simply in financial terms, since the center in its 15 years of operation has assumed national and international significance among behavioral scientists. As one of the current group of fellows put it, "The place has a tremendous reputation as a Shangri-La."

It would be a distortion to say that the center before the fire was an intellectual retreat sequestered from the turmoil outside. Concern about divisions in society and in the university have been reflected for several years in the activities of the center's fellows, but, as the center's associate director Preston Cutler observed, "The chief casualty of the fire was the conception of the center as a place of safety and peace." (Damage from the fire might, in fact, have been much more serious save for fast work by firemen and a stroke of luck. Major damage occurred in two buildings containing office-study rooms occupied by the fellows. The Santa Clara County fire marshal said that in each case flammable liquid was ignited in a small telephone room lined with acoustical tile, which burned very rapidly. A third fire was set in a service room in the central block of buildings housing the center's library, refectory, administrative offices, and meeting rooms, but the service room happened to be lined with wallboard, which simply smouldered and contained the fire.)

Whatever the objectives of the arsonists, the fire unquestionably disturbed behavioral scientists at the center and elsewhere particularly deeply because it seemed aimed not simply at causing physical damage but at destroying the scholarly work of individuals. The effect of the fire on life at the center was probably greater because there were no threats beforehand and no claims afterward by the perpetrators. There are still no suspects in the case. In the ab-