

Browder, John O.
1989 **FRAGILE LANDS OF LATIN AMERICA: STRATEGIES FOR SUSTAINABLE DEVELOPMENT.** Westview Press, Boulder, Co.

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Raised Fields and Sustainable Agriculture in the Lake Titicaca Basin of Peru

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Introduction

Many non-western traditional agricultural systems have been proven to be highly productive, ecologically sound, and sustainable (Altieri 1983; Denevan 1980; Wilken 1987). Although they supported hundreds of generations of farmers, many of these systems have not survived into historic times (Denevan 1970, 1983; Turner and Harrison 1983). While most of the surviving systems continue because of their resilience and ecological stability, many others have or are in the process of disappearing in the face of major social, economic, and political changes occurring in developing countries (Altieri 1983; Denevan 1980; Wilken 1987).

The reconstruction of raised fields in the Lake Titicaca Basin illustrates the role archaeology can play in developing alternative technologies. Because raised field agriculture was completely abandoned in the Andes, archaeological methods provide the only means to understand the history of the system and to develop models for its proper rehabilitation. Excavation indicates that the prehistoric abandonment of the raised fields was due to socio-political changes rather than environmental limitations or change. This implies that, with proper consideration of the contemporary socio-economic context and the ecologically sound prehistoric models, raised field agriculture has productive potential for the future of development in the Lake Titicaca Basin (Erickson 1988; Candler and Erickson 1987).

This paper presents a summary of the results from 5 years of raised field reconstruction by the Proyecto Agrícola de los Campos Elevados, in conjunction with the 5 Quechua communities in and around the District of Huatta, Peru (Figure 1). Raised fields are a highly productive

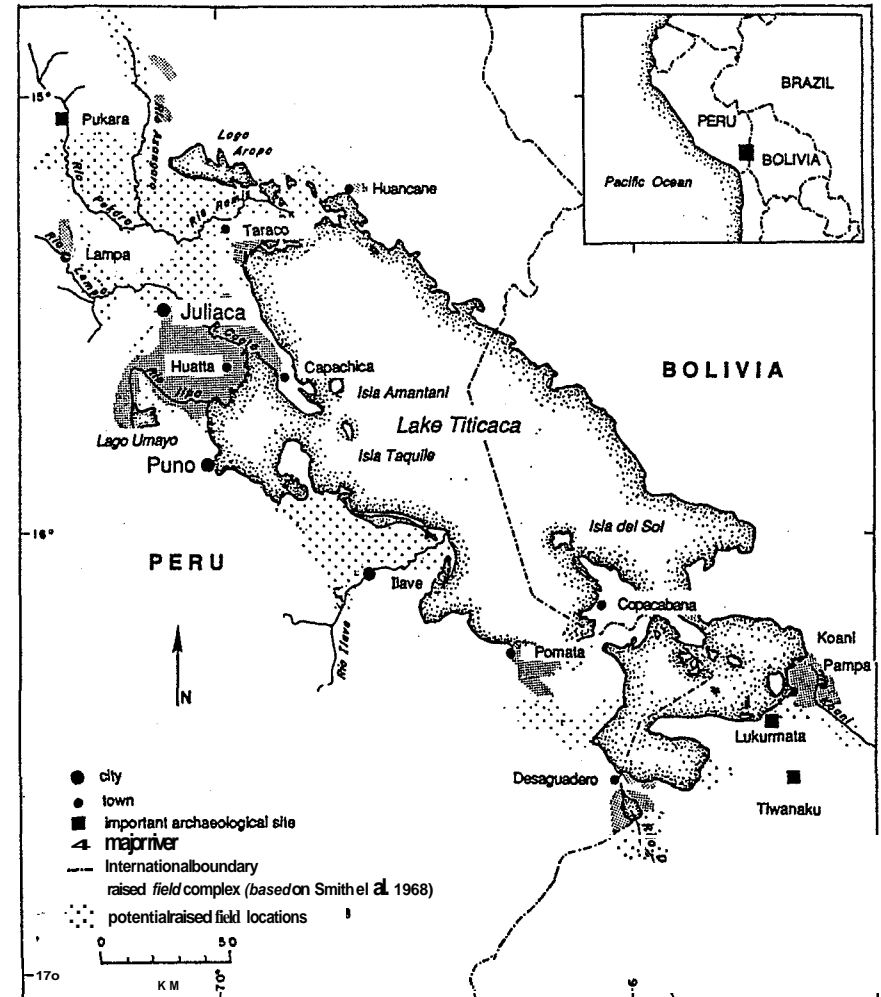


Figure 1 Map showing the location of prehistoric raised fields (based on Smith et al., 1968) and areas potentially cultivated by raised field farming.

alternative to the various capital intensive agricultural schemes being introduced by development agencies in the area. Raised field agriculture is compared to a government-sponsored irrigation project that would destroy the remains of thousands of potentially recuperable raised fields.

