Raised Field Agriculture in the Lake Titicaca Basin

Putting Ancient Agriculture Back to Work

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The remains of an extensive ancient agricultural system built and used by Andean peoples centuries ago are found throughout the vast high plain surrounding Lake Titicaca in the Andean countries of Peru and Bolivia (Figs. 1, 2). Raised fields are large elevated planting platforms which provided drainage, improved soil conditions, and improved temperatures for crops. The remains of prehistoric raised fields, elaborate sunken gardens, and agricultural terraces cover tens of thousands of hectares in the region, and provide evidence of the impressive engineering abilities of the peoples who lived here in pre-Columbian times.

Our recent investigations of raised field agriculture demonstrate not only the technological expertise of the past cultures, but also that these systems could be re-used today to make high altitude lands more productive. In a region such as the Andes, where conditions of soil and climate greatly limit agricultural potential, technological methods to augment productivity have been increasingly necessary to support the growing populations of Quechua and Aymara farmers who live there today. The reuse of raised fields may be an economical and ecologically sound alternative to agricultural development based on expensive imported technology.

Until recently, very little was known about the origins and evolution of raised field technology in the Lake Titicaca Basin. Observant Spanish chroniclers in the 16th century described many aspects of the indigenous agriculture, such as terraces and irrigation canals, but they did not mention raised fields. This omission suggests that raised fields had probably been abandoned before the arrival of the Spanish. Questions such as who constructed the fields, when were they built, what crops were cultivated, why the fields varied so much in size and shape, and how raised field agriculture functioned needed to be answered.

Between 1981 and 1986, I directed a small team of researchers investigating prehistoric raised field agriculture in the community of Huatta in the northern Lake Titicaca Basin of Peru. Huatta is located in the center of the largest block of raised field remains, estimated to cover 53,000 hectares. The project, combining archaeology and agronomy, addressed the important questions raised above, as well as those more relevant to modern agriculture, such as estimating the potential productivity of the raised fields and investigating their effects on the local agricultural environment. The investigation was based on archaeological survey and excavation of prehistoric raised fields and selected habitation sites, together with the construction and study of experimental raised field plots (see box). To apply the results of this research, a small-scale development project involving local Quechua farmers was begun in 1982 to put raised fields back into use.

Raised Field Agriculture and the Lake Titicaca Environment

Raised fields are constructed by excavating parallel canals and piling the earth between them to form long, low mounds with flat or convex surfaces. These raised platforms increase soil fertility, improve drainage in low-lying areas, and improve local micro-environments, primarily by decreasing frost risk. The canals between raised fields provide vital moisture during periods of short- and long-term drought. Water in the deep canals might have been used to cultivate aquatic plants and fish, as well as attract lake birds that were an integral part of the prehistoric diet. The raised fields of the Lake Titicaca region are diverse in form and in size, but generally range from 4-10 m wide, 10 to 100 m long, and are 1 to 2 m high.

The prehistoric raised fields, covering some 52,000 hectares of low-lying land around Lake Titicaca in both Bolivia and Peru (Fig. 1), have been badly eroded by a combination of wind, rain, flooding, and modern urbanization, but their remains can be seen clearly on the ground and in aerial photographs. They were specifically adapted to the particular environment, crops, and technology available to the indigenous farmers. Most of the land lies above 3800 m (12,500 feet), and nights can be bitterly cold, despite warm sunny days. The year is divided into distinct wet and dry seasons of roughly six months each, but even this situation may vary greatly from year to year, producing an unpredictable, high-risk agricultural environment. Frosts are most common during the dry season, and at the beginning and end of the growing (wet) season, but may occur locally at any time without warning, especially in low-lying depressions at the bases of hills.

