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CLARK L. ERICKSON

12

THE LAKE TITICACA BASIN
A Precolumbian Built Landscape

Any understanding of contemporary biodiversity change in the Americas is likely to be uninformative and misleading if it employs a prehistoric baseline imbued with pristine characteristics.
—STAHL(1996:105)

The landscapes of the Americas hold a material record of a long and complex history of human transformation of the environment. As William Denevan (1992) has pointed out, "the myth of the pristine environment" has long dominated the literature on the environments of the Americas. The human impact on the land before the arrival of Europeans was so profound and at such a massive scale that it could be argued few, if any, of the environments of the Americas occupied by humans past and present could be considered natural or pristine. Humans have cut, cleared, and burned forests for agriculture and settlement, maintained savannas through annual burning, determined plant and animal species composition through direct and indirect selection, transformed hill slopes and wetlands into productive farmland, and made deserts bloom through irrigation agriculture (e.g., Denevan 1992, 2000; Treacy 1994; Stahl 1996; Balée and Posey 1989; Doolittle 1992).

One of the best examples of an anthropogenic or human-built landscape is the Lake Titicaca Basin of present-day Bolivia and Peru (figure 12.1). The high-altitude basin, located between the eastern and western Andean cordilleras, covers an area of 57,000 km^2. The area adjacent to Lake Titicaca has long been a major center of agricultural production and dense human populations and the home of several important Precolumbian civilizations. Over the past 8,000 years, the environment of the basin has been transformed into a highly patterned, artificial landscape (figure 12.2). The construction of raised fields (*waru waru, suka kollas*), stone-faced terraces (*andenes*), sunken gardens (*q'ochas*), irrigated pasture (*bofedales*), and a multitude