The Agro-Environment of the Lake Titicaca Basin

The Lake Titicaca Basin, located about 3800 meters above sea level, is a difficult environment for agriculture because of irregular rainfall,

poor and degraded soils, and frequent and severe frost during the short growing season (Erickson 1988). Prehispanic farmers developed sophisticated methods to overcome these limitations, including diverse and well-adapted crops, highly efficient agricultural tools, and intensive agricultural systems such as terraces (andenes), sunken gardens (go-chas), and raised fields (campos elevados, camellones, or waru waru) (Donkin 1979; Erickson 1987, 1988; Flores and Paz 1987; Garaycochea 1987; Kolata 1986; Lennon 1982; Marion et al. 1982; Smith et al. 1968; Torre and Burga 1986). In addition to agricultural technology, complex social mechanisms were developed to minimize risk and land degradation by dictating sectorial fallow and crop rotation and to efficiently organize labor.

Today, the descendants of these farmers employ an impoverished agricultural technology. Land in Huatta is roughly categorized as one of two types: cerro (hillslope) or pampa (lacustrine and riverine plain). The cerro lands continue to be cultivated intensively, but without the benefit of the sectorial fallow system (which was discontinued in living memory), and with very reduced benefit from the ancient terrace and erosion control systems on the slopes. These structures have generally fallen into a state of disrepair, and some have been dismantled to permit cultivation of larger contiguous areas and to facilitate the use of yoked oxen.

The eroded remains of raised fields in the pampa are essentially ignored. As the pampa lands are more vulnerable to climatic extremes (especially flood and frost), they have been cultivated only in a very desultory manner, with little expectation of profit. The major economic use of the pampa is for pasture land; although the indigenous grasses are not especially nutritious for the introduced species of domesticated ruminants (sheep and cattle), there is, at the present time, little alternative.

The Altiplano as a Fragile Environment

The landscape of Huatta, as in most of the low-lying parts of the Lake Titicaca Basin, can be seen as two poorly-articulated parts (the cerro and the pampa) in a single system of economic exploitation. The hillslope is essentially vulnerable to soil impoverishment through over-cropping and erosion; unfortunately the present-day economic patterns accelerate rather than reduce this vulnerability. While the pampa lands themselves cannot be considered "fragile" to the same degree as the hillslopes, in that they are not subject to ecological degradation, their under-utilization in the present-day economic system has contributed to the degradation of the cerro, and therefore to the system as a whole.

While the disruption of the sectorial fallow system and the decay of the erosion control systems on the cerro have led to reduced fertility, the erosion of the raised fields has not caused a similar deterioration in pampa ecology. However, when these remains are viewed as a part of the system's potential resources for agricultural production, the active destruction of raised fields poses a dilemma. Some 15,000 hectares of raised fields have been destroyed in the Huatta pampa area alone (Garaycochea 1983). It is ironic when raised field remains are destroyed as a result of projects intended to increase agricultural production in the altiplano.

Two examples merit discussion. The first is "Irrigación Buena Vista y Ilpa," sponsored by USAID and the Corporation of Puno to develop much of the raised field-covered zone (ONERN-CORPUNO 1984: 118-120). This project would construct an earthen dam (4 meters tall and 1.1 kilometers long) upstream on the Rio Ilpa near Lago Umayo that would control a large reserve of water (110 million cubic meters) and, theoretically at least, prevent flooding of the pampa during the wet season. This water would also be used to irrigate the pampa when necessary, and a proposed network of canals (covering approximately 800 hectares for Buena Vista and 5,000 hectares for Ilpa) would permit the mechanized cultivation of improved pasture crops. Much of the expensive infrastructure, including the dam earthworks, has already been constructed. However, the project has not yet been fully implemented because of conflicts among the communities in the areas it encompasses. Ironically, the project area is covered by well-preserved raised fields with a network of sophisticated pre-Columbian water-management structures (Lennon 1982; Erickson 1988). If the project continues, these ancient raised fields will be leveled or inundated by the reservoir. If the new capital-intensive system works at all, it will probably benefit only the government cooperative and the experimental agricultural station.