The land immediately adjacent to Lake Titicaca has a somewhat more favorable environment for cultivation, mild enough for special races of corn to be grown in sheltered valleys and on the islands and peninsulas of the lake. The stored heat of the massive body of lake water warms the areas around it, an especially important effect at night when frosts are common. Further from the lake, this warming effect diminishes, but the entire region around the lake benefits from a slightly higher than average annual rainfall. The major obstacle to lakeside agriculture is that most of the surrounding land is either rocky debris or flat, waterlogged lake plains which may be seasonally inundated. Both areas have relatively poor soils and are classified as areas of limited agricultural potential by government studies. Today, large rural populations are located in areas that have better drainage, favorable temperatures, and good soils, combined with access to the lacustrine resources of Lake Titicaca.
The rich and varied biotic resources of the region would have made it an excellent location for prehistoric experimentation with domestication of plants and different cultivation techniques. Once local peoples learned to protect fields from inundation, the pampa (the grass-covered low-lying lake plain) would have been a relatively good area for crop production. In fact, botanical and archaeological research indicates that the potato, quinoa and cañihua (two seed crops rich in vegetable protein) and many other important Andean crops were probably first domesticated in the Lake Titicaca region (see also K. Chávez, this issue). Selection of special traits has produced crop varieties that can withstand harsh environmental conditions, such as high altitude, intense solar radiation, low nocturnal temperatures, and crop pests. The nocturnal cold was put to use by the prehistoric inhabitants in an elaborative freeze-drying technique which enabled vast amounts of agricultural surplus to be preserved and stored indefinitely. This Andean crop complex and its accompanying preservation technology, combined with the herding of llamas and alpacas and exploitation of lacustrine resources, provided a sound subsistence base for the civilizations that developed in the Lake Titicaca Basin.

The indigenous Andean agricultural tool inventory appears limited in technological complexity, but is more than adequate for the needs of the Andean farmer. Traditional tools include the Andean footplow, hoe, and chisel breaker which are still the basic tools today, although the stone and wooden blades have been replaced by metal blades (see Fig. 10). The footplow, a remarkable implement which is excellent for turning over blocks of tough pampa sod for construction of lazy beds for tubers and for plowing stony ground on steep hillside plays a major role in the development of raised field agriculture.

The Archaeology of Raised Field Agriculture

Our trenches excavated through the prehistoric raised fields showed that those seen today in the pampa (Fig. 3) are only the badly eroded remains of fully functioning prehistoric field systems. The field surfaces were originally much higher, with deep canals between them, which have now become filled with sediment. In some trenches, several distinct phases of construction, use, reconstruction, and re-use of the fields can be delineated (Fig. 4). Some early fields were narrow ridges of 5 m wavelength (distance from canal center to canal center) which at a later time were expanded to larger fields of 10 m wavelength. From each stratum of the trench profile, samples were obtained for pollen and soil laboratory analyses. The data obtained from these analyses provide interesting insights into prehistoric agriculture.

Soil analysis indicates that the canal sediment, composed primarily of organic matter, is rich in nutrients, much more so than the average pampa soil. In addition, soil alkalinity, a major constraint on agriculture in the lake edge soil, is markedly lower in the canal sediments. These rich sediments were periodically removed from the canals and added to the raised fields to improve the crop soils. Pollen samples from these excavations have been analyzed by Dr. Fred Wiseman of the Massachusetts Institute of Technology. He finds that pollen grains of quinoa and potato are present in many soil samples from the raised fields, indicating that these may have been the crops grown on the fields. Unfortunately, there is no way to distinguish between the pollen of the domesticated and wild strains of these plants.

The precise dating of raised fields presented a problem. Radio-carbon dating of material recovered from the excavation of two prehistoric habitation mounds associated with raised field agriculture indicated that most of the garbage middens and construction fill of these sites dates to the period from 1000 B.C. to A.D. 400 (corresponding to the Qahyu and later Pucara cultures), with a smaller occupation after A.D. 1000 (related to the Aymara kingdoms and subsequent Inca occupation). However, direct dating of the raised fields themselves has proven to be much more difficult. Changes in field use were determined through relative dating of
Excavations in habitation mounds provided an excellent context for documenting the lifeways of prehistoric farmers. The archaeological crew is excavating a floor and foundation of a house of the Pucara culture at the site of Tancahua. From this floor, the archaeologist recovered cooking and serving vessels, food remains, and agricultural implements used to construct raised fields.

The field stratigraphy, but the duration of each phase could not be ascertainment through stratigraphic analysis alone. Carbonized remains for radiocarbon dating were not present in raised fields, but six pottery samples recovered from stratigraphic contexts in the construction fill and the canals could be dated by the thermoluminescence technique. This technique determines the time elapsed since the original firing or last exposure to fire of the ceramic vessel. These dates give us a secure chronology for the raised fields and correlate nicely with the dates from the occupation mounds. The surprisingly early dates between 1000 B.C. and the beginning of our era, and the successive building stages and abandonment periods, demonstrate that the raised field system was not a brief late phenomenon as previously suspected. It appears to have been a relatively early agricultural development which was expanded gradually and was used by many generations of Andean farmers.