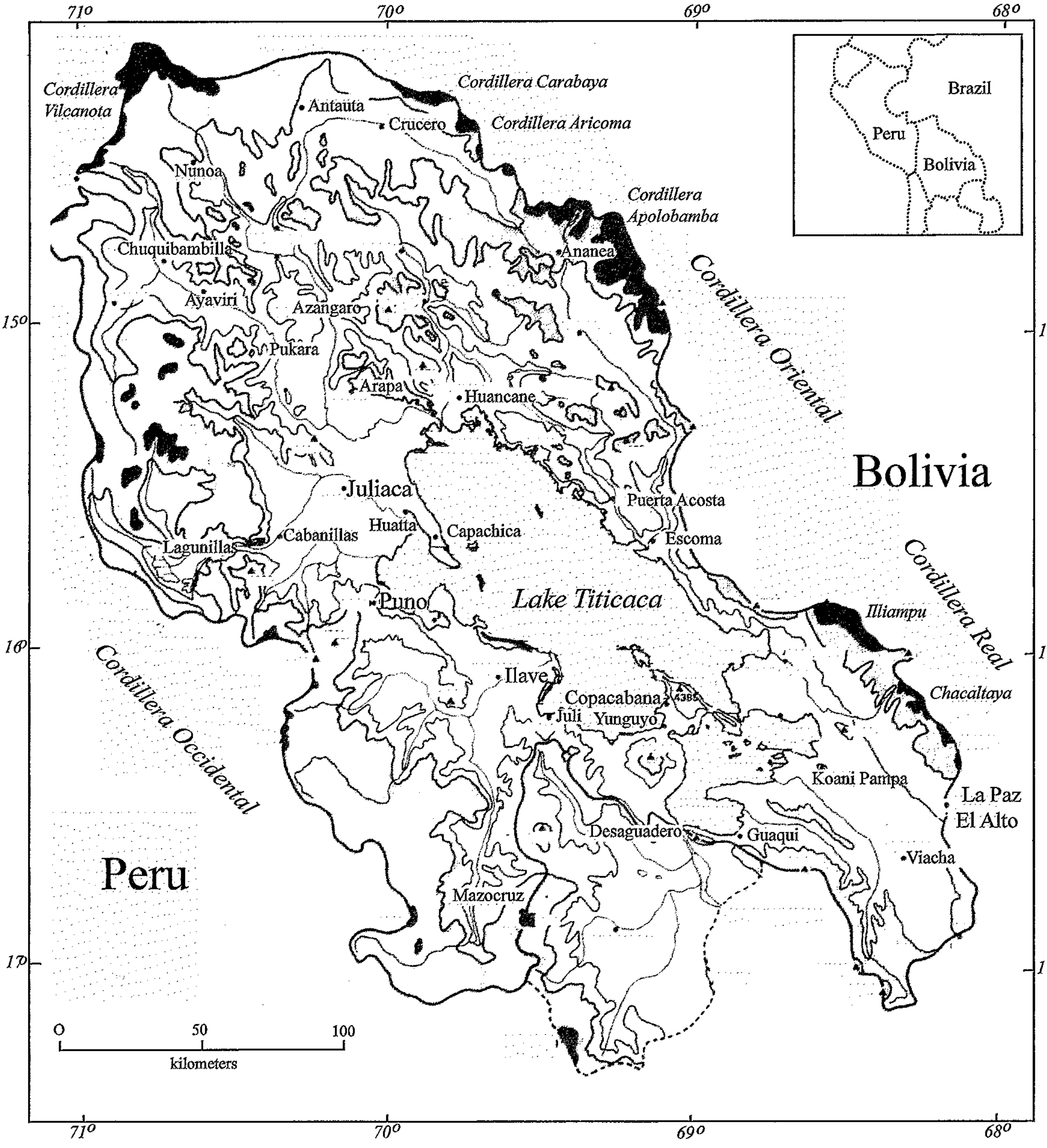


FIGURE 12.1. The Lake Titicaca Basin. The lake surface is approximately 3,810 m above sea level, and the cordilleras bordering the basin are more than 5,000 m above sea level. *Source:* After Boulange and Aquize 1981.

FIGURE 12.2. Patterned raised field landscape near Pomata, Puno, Peru. The platforms (dark linear features) are approximately 20 m wide and 30–70 m long.

of features related to the infrastructure of agriculture and settlement are essential elements of this anthropogenic landscape. Although Precolumbian states may have been responsible for some of the transformation (e.g., Kolata 1993; Stanish 1994), I believe that the majority of the cultural landscape was constructed piecemeal by rural farming peoples through their daily activities. These people, and their descendants, the Aymara and Quechua, are what Netting (1993) describes as "smallholders," farmers who practice small-scale intensive agriculture, making physical improvements to their lands, which are inherited by their descendants. The built environment represents the landscape capital of hundreds of generations of farmers and herders and reflects a rich indigenous knowledge system (Erickson 1993, 1996; Morlon 1996; Denevan 2000; Zimmerer 1996).

In this essay, I will address the issue of the long-term relationship of people and the environment of the Lake Titicaca Basin. Since the end of the Pleistocene, there is little in the landscape that could be considered natural or pristine. This is a truly anthropogenic landscape, one in which humans played a central, active role in shaping the past and present environment. I will discuss the archaeological record for this transformation in terms of a human-centric perspective.

HUMANS AND THE ANDEAN ENVIRONMENT

Our understanding of the relationship between humans and the Andean environment draws upon ecology, evolutionary ecology, cultural ecology, cultural materialism, human ecology, agroecology, geoecology, landscape ecology, political economy, foraging theory, farming systems, system theory, political ecology, and historical ecology. Although these approaches share basic theoretical assumptions about the relationship between humans and the environment, they often differ in important areas such as causality (whether they attribute conditions and change of those conditions to human or natural causes), temporal scale (whether they emphasize the short term or long term), and static-dynamics (whether they stress continuity or change). These approaches can be reduced to four broad and somewhat overlapping categories: (1) the nature-centric perspective, (2) the human adaptation perspective, (3) the environmental determinism perspective, and (4) the human-centric perspective.

THE NATURE-CENTRIC PERSPECTIVE: AN ANDES WITHOUT PEOPLE

The nature-centric perspective (geoecology, landscape ecology) treats the Andes as natural history, a given and often assumed to be constant (at least since the end of the Pleistocene). The Holdridge classification applied by Tosi (1960) to the Andean region is based on the assumption that latitude, altitude, and rainfall determine climax communities of vegetation in tropical montane environments. These "natural" communities are expected to take the form of vertically stacked ecological tiers (e.g., Tosi 1960; ONERN-CORPUNO 1965; Troll 1968; Ellenberg 1979; Dollfus 1982). Environmental change in the Holocene is generally attributed to continental and/or global climatic change (Abbott et al. 1997; Wirrmann et al. 1992; Ybert 1992). Human influence on the natural environment is downplayed or factored out in an attempt to define a "pristine," "original," or "climax" Andean environment (e.g., Seibert 1983; Ellenberg 1979). Precolumbian peoples are often characterized as having (1) had little or no impact on the environment or (2) achieved a harmonious state of equilibrium with the Andean environment through sustainable and ecologically sound agropastoral practices adapted to local conditions (usually attributed to the Inka). In the versions that accept the human factor, the environment is considered "fragile," in that humans can disrupt the mature or climax state of the natural environment (e.g., Glaser and Celecia 1981; Gomez-Molina and Little 1981; Seibert 1983). Environmental change and degradation (removal of natural vegetation through agriculture, overgrazing, fuel collection, burning, soil erosion and exhaustion, and desertification) is often attributed to Colonial policies and modern world systems (ONERN-CORPUNO 1965; Dollfus 1982; Winterhalder and Thomas 1978; Seibert 1983; Gade 1992).