A second government project, directed by the National Agrarian University, plans to test a design based on blocks of raised platforms with encircling ditches developed by their engineers. Altiplano farmers will then be encouraged to adopt this technology. These modern engineers recognize the advantages of the technology for minimizing the effects of flood and frost, but are apparently unaware that a similar solution was discovered in prehistoric times. The new earthen structures will be constructed with heavy machinery. These modern fields will, at great capital expense, destroy the ancient raised field system and replace it with a technology that is beyond the means of the average farmer. In the sense that raised field remains are becoming increasingly vulnerable to eradication by Western technology, they may be consid-

ered "endangered landforms," important resources to preserve and rehabilitate.

Raised Field Agriculture: Definitions and Functions

Raised fields are defined as "any prepared land involving the transfer and elevation of earth in order to improve cultivating conditions" (Denevan and Turner 1974:24). Raised field agriculture has been documented in many areas of the Americas, and appears to have provided an important economic base for New World civilizations (Darch 1983; Denevan et al. 1987; Denevan 1970, 1983; Farrington 1985; Harrison and Turner 1978).

Remains of raised fields are found throughout the vast lake and river plains or *pampa* of the Lake Titicaca Basin; some 82,000 hectares of raised fields have been observed in aerial photographs and limited ground survey (Smith et al. 1968), but it is believed that their original extent was actually much larger, possibly double that figure (Erickson 1988). The largest continuous block of raised fields in the basin (56,000 hectares) lies in the Huatta area, where our archaeological and experimental research was conducted.

Although the raised fields of Huatta were abandoned, we have been able to document many technological details and functions of raised fields, in addition to the crops cultivated (Erickson 1985, 1986, 1988; Garaycochea 1986a, 1986b, 1987; Denevan and Turner 1974). These functions are summarized as:

The Concentration, Production, and Recycling of Soil Nutrients. The construction of raised fields doubles topsoil thickness on the planting surface, while the canals produce "green maure" in the form of rapidly-growing aquatic plants, and organic matter and other nutrients produced by the decomposition of animals. The canals also act as sediment traps for the recapture of topsoil eroding from the platforms and also from the nearby hilltops.

Improvement of Crop Microclimates. We have demonstrated that raised fields improve microclimates by slightly raising ambient temperature during radiation frost episodes. This is effected through the effective capture and nocturnal release of solar energy in canal water.

Water Control and Conservation. The canals can be used either to provide drainage or to conserve water, depending upon hydraulic needs.

Minor Functions. Raised field canals could also be used for aquaculture and pisciculture, serve as barriers to crop pests and grazing animals, and provide routes of transportation and communication.

The major functions of raised fields are exactly tailored to overcome the limitations to agriculture in the lake basin. Soil depletion, which

has become critical on the over-cultivated hillslopes, is not a problem in functioning raised fields. At the same time, the effects of climatic extremes on rainfall and temperature are ameliorated by the raised fields' morphology.

Applied Archaeology in Huatta: 1981-1986

Raised field experiments were conducted between 1981 and 1986. Eroded raised fields were reconstructed according to models developed from archaeological excavations in prehistoric raised fields (Erickson 1985, 1986, 1987, 1988; Garaycochea 1987). The first plots were built on privately owned land. In 1982 the project expanded to include the reconstruction of raised fields by local members of farmer organizations of Huatta on their communal lands. By the end of 1986, about 30 hectares of raised fields had been reconstructed in 10 different communities. In Huatta alone, over 500 families were involved. A large part of the success of the project was due to community participation and the development of effective teaching materials and a video program (Brinkmeier 1985; Candler and Erickson 1987; Garaycochea 1987: pers. com.). After 1986, the raised field project was subsumed under a Peruvian government program, and since then has been expanded to include over 30 *altiplano* communities where an estimated 50 hectares of raised fields have been rehabilitated (Garaycochea 1987: pers. com.).