Our archaeological survey focused on locating the sites occupied by farmers who constructed and maintained the raised fields around Huata. Most sites on the pampa in direct association with raised fields were earthen mounds that had once been small farmsteads or hamlets. Several larger sites both on the pampa and in the hills overlooking the plain were once towns with rustic public architecture. All that remains now are the stones that served as the foundations for the adobe structures. The number and distribution of habitation mounds indicate a rather dense population in the raised field area throughout the prehistoric period of raised field use, much larger than that of today, surprisingly.

Two of the larger sites (those mentioned above for which dates were obtained) were partially excavated, and showed evidence of long-term occupation. These mounds were the cumulative result of continual rebuilding atop the remains of older, eroded structures. Many of these mounds are still considered to be ideal habitation locations due to their elevation, especially during the seasonal flooding of the pampa. Their garbage middens yielded in formation about prehistoric subsistence strategies, agriculture, and ceramic and weaving technology.

Plant fragments, direct evidence of agricultural crops preserved by accidental carbonization, have been recovered by the screening and flotation processing of soils from the garbage middens and fill of habitation sites. These samples include fragments of potato and possibly other tubers and quinoa. Also identified were aquatic lake plants and other wild plants that could have been used for food, fish, construction, or dyes (the domesticated alpaca and llama), guinea pig, and various aquatic birds. These remains are represented by bone material recovered in the excavations. The floral and faunal remains are found throughout the sequence of occupation and indicate a remarkable economic stability. All of this evidence indicates a prehistoric subsistence pattern similar to that still practiced today by lake-edge-dwelling Aymara and Quechua farmers, a pattern based on a combination of potato and quinoa cultivation, herding, fishing, and intensive gathering of wild plant resources. The recovery of thousands of basalt hoe fragments, polished through years of use to test their importance in the tool inventory of the ancient agricultural technology. These stone hoes were among the implements used to construct the raised fields. Pottery remains included utilitarian serving and cooking vessels, in addition to ceremonial or fine wares decorated with burnishing, painting, and painting. One nearly complete house structure belonging to the Pucara style (A.D. 300 B.C. – A.D. 400) excavated (Fig. 5), and it has many features similar to those of adobe houses with thatched roofs constructed today in the area.

Interpretations of the Excavations

Our research results show that large farming systems were settled throughout the lake area by 1000 B.C. By 300 B.C., Lake Titicaca occupation had evolved sufficiently to support large agricultural and population centers. The site of Pucara in the northern shore of the lake has approximately 4 km of urban sprawl, complete with pyramidal platforms and temples with semi-subterranean courtyards (see K. Chavez, this issue). Tiahuanaco (A.D. 300- 1000), one of the most important Andean sites, probably had its humble beginnings at this time and rapidly grew to influence most of southern Peru and the Bolivian highlands by A.D. 500 through its control of long distance trade, its colonies, and religious missionary dispositions (Brown 1973). Tiahuanaco subsequently collapsed and was replaced by several competing Aymara kingdoms around A.D. 1000. These in turn were conquered by the Inca empire around A.D. 1430. Some hypotheses suggest that construction of raised fields and terracing was related to the later cultures, when population stress resulted in the development of labor-intensive agricultural technology, and a centralized bureaucracy was available to plan, direct and manage the agricultural systems (Smith et al. 1986; Kolata 1986).

Our investigation suggests some alternatives. The growth of the Andean polity of Pucara at the north end of the lake basin was certainly related to the expansion of raised field agriculture. However, this agricultural culture was well established several centuries earlier. As Pucara's power as a ceremonial center was snatched by Tiahuanaco in the southern lake basin, raised field use appears to have declined in the north, but it was probably never completely abandoned. New research indicates that, as might be expected, raised field construction at the southern end of the lake was related to the growth of Tiahuanaco (Kolata 1986). A later resurgence of raised field construction occurred when a number of independent Ayamara kingdoms were established around the lake after the collapse of Tiahuanaco sometime after A.D. 1000. Limited raised field use may have continued during the brief period of Inca domination of the lake basin, sometime after A.D. 1450.

