

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 there 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



1 Map showing distribution of raised field remains (based on Smith et al. 1968; fig. 1) and potential raised field sites within the Lake Titicaca basin of southern Peru and northern Bolivia.

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 m tall.

The prehistoric raised fields, covering some 82,000 hectares of low-lying land around Lake Titi-



2 Map showing locations mentioned in the text.

caca 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. Farther 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 lake-side agriculture is that most of the surrounding land is either rocky steep slope or flat, waterlogged lake plain which may be seasonally inundated. Both areas have relatively poor soils and are classified as areas of limited agricultural potential in 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 indicate 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 elaborate 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 clod 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 hillslopes, played 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 pre-

historic 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,



4 Archaeological excavations in raised fields provided the archaeologists and agronomists with specific data on original field form, building stages, use period and abandonment, and samples of soil, pollen, and artifacts. Here, soil stratigraphy is being mapped by archaeological crew members. These stratigraphic profiles of prehistoric fields provided the models for proper reconstruction in the experiments.

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. Radiocarbon dating of material recovered from the excavation of two prehistoric habitation mounds associated with raised field agriculture indicated that most of the garbage midden and construction fill of

these sites dates to the period from 1000 B.C. to A.D. 400 (corresponding to the Qaluyu 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

Glossary

Aymara: the indigenous peoples of present-day Peru and Bolivia who speak the Aymara language
cañihua: an Andean grain crop related to our weed lambsquarters; high in protein

chakitaqlla: the Andean footplow, composed of a handle, shaft, and footpeg of wood with a heavy metal cutting blade bound by leather tongs

flotation: a water separation process used by archaeologists for the recovery of small plant and animal remains from the soils of archaeological sites

pampa: a grass-covered, treeless plain which may be seasonally inundated or waterlogged

pollen analysis: the study of microscopic pollen grains which may give information on past climatic conditions, local environments, or crops cultivated

Quechua: the indigenous peoples of present-day Peru and Bolivia who speak the Quechua language

quinoa: an Andean grain crop related to our weed lambsquarters; high in protein

raised fields: large elevated planting platforms with intervening water-filled canals designed to improve drainage, maximize soil fertility, prevent frosts, and/or provide irrigation

3 A panorama of ancient raised field remains of the Viscachani Pampa belonging to the residents of Collana Segunda, Huatta, Peru, shows only a small portion of the 82,000 hectares of ancient raised fields in the Lake Titicaca Basin. The lighter surfaces are water-filled canals and the darker surfaces are raised fields or drier pampa. The project's reconstructed raised fields are located in the left center of the photograph (May 1986).





5 Excavations in habitation mounds provided an excellent context for documenting the lifeways of prehistoric farmers. The archaeological crew is exposing a floor and foundation of a house of the Pucara culture at the site of Pancha. 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 ascertained through stratigraphic analysis alone. Carbonized remains for radiocarbon dating were not present in raised fields, but six pottery samples recovered from stratigraphic contexts in both 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 Huatta. 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 information 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 midden and mound 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 making mats, nets, and bags, as thatching material, or as forage for domestic animals. Fish, camelids (probably the domesticated alpaca and llama), guinea pig, and various aquatic birds are represented in abundant 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 lake resources. The recovery of thousands of basalt hoe fragments, polished through years of use, attests to 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, incision, and painting. One nearly complete house structure belonging to the Pucara culture (300 B.C.-A.D. 400) was 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 villages were settled throughout the lake area by 1000 B.C. By 300 B.C., Lake Titicaca society had evolved sufficiently to support large ceremonial and population centers. The site of Pucara in the northern lake basin has approximately 4² km of urban sprawl, complete with pyramidal platforms and temples with semi-subter-

anean courtyards (see K. Chávez, this issue). Tiahuanaco (A.D. 300-1000), one of the most impressive 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 missionization (Browman 1978). 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. 1450. Earlier hypotheses suggested 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. 1968; Kolata 1986).



6 (above) Members of the Community of Segunda Collana using footplows to cut sod blocks from old canals for the retaining walls for rebuilding the raised field platforms in Viscachani Pampa, Huatta (October 1985).

7 (right) Cañihua on raised fields in Sangachi, Huatta (April 1985). All the traditional Andean crops grew well on the experimental raised fields, in addition to introduced crops such as winter wheat, barley, and garden vegetables.

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 agriculture was well established several centuries earlier. As Pucara's power as a ceremonial center was usurped 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 Aymara 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 and 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 tectonic 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 area. 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 zones 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, 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, nor do the earliest phases of field construction and use appear to have been planned and directed by a centralized authority. This technology may have been one of the earliest forms of intensive agriculture, a logical outgrowth of early fishing, gathering, and hunting settled life based on the exploitation of rich lake resources. This subsistence strategy permitted a dense population of wetland-oriented peoples to maintain sedentary lives.



8
Mature potatoes on raised fields in the Community of Segunda Collana in Viscachani Pampa, Huatta. Platforms and canals are approximately 10 m wide each (February 1985). The canals, originally between 1.0-1.5 m deep, accumulate rich organic silts and aquatic vegetation that can be periodically used on raised fields for sustained 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 experimental fields were constructed to these specifications by local Quechua farmers using traditional agricultural implements available in all households (foot-plow, hoe, clodbreaker, shovel, and pick). The 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 three people; two used footplows to cut blocks of sod from the old canals between the ridges (Fig. 6), while the third tossed the sod 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 crops planted, potatoes, quinoa, and cañihua (Fig. 7) produced the greatest yields. Potato production during five years of experimentation was between 8 and 16 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 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 muck.