Field Reconstruction

Construction began with measuring the surface of the ancient field remains to determine the proper spacing of canals and raised field platforms. A ratio of 1:1 was usually maintained between the widths of the reconstructed platforms and canals. The borders between the canals and platforms were then marked to guide the construction. The *chakitaqlla* (Andean footplow) was used to cut sod blocks (rich in organic matter) from the canals, first for rebuilding retaining walls along the platform edges, and then for the fill of the field. The elevation of the reconstructed raised fields varied between 20 and 50 cm. The final height of the platforms depended upon both the depth of good agricultural soil in the canal (excavation generally stopped when a hard clayey horizon was encountered) and the local farmers' estimates of how high the water level rises during a typical growing season.

Our approach was oriented to the technology currently employed by the local farmers; we used common implements such as *chakitaqllas*, *waqtanas*, ("clod buster"), *rawkanas* (indigenous hoe), picks, and shovels rather than attempting to promote mechanization of raised fields. The

altiplano has an over-abundance of available labor, and the maintenance and capital needed for mechanization is not presently available to most small farmers. It would be theoretically possible to mechanize certain aspects of raised field farming, particularly the initial construction of fields, but this is not practical given the present socio-economic context of the small farmer in the *altiplano* (Plates 1-4).

Social Organization of Labor and Land

Labor for raised field reconstruction was organized at the individual family, multifamily, and communal levels. Several individual families constructed raised fields on their privately-held plots of land. Labor for these fields was generally provided by the nuclear family or an extended family group. Small blocks of fields were easily constructed using this form of labor organization.

Most of the raised fields were constructed through communal labor on community-owned land. Huatta is currently organized into 4 *parcialidades*, or semi-independent communities, based loosely on the traditional Andean *ayllu* (a localized landholding group, whose members are generally related by common descent). It already has been observed that, in living memory, a sectorial system of cultivation was followed on the *cerro*. Although the actual plots were privately held, their cultivation was communally controlled. It also has been mentioned that the land in the *pampa* has been used primarily for grazing animals, with only occasional cultivation. In this context, some developments of recent years have been highly significant. Under pressure of legal suits brought by the community, and threatened by "restructuring" (in effect, dissolution), the government cooperative (Sociedad Anónima de Interés Social [SAIS] Buenavista) which controls most of the *pampa* surrounding Huatta has released various plots of *pampa* land to the District of Huatta. This land was then distributed among the four *parcialidades*, as there is no mechanism for the distribution of land among private individuals. Some of these land "donations" have been outright concessions, while others have been temporary "loans," with somewhat vague terms of usufruct. Most of the *parcialidades* consider it politically expedient to demonstrate that they are making more productive use of the land than the SAIS Buenavista did. In effect, this means that they must make an attempt to cultivate these *pampa* lands (Candler and Erickson 1987). Therefore, when research began in 1981, sizable blocks of *pampa* land covered with raised field remains were controlled by communal organizations. Moreover these organizations wanted to cultivate the *pampa* lands as a political expedient, whether or not it would be economically rewarding. While previously



Plate 1 Manual reconstruction of raised fields using the *chakitaqlla*, or Andean footplow, to cut and remove organic-rich sod blocks from sediment-filled canals. Chojnocoto, Huatta, Peru, November 1986.



Plate 2 Final construction and leveling of the raised field planting platform. Chojnocoto, Huatta, Peru, November 1985.

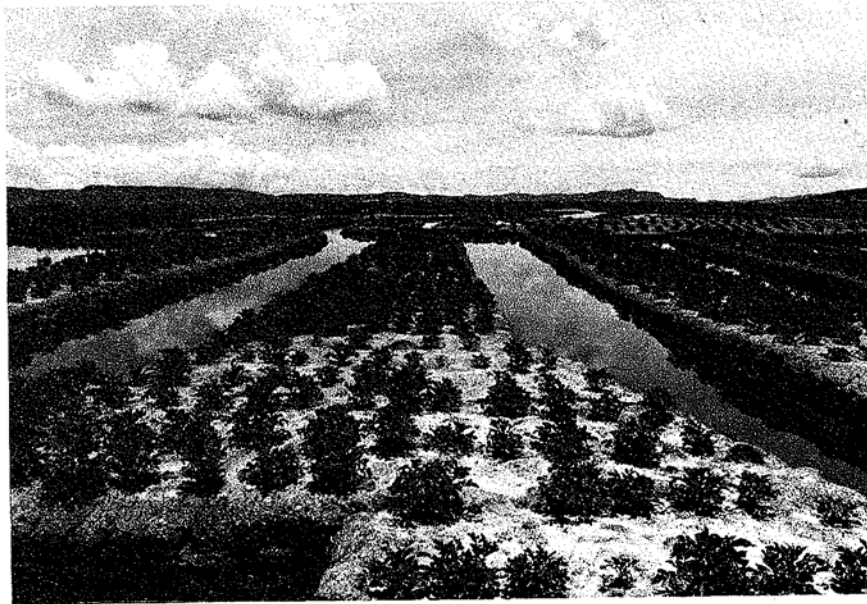


Plate 3 Young potato plants on raised fields at Viscachani Pampa. Community of Segunda Collana, Huatta, Peru, January 1986.



Plate 4 Mature potato plants on raised fields at Viscachani Pampa during the end of the rainy season, February 1986.

Table 1
Comparative Labor Calculations for Raised Field construction^a

| Example | Depth of Fill (cm) | Area of Platform Constructed (m ²) | Fill for ha r.f. & Canal (m ³) | Rate of Construction (m ³ /person/day) | ha r.f. & Canal (person-days/ha) |
|---------------|--------------------|--|--|---|----------------------------------|
| Erickson b | 20 | 1,943 | 1,000 | 50 | 200 |
| Garaycochea C | 20 | 642 | 1,000 | 40 | 250 |
| Garaycochea d | 20 | 1,351 | 1,000 | 32 | 310 |
| Garaycochea e | 20 | 66,801 | 1,000 | 1.3 | 786 |
| Ramos 1 | 24 | 8,613 | 1,752 | 1.9 | 900 |
| Denevan g | 20 | na | 1,000 | 26 | 769 |

^a One day = 5 hours.

^b Based on Erickson (1985).

^c Based on Garaycochea (1986a, 1987b).

^d Based on Garaycochea (1986b), converted to a 5-hour day.

^e Based on Garaycochea (1987b).

^f Based on Ramos (1986b).

^g Based on Denevan (1982).

there were some communal structures associated with cultivation of *cerro* lands, there was not a tradition of *pampa* cultivation at all, much less communal cultivation on the *pampa*. Fortunately for our project, the situation described above which motivated the *parcialidades* to become involved in communal cultivation of *pampa* lands also engendered a lively interest in raised field reconstruction.

Labor Requirements of Raised Field Agriculture

The person-hours necessary to reconstruct and maintain raised fields were recorded during several events between 1981 and 1986 (Erickson 1986, 1988; Garaycochea 1986a, 1986b, 1987b). Table 1 summarizes the labor figures derived from these data. The labor used in the initial construction of the raised fields was highly variable, from 200 to 1,000 person-days/ha (Andean "day" = 5 hours) (Erickson 1988). It is estimated that the initial construction, rebuilding every ten years, and annual planting, weeding, harvest, and maintenance of raised fields planted in potatoes requires 270 person-days/ha/year (see Table 2).

Production of Raised Field Agriculture

The reconstructed raised fields produced impressive harvests. In 1981–1982, the average potato yield on the initial test plots was 8

Table 2
Estimated Annual Labor Costs for Raised-Field Activities

| Activity | Person-Days/ha/year Raised Fields and Canals |
|--|---|
| Preparation of soil ^a | 20 |
| seeding ^b | 50 |
| Aporque (potato banking) ^c | 100 (twice/yr) |
| Irrigation | |
| normal year ^d | 0 |
| short drought | 20 (4 splash irrigation) |
| long drought | 100 (once/week for 5 months) |
| Harvest ^e | 100 (potatoes) |
| Total (minus irrigation) | 270 |

- a** Preparation of the soil is not necessary following tuber harvest and is minimal after the harvest of grains. If the raised fields were rebuilt every 10 years (which is probably excessive), the annual labor costs would be 20 person-days/yr (based on 200 person-days/10 yrs for original construction or rebuilding). Fields with year-round water-filled canals would be "mucked," a more laborious procedure. These cases would be rare since most canals dry out periodically during the dry season or during droughts.
- b** This figure is based on planting potato seed and other tubers. Much less time would be needed for most other crops.
- c** The figures for **aporque** are based on potatoes and other tubers. Traditionally in Huatta, other crops are banked only in exceptionally wet years. **Aporque** also incorporates weeding.
- d** Irrigation is relatively easy to do because of the close proximity of the water to the field surfaces. General "splash" irrigation was 4 times faster than bucket irrigation of individual plants (5 person-days/ha vs. 20 person-days/ha).
- e** This figure depends upon the amount to be harvested. The figure presented is based on a year of excellent harvest.

metric tons/ha (Erickson 1986).¹ Potato production on larger field blocks was measured during 1983–1986. Data from these years indicate a sustained yield of 8–14 metric tons/ha/year, with an average of 10 metric tons/ha (Garaycochea 1987; Erickson 1988). These figures contrast favorably with the average production of 1–4 metric tons/ha in the Department of Puno (Erickson 1988; Garaycochea 1986b), which is somewhat lower than the Peruvian national average of 5.3 metric tons/ha (Christiansen 1967). Potato production rates on raised field experiments conducted in Asillo, north of Lake Titicaca, are similar to those we calculate for Huatta (Ramos 1986a).

It is to be expected that raised fields constructed on "virgin" or long-fallowed soils would produce high yields the first year. However, our plots also demonstrated sustainable yields; some plots have been

continuously cultivated for 6 years without a decline in production (Erickson 1988). As field block size increases, we predict that yields will also increase, due to the improved micro-climate and reduced "edge effects." In addition, some fields produced higher yields in the second to fourth years, possibly because of the increased availability of nutrients formed by the decay of "green manure." Increased yields are also expected after certain crops become adapted to the conditions of the raised fields, as the well-adapted genetic material that would certainly have developed during prehistoric times has, since then, disappeared.

The potential carrying capacity of raised field agriculture is 37.5 persons per hectare (Erickson 1988). Using Denevan's (1982) conservative figures for the extent of prehistoric remains of raised fields, and the assumption that 100% of them are in use (which is highly unlikely), 1.5 million people could be supported in the Lake Titicaca Basin (Erickson 1988). Because of the complexity of the variables affecting the flow of water through the system—ultimately dependent on the highly irregular seasonal rainfall in the Lake Titicaca watershed—it is impossible, at present, to determine a likely percentage of the total field area which could, theoretically, be productive in any one year. However, this figure gains meaning when it is compared to the present population of the Department of Puno, which is 890,000. This is even more provocative in light of the surprising fact that during most of the early 1980s Puno actually had to import potatoes from other parts of Peru and overseas.

The Success of Raised Field Agriculture: Will It Be Adopted?

Andean farmers of the Lake Titicaca region are, like many farmers, very conservative; they do not readily adopt new techniques (although they may experiment, on a small scale, with surplus time and seed). Raised fields are adaptable in that farmers have been able to maintain traditional crops, tools, and social organization against the onslaught of introduced western technology, which is very often economically and socially unsound for the *altiplano*, no matter how well-intended. The unsuitability of numerous recent development projects (introduction of rapeseed, expensive mechanized irrigation projects, and capital-intensive mechanized agriculture) was not recognized until after attempts to introduce them in the *altiplano*. The traditional farmers' reluctance to adopt unproven techniques has insulated them against development fiascos.

Raised field technology, although an ancient indigenous technique, had been completely forgotten; thus, it is a new technology to the present-day farmers. Because of its simplicity and efficiency, raised field agriculture is relatively easy to teach. Both informal and formal means of communication were used to spread information about raised field agriculture between 1981 and 1986 (Brinkmeier 1985; Erickson et al. 1986). One of the most significant aspects of the project was that the farmers themselves collaborated in developing and adapting this ancient technology for their present-day use. While the archaeologist suggested guidelines based on his research, it was the farmers themselves who, from experience and experimentation on their own, refined the construction techniques and developed new approaches. This process generated an active interest in the raised field experiments, while at the same time, it produced a technology especially suited to the present local, social, and economic environments. As a result, some 30 communities were practicing raised field agriculture by early 1987 (Ignacio Garaycocha 1987: pers. com.)

Many political parties within Peru maintain development agencies, and they recently have begun to promote raised field agriculture in the Lake Titicaca region. Political groups see the introduction of raised fields as an inexpensive means of raising the standard of living, and thereby minimizing potential social discontent. The revitalization of traditional agriculture has been a goal of APRA, the political party presently in power, and several programs have proceeded with limited success. Many of these efforts are genuine, but fail because the technology is promoted without consideration of the existing socio-economic context of the Andean communities, as was the case in the Colca Valley (Treacy 1987, and this volume). Leftist groups commonly associate Andean "tradition" with communal "socialist" organization and land control, and their conceptions of the prehispanic Inca and Qolla States are often highly romanticized and idealized.

Possible Limitations to Raised Field Agriculture

We encountered some factors that may limit the use of raised field agriculture in the Lake Titicaca Basin. The most serious hindrance in many communities is the lack of large blocks of suitable land under the control of communal organizations. A solution to this problem was suggested by farmers in Coata, where individual families collaborate in farming contiguous private fields, with reciprocal labor exchanges in the traditional patterns of ayni and minka.³

Although we worked primarily with the parcialidad organizations in Huatta, we also worked with a few private groups, and noticed that

there are some social mechanisms which can be used to coordinate group labor on private land (e.g. ayni and minka). Also, the "fictive kin" relationships (compadrazco) are often associated with economic partnerships which can include agricultural collaboration.

While the availability of communal labor and land permitted the rapid construction of large blocks of raised fields in Huatta, other communities around the lake lack these advantages. The diffusion and implementation of raised field agriculture in these communities would be much more difficult, but we believe that, once the advantages of the technology have been clearly demonstrated, Andean communities will be able to find ways to overcome these obstacles. While we can imagine some solutions to these problems, we feel that it would be important for each community to work out its own solution. The foreign researcher may be able to provide some suggestions and alternatives, but cannot dictate changes in social organization and land tenure to conform to technology.

A minor obstacle to raised field agriculture is the grazing of animals on the pampa and in harvested fields. We found that this was generally incompatible with raised field farming since sheep, pigs, and cows can easily destroy the raised fields if allowed to graze and root freely. More stringent control of the animals is necessary, either by caretakers of the fields (some groups selected raised field sites close to a member's house compound for this purpose) or by the shepherds. The cultivation of raised fields also reduces the amount of pasture land. The systematic harvest of aquatic plants in the canals, and the intensive production of forage crops on the platforms could be used to support confined animals. The carrying capacity of the native vegetation on the pampa is low, only approximately one sheep/ha. In contrast, an average of 10 metric tons of potatoes (which would feed 18.7 people for one year) can be produced on the same amount of land using raised fields. Forage crops such as winter wheat, oats, and barley also have been successfully grown on raised fields and could be used to support a large number of domestic animals (Erickson 1988). Cattle are often kept in corrals where they are given aquatic vegetation in areas near the lakeshore. As the pampa lands become more valuable for cultivation than for pasture this arrangement will probably become more widespread.

Potential Application: Raised Fields vs. Western Capital-Based Agriculture

The advantages of raised field agriculture over the modern introduced technologies promoted by the various development agencies have been demonstrated in the Andean highlands. "High tech" agricultural proj-

ects, such as those introduced by the Canadians (rapeseed) and New Zealanders (improved pasture crops and genetically improved sheep stock) in the 1970s and early 1980s failed because of their incompatibility with both the harsh physical environment of the *altiplano* and the limitations imposed by the existing socio-economic context. The capital invested by the SAIS Buenavista and local communities in these projects was lost. In contrast, the suitability of raised field agriculture to the environment of the lake basin was demonstrated in 1986 at the government experimental agricultural station of Illpa. Hundreds of hectares of mechanically prepared fields of winter wheat, improved seed potatoes, and other experimental crops were destroyed by floods, while the 2 hectares of experimental raised fields adjacent to them remained unaffected and produced a bumper crop.

Can raised field technology developed in the *altiplano* be successfully applied in other zones? Denevan (1982:190 Table 1) estimates a total area of 2,500 square kilometers of reported prehistoric raised fields in Latin America (excluding the Llanos de Mojos in Bolivia and the Basin of Mexico, where the total area of raised fields has not been accurately determined, but is expected to be quite extensive). Much of the vast *altiplano* of western Bolivia south of Lake Titicaca is either permanent wetland or seasonally inundated, especially the areas around Lake Poopo and along the Rio Desaguadero. Very little of these lands are currently under cultivation, although raised field remains indicate their past productivity. It is also possible that this technology could be introduced in seasonally and permanently waterlogged areas around other highland lakes, rivers, and springs where the remains of raised fields have not been found.

The most extensive raised field remains are located in the vast tropical lowlands of Latin America; over 150 square kilometers of raised field surfaces have been documented for the Llanos de Mojos in Bolivia (Denevan 1970, 1982) and experimental raised fields have proven successful in the lowlands of Veracruz and Tabasco of Mexico (Gomez-Pompa et al. 1982). Much of the knowledge and experience gained from the reconstruction of raised fields in the Lake Titicaca Basin could be useful in developing raised field agriculture in the tropical lowlands. Because of the social, economic, political, agronomic, and environmental differences between the Lake Titicaca Basin and these other areas, detailed multidisciplinary investigations will be necessary before the raised field technology could be implemented on a large scale. Our experience indicates that small-scale experimental and demonstration plots, which draw the interest and active participation of the local community, are the most effective way to initiate such development.

Conclusion: Andean Agriculture of the Past for the Future

The Lake Titicaca Basin is a difficult agro-environment for present-day farmers. The current agricultural systems practiced by both small and large scale farmers under-utilizes the vast *pampa* lands and hastens the destruction of the fragile *cerro* lands. Centuries of poor farming practices have depleted the soil fertility, caused massive topsoil erosion, and denuded slopes of natural vegetation. Poor land management, in addition to other social, economic, and political factors, has severely reduced the carrying capacity of the land, promoting massive migration to coastal urban centers, and continuing the cycle of poverty in the *altiplano*.

In contrast, the widespread remains of prehistoric intensive agricultural features such as raised fields, terraces, and *gochas* document a successful adaptation to this difficult agro-environment by prehispanic peoples. Our archaeological and experimental investigation, combined with an applied project, indicates that raised field agriculture is 1) highly productive and sustainable, 2) ecologically sound in terms of both the cultivation of the *pampa* lands and as an effective means of relieving stress on the easily degraded *cerro* lands, and 3) a socio-economically appropriate technology.

The highly sustainable productivity of raised fields, in contrast to "modern" agricultural technologies presently used in the *altiplano*, could greatly improve the economic well-being of the indigenous communities. Because the raised fields are constructed on *pampa* lands currently under-utilized, raised field technology expands the agricultural frontier and permits fallowing of overused hill lands. Capital, rather than labor, is the limiting factor to agricultural expansion in most *altiplano* communities. Raised fields make efficient use of labor, and do not require capital investment. The most efficient social grouping for the construction and operation of these systems in Huatta is communal, based on traditionally defined local Andean social units (*ayllu*, *parcialidad*, or *comunidad*.) This may not be practical in other situations where historical, social, and political factors have resulted in different forms of social organization and land tenure. In these cases, the family or some other social grouping may be more appropriate.

Many development projects currently in the *altiplano* are ecologically unsound, relying on introduced crops and farming practices developed for completely different environmental zones. More importantly, these systems are socially and economically inappropriate, relying on heavy capital inputs such as mechanization, petro-chemicals, and imported seed. Even if successful, these projects would benefit only a small

portion of the local populations. Several of these projects proposed for developing the *pampa* would destroy vast areas of raised field systems. This might result in the tragic loss of the real agricultural potential of the *pampa* land which could be sustainably developed through the use of this indigenous technology.

Notes

1. All raised field production calculations include the canals, which comprise approximately 50% of the area used in the calculation. In addition, no fertilizers or insecticides were used on the raised fields, in contrast to the fields used to obtain the departmental and national averages.

2. Production along field boundaries is often less than in the interior of agricultural plots; this is called the "edge effect," and occurs regularly in raised field blocks. Although increased field area obviously increases perimeter, it reduces the proportion of edge to interior.

3. *Ayni* is a traditional form of symmetrically balanced reciprocity of labor between individuals who are equals. Labor or services performed by one individual for another are repaid in kind at a later date. *Minka* (also known as *faena*) is another form of reciprocal labor, and is usually practiced by groups larger than the family. It is asymmetrical and includes the exchange of goods (food, drink, gifts) for short-term labor or services for the benefit of an individual or the community.

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PART FOUR

A Strategy for Sustainable Agriculture on Desert Streambeds