Why was the use of raised fields discontinued in the northern basin after the decline of Pucara before the arrival of the Spanish? Many ideas have been put forward to account for the abandonment of the system, such as climate change, devastating droughts and floods, and political uplift. I find none convincing. In my opinion, the raised field construction, expansion, and abandonment relate less to environmental factors than to the changes in the relative importance of various ceremonial centers in the Lake Titicaca Basin. As ceremonial and population centers grew, agriculture expanded to keep pace with them. When power and influence shifted to other areas, production needs dropped and fields were removed from production. Some of the prehistoric communities in the raised field zone may have been depopulated and the inhabitants perhaps even forcibly removed to other locations. Although the area and intensity of cultivation were reduced at various times in the past, the raised fields were probably never completely abandoned until the severe depopulation of the region that followed the arrival of the Spanish.

Raised field technology enabled the prehistoric inhabitants of the Lake Titicaca Basin to effectively maximize crop production. The earliest raised fields documented in our project do not appear to have developed as the result of population stress, or do the earliest phases of field construction and use developed as the result of raised fields directed by a centralized authority. This technology may have been one of the earliest forms of corporate agriculture, a logical outgrowth of early fishing, gathering, and hunting sedentary life based on the exploitation of rich lake resources. This subsistence strategy permitted a dense population of wetland-oriented peoples to maintain sedentary lives.
Mature potatoes on raised fields in the Community of Segunda Collina in Vasconchal Pampa, Huatta. Platforms and canals are approximately 10 m wide each (February 1965). The canals, originally between 1.0-1.5 m deep, accumulate rich organic soils and aquatic vegetation that can be periodically used on raised fields for maintained production. The canals collect and store solar energy to prevent frosts, conserve water for use during periodic droughts, and may have been used for raising fish.

Experiments in Raised Field Agriculture

More detailed information about raised fields as an agricultural technology was gained from the construction and cultivation of several experimental fields. An excavated archaeological trench provides original canal depth and ridge spacing, and the dimensions of the fields constructed to these specifications by local Quechua farmers using traditional agricultural implements available in all households (foot-pow, hoe, clothbreaker, shovel, and pick). Traditional Andean tools proved to be excellent implements ideally suited for the preparation of raised fields. It was found that the easiest, most efficient method of construction involved teams of two people; two foot-pow, two clothbreakers, four spades, and none to cut blocks of soil from the old canals between the ridges (Fig. 6), while the third tossed the soil blocks onto the old field surface. In this way, a thick layer of rich organic topsoil, a perfect medium for cultivation, was rapidly built up on the eroded field surface. It was calculated that for each hour of work, the team could move three cubic meters of earth, a construction rate much faster than had been expected.

Major crops native to the Andean highlands were cultivated on the experimental raised fields of the plants, potatoes, quinoa, and cabbages (Fig. 7) produced the greatest yields. During five years of experimentation, there was between 8 and 18 metric tons per hectare, with an average of 10 metric tons. This figure is much larger than today’s average potato production figures of between 1 and 4 metric tons per hectare for the Department of Puno. These larger yields are especially significant because we used local and improved potato varieties without fertilizers in the experiments (Fig. 8), while most of the potato fields upon which the current regional estimates for Puno are based were not fertilized. We have also demonstrated that high yields can be sustained for several years of continuous cropping. Green manure produced in the canals, including nitrogen-fixing algae, can be used to replenish depleted soil nutrients on the fields after several years of continuous cropping. The canals were also productive in another way. Various useful aquatic plants, valuable resources in prehistoric times, rapidly colonized the water. Fish might have been raised in the deeper canals, providing a useful source of protein to supplement a diet based on starchy tubers while at the same time increasing the nitrogen content of the canal mud. The value of raised fields in the cold Lake Titicaca Basin was dramatically demonstrated during a severe local frost in 1953. Crops in nearby fields were severely damaged, while potatoes cultivated on our experimental raised fields suffered only minimal damage and quickly recovered. Several investigators have hypothesized that raised field microtopography tends to drain heavy dense cold air from the elevated field surfaces into the canals. Frost drainage may have played a role in this effect, but the data indicate that the presence of water in the canals was most important. In order to test this hypothesis, we conducted an investigation of the local climate of the experimental raised fields. Continuous records of incoming and outgoing energy were collected using sensitive meteorological instruments both for an experimental raised field and for nearby non-raised field areas. The study indicated that during a night of light frost in the growing season, soil and air temperatures on the raised fields were a couple of degrees Celsius higher, and the frost was of several hours shorter duration than on nearby regular fields. The water temperatures in the canals between the raised fields were even warmer than that of the soil and air, indicating that the water acts as a heat sink for storage of solar energy. We suggest that this energy is released slowly at night, when frosts are most common, blanketing the surrounding fields in warmer air. Although the increased temperatures are only slight, our experience indicates that it was enough and that it may have been important in minimizing the risks due to frosts for the prehistoric farmers of the area. Both lowering crop damage during the growing season and actually extending the season.