The value of raised fields in the cold Lake Titicaca Basin was dramatically demonstrated during a severe local frost in 1982. 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 micro-topography 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 increase in temperatures is only slight, our experience indicates that it was enough and that it may have been very important in minimizing the risks due to frosts for the prehistoric farmers of the zone, both lessening crop damage during the growing season and actually extending the season.

Simple cultivation on the floating islands as practiced today by the Uru of the Bay of Puno would have been a preadaptation to raised field agriculture, which was later expanded to include lake and river edge cultivation. Population appears to have grown along with agricultural expansion. Labor figures calculated from the experimental raised fields indicate that construction was not necessarily labor intensive, especially if fields were built and used over many generations. Field maintenance was found to be minimal in the experiments, but may increase after several years of cultivation. If fields can be continually used, with fertility maintained through the periodic application of decomposed organic matter from the canals, the initial labor investment for field construction is offset by the long-term benefits of continuous fertility combined with a high yield.

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 region have failed and in some cases we can determine why. For instance, certain projects have attempted to introduce capital-intensive agriculture that depends primarily on petro-chemical fertilizers, heavy farm machinery, imported seed, irrigation pumps, or special animal forage, none of which the small-scale farmer can afford. 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, food 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 is through what is referred to as "appropriate tech-



9
Community lands are cultivated today by representatives from each family household, an old Andean pattern of communal labor. Here, the final construction of a large raised field platform of the Community of Yasin in Chojñocoto, Huatta. Loose soil is tossed on the field using carrying cloths to create a convex surface over the sod blocks which make up the fill (September 1985).

nology." This approach stresses the use of traditional forms of technology and ecologically sound modern forms that are not capital intensive. In the Andes, there is a large work force available, but little capital. Since communal work forces are the traditional form of labor organization, an appropriate technology that is more easily adopted by peasant communities would involve cooperative labor (Fig. 9). Besides increasing productivity of land now under cultivation, time-tested agricultural systems such as raised fields could be used in areas that are not currently farmed, such as on the vast pampa of the Lake Titicaca Basin.

In order to make the information collected through our archaeological and agronomic studies available as appropriate technology to the present-day Quechua and Aymara farmers of the area, a small-scale development project, the Raised Field Agricultural Project, began in 1982. We formed a multidisciplinary team, combining archaeology, cultural anthropology, agronomy, and agricultural communications

that worked directly with indigenous farmers for over five years to rehabilitate the raised field system. Working with the small farmers of communities in Huatta and Coata (Fig. 10), 10 hectares of raised fields that had been abandoned or underutilized for centuries were put back into use on communal lands. The Project, in cooperation with the Swiss government and the Peruvian Ministry of Agriculture, designed and prepared an intensive video training program in Quechua, in addition to written textbook materials, to rapidly disseminate the ancient technology.

Our applied archaeological program has finally begun to have an impact. In 1986-87, Ignacio Garaycochea, an agronomist who conducted many of the experiments, directed a government-sponsored project in collaboration with 10 Quechua communities. In our recent 1989 evaluation, we calculate that 100 hectares are now in production. A measure of the success of this project is that many individual farmers have begun to build raised fields on their own private land.



10
Quechua farmers of Yasin, Huatta, holding traditional Andean tools: the rawkana or hoe (woman second from left in front row), the waqtana or clod breaker (woman at right end of first row), and the chakitaqlla or footplow (men in back row). After several years of successful harvests, many community groups and individual families in the region collaborated with the project, donating the use of communal land and their labor in return for potato seed and the subsequent harvest from the experimental fields (October 1982).

Not only can the Quechua- and Aymara-speaking peoples take great pride in the sophisticated agricultural technology of their ancestors, but they can actually apply it to solve some of the contemporary economic and agricultural problems of Peru and Bolivia. The farmers of the communities participating in rehabilitating raised fields are taking that step. The high productivity of raised field technology not only helps to support the growing populations of the towns and cities of the region where many small farmers have had to migrate in search of a livelihood, but also helps us to understand and preserve this technology for the future. It is ironic that such an immensely important and productive technology is being destroyed in many areas around Lake Titicaca by modern plow farming, urbanization, and road-building. **2**

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In addition to the applied research on raised field agriculture in the Lake Titicaca Region (1981-1986) as part of a doctoral dissertation project (University of Illinois, Champaign-Urbana), **Clark L. Erickson** has been involved in a number of archaeological projects in Peru, Bolivia, and Ecuador. He has conducted surveys in the western montaña of Ecuador (1979) and the savannas and tropical



forests of the Llanos de Mojos of the eastern Bolivia (1978). His deep interest in Andean archaeology began with participation as an archaeological assistant and archaeobotanist for Bolivian Institute of Archaeology-Washington University excavations at the site of Chiripa, on the Bolivian shores of Lake Titicaca (1974-1975). He is currently Assistant Curator in the American Section of The University Museum and Assistant Professor in the Department of Anthropology at the University of Pennsylvania.