HUMAN ADAPTATION PERSPECTIVE: THE CULTURE OF ECOLOGY

In the human adaptation perspective, humans "adapt to," "interact with," "impact," and "influence" the Andean natural environment (e.g., Seibert 1983; Dollfus 1982; Troll 1968; Knapp 1991; Tosi 1960; Winterhalder and Thomas 1978; Kuznar 1993; Aldenderfer 1998). Humans adapt to the Andean environment through rational and efficient practices of energy use and manage resources through verticality or ecological complementarity (field scattering, sectorial fallow systems, the ideology of reciprocity, scheduling of seasonal activities, high crop diversity, food storage technology, and land races appropriate for specific local conditions). In these functionalist and neofunctionalist interpretations, Andean cultural institutions or strategies attempt to reach a state of equilibrium or homeostasis with local environments. This approach has been incorporated into contemporary schemes for "sustainable development" and "appropriate technology" (e.g., Browder 1989; Morlon 1996). Most human adaptation studies are synchronic and ahistorical, treating the environment and cultural adaptation to it as static and given.

In the revisionist human adaptation perspective, people are given a causal and active role in shaping human-environment relations (e.g., Knapp 1991; Ellenberg 1979; Treacy 1994; Allan et al. 1988; Brush 1976). The environment is an open system capable of change. Based on systemic regularities of the physical environment and rational human decision making, the "adaptative dynamics" of humans to the environment can be predicted or retrodicted (Knapp 1991). The human adaptation perspective and its variants dominate archaeological interpretations of the Andean past.

THE NEOENVIRONMENTAL DETERMINISM PERSPECTIVE: HUMANS AT THE MERCY OF CLIMATE CHANGE

There is an increasing recognition that the environments of the southern Andes have not been stable during the Holocene (Cardich 1985; Binford et al. 1997; Abbott et al.

1997; Thompson et al. 1988; Kolata 1993, 1996; Chepstow-Lusty et al. 1998; Shimada et al. 1991). This perspective acknowledges the long-term historical dimension of human-environment relations in the Andes. Most paleoenvironmental reconstructions for the basin and surrounding regions are based on analyses of sediment and glacial cores (analysis of sediments, ice accumulation, pollen, unstable isotopes, and radiocarbon dating). Climate is assumed to fluctuate around some norm or benchmark (often averages based on historical records of lake level, precipitation, and temperature). Changes in archaeological settlement patterns, agropastoral strategies, sociopolitical organization, and environmental deterioration are causally linked to major "abnormal" climate change (mega El Niños, Little Ice Age, and "chronic droughts") (e.g., Paulsen 1976; Shimada et al. 1991; Binford et al. 1997; Kolata 1993, 1996). In this perspective, humans are passive and assumed helpless in the face of extreme environmental perturbations such as long-term droughts and floods. Anthropogenic processes are secondary to large-scale and long-term natural processes. Human activities are rarely considered as possible explanations of perturbations and discontinuities recorded in sediment and ice cores (e.g., Chepstow-Lusty et al. 1998).

THE HUMAN-CENTRIC PERSPECTIVE: THE ANTHROPOGENIC ENVIRONMENT

There is an increasing recognition that humans play an active and important role in modifying, creating, transforming, and maintaining the environments in which they live. The human-centric perspective incorporates elements of historical ecology (Crumley 1994; Balée and Posey 1989; Kirch and Hunt 1997), the archaeology of landscapes (Yarmin and Metheny 1996; Tilley 1994; Erickson n.d.), the new ecology (Botkin 1990; Stahl 1996; Zimmerer 1994), and historical geography (Denevan 1992, 2000; Siemens 1998; Zimmerer 1996). This perspective emphasizes the cultural, anthropogenic, or built environment, in this case human modification, transformation, and creation of the landscapes over the long term. The concern is to understand how and why human actors consciously and unconsciously modified and created the cultural landscape for economic, political, social, and religious purposes (Bender 1998; Tilley 1994; Deetz 1990). The patterning of landscape features (pathways, roads, causeways, monuments, walls, gardens and fields and their boundaries, astronomical and calendrical sight lines, shrines, and sacred places) is examined in terms of the "social logic" that can provide insights into indigenous structures such as measurement systems, land tenure, social organization, cosmology, calendrics, astronomy, sacred geography, cognition, and ritual practices (e.g., Miller and Gleason 1994; Aveni 1990; Erickson 1993; Siemens 1998). The perspective considers human land use at multiple spatial and geographic scales (Crumley 1994). The approach also assumes that environments are dynamic and have complex, and often chaotic, histories (Botkin 1990; Zimmerer 1994; Stahl 1996).

I adopt a human-centric perspective for my discussion of the role of Andean peoples, past and present, in creating the landscapes of the Lake Titicaca Basin. I will argue that human agency over the long term must be central to any understanding of past and present environments in the Andes. Humans did not adapt to local environments, but rather they transformed and built the landscape in which they lived. Humans have so altered the natural environment that it no longer exists and probably has not existed for thousands of years. Humans have also played an important role in maintaining and increasing biodiversity of natural resources of the basin. The long-term development of the Andean landscapes is discussed in terms of archaeological, historical, and ethnographic evidence. This record shows that rural farming peoples survived, even thrived during periods of climatic perturbation and environmental change. Much of what has been interpreted in the paleoclimate studies as climate change may in fact be anthropogenic perturbation of the regional environment.

THE NATURAL ENVIRONMENT OF THE LAKE TITICACA BASIN

What is the natural environment of the Lake Titicaca Basin? What is the undisturbed climax ecosystem for the region? What was the pristine or original environment before humans colonized and transformed the region? Is there an environmental benchmark that can be used to compare and contrast the changes imposed by humans on the landscape over time? Most discussions begin with a survey of the natural environment followed by a discussion of how humans have adapted to or adjusted to the "harsh," "hostile," or "marginal" environments of the Lake Titicaca region. The assumption is that the basin environment is a given and stable within a range of cyclical variation or climatic fluctuation.

The transition from the Pleistocene to the Holocene in the Lake Titicaca Basin is believed to have occurred between 12,000 and 10,000 B.P. The reconstruction of the early Holocene environment is based on paleoclimatic evidence derived from dated glacial and lake sediment cores (Wirrmann et al. 1992; Ybert 1992; Binford et al. 1996; Abbott et al. 1997; Binford and Kolata 1996). This evidence suggests that during the Holocene, the climate fluctuated between periods of warm and cold and wetter and drier periods. Unfortunately, these reconstructions are imprecise and ambiguous. For example, one core shows little change over the past 6,000 years, suggesting an environment strikingly similar to that of today (Binford et al. 1996:106; Binford and Kolata 1996:36). The variations in sedimentation rates in other cores covering the same period are interpreted as dramatic climatic variation and lake level change (Binford and Kolata 1996; Abbott et al. 1997; Binford et al. 1997). On the basis of selected cores, Kolata and colleagues conclude that sustained agriculture could not have been practiced in the basin before 3500 B.P. due to an extended period of drought and low lake level (Binford and Kolata 1996; Binford et al. 1996).

More reliable reconstructions of climate and environment are available for later prehistory. By this time full-scale intensive agriculture so altered the landscape that there is no pristine baseline for comparison. To Kolata and colleagues, "normal climatic fluctuation" for the basin is based on averages of the short-term historical record of lake levels, annual rainfall, and temperatures. The cycles of instability and fluctuation interpreted from the cores are compared to these norms (Binford et al. 1997; Abbott et al.

1997; Binford and Kolata 1996). An alternative perspective is provided in the new ecology (Botkin 1990; Zimmerer 1994) and historical ecology (Crumley 1994), which considers the environment to be dynamic. Change, at times chaotic, is natural and expected. Environmental change is historically contingent rather than cyclical, varying around some norm. Thus there is no original pristine or climax baseline environment for comparison.

The present-day environment of the Lake Titicaca Basin has been described in many publications (Winterhalder and Thomas 1978; Kolata 1996; Dejoux and Iltis 1992; Morlon 1996; Luteyn and Churchill this volume). I will present an abbreviated scheme for the Lake Titicaca Basin that is based on Prehispanic, historical, and contemporary land use or production zones (for details, see Erickson n.d.; Kolata 1996; Morlon 1996; Winterhalder and Thomas 1978). The Quechua and Aymara of the Lake Titicaca Basin classify the landscape into the following categories: (1) *lago,* or the lake and permanent and semipermanent wetlands, (2) *pampa,* or the seasonally inundated lake plain, (3) *cerro,* or lower hill slopes near the lake (including islands and peninsulas), and (4) *puna,* or high-altitude grasslands.

LAGO. Lake Titicaca is located at 3,812 m above sea level and covers an area of approximately 8,100 km^2. Vast areas of seasonal and permanent wetland are found at the lake edge and along the rivers that feed Lake Titicaca. Dense communities of aquatic plants (*Schoenoplectus tatora, Myriophyllum, Elodea, Potamogeton*) dominate the wetlands and shorelines. The annual production of dry biomass in these wetlands has been calculated at 8 MT/ha (Vacher et al. 1991). The most important resource for humans is the totora reed (*Schoenoplectus tatora*), which provides material for roofing, mats, and boats, forage for livestock, and food for humans (the starchy roots). Fish and aquatic birds that thrive here are important in local diets. The annual harvest of fish is estimated to be 12,000 MT (Richarson 