Raised Field
Technology and Rural Development

Countries such as Peru and Bolivia often use models from more technologically advanced nations to develop their agriculture and industry. A succession of apparently sophisticated development projects in the Lake Titicaca Basin have failed and in some cases we can determine why. For instance, certain projects attempted to introduce capital-intensive agriculture that depends primarily on petro-chemical fertilizers, farm machinery, imported seed, irrigation pumps, or special animal forage, none of which are within the reach of most farmers and may not work. Other projects have been oriented towards producing cash crops, but small farmers who produce a cash crop on their land often cannot make enough profit to buy food for their family; they would otherwise produce themselves. In most cases, the majority of the farmers have not benefited from such development projects.

A more effective approach to development that is referred to as "appropriate tech-
The Significance of Chiripa in Lake Titicaca Basin Developments

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The site of Chiripa is located in Bolivia on the southern shore of Lake Titicaca. A series of structures revealed by excavation there have long been interpreted as ordinary houses of a residential village belonging to a relatively localized culture named Chiripa after the site. Using available published data as well as unpublished evidence, I have reinterpreted this unusual Late Chiripa architectural complex (ca. 600-100 B.C.), with its structures surrounding a sunken court, as a temple-storage complex. In this article I examine how it served as a direct model for the monumental temple complexes belonging to the later Pucara culture (ca. 100 B.C.) that are found in Peru at Pucara in the northern Titicaca Basin. The occupants of the high-prestige temple/storage complexes at Chiripa and Pucara may have been involved in the administration of ritual and worship, and even of production, circulation, and consumption, perhaps regulated by periodic ceremonies associated with the temples. Chiripa was part of the widespread Yaya-Mama Religious Tradition, defined here for the first time, that appears to have unified populations in the Lake Titicaca Basin. This tradition directly contributed to Pucara, and in many ways persisted into later, more powerful Tiahuanaco, Huari, and perhaps even Inca societies (see map and chronology, pp. 2-3). Beginning at least by Late Chiripa times, the Yaya-Mama Religious Tradition, named after the style of associated stone sculpture, was characterized by: (1) temple-storage centers such as at Chiripa, (2) Yaya-Mama style stone sculpture having supernatural images, associated with the temples, (3) ritual paraphernalia including ceramic trumpets and ceremonial burners, and (4) a supernaturally iconography including heads having rayed appendages and a vertically divided eye.

Tiahuanaco and the local societies that preceded it were set in the altiplano, a high, virtually treeless plateau that surrounds Lake Titicaca at over 3800 m. above sea level. This region provides both limitations and advantages in terms of subsistence (see Erickson, this issue). The most salient limitation of the cold and altitude was in agriculture, so that crops included only native grains, like quinoa, and tubers, such as potatoes. The open grasslands, however, were ideal for the hunting of wild guanaco, vicuña, and deer, and for the herding of domesticated llama and alpaca. In addition, the lake provided abundant resources like fish, frog, and reeds used for such things as rafts for transport, roof thatching, and food.

The Tiahuanaco polity flourished between about A.D. 300 and 1200 and extended from southern Peru into parts of Chile and Argentina. It is named after the large urban and ceremonial site in the southern Lake Titicaca Basin that surely must have been its administrative and religious center.

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1. Exposed north face of the Chiripa mound, Bolivia, in the area of Coe's excavation, 1955. The distance from the edge of the mound at right to the left (east) edge of stone structure is 11 m. This stone structure belongs to the Middle Chiripa Level (900-600 B.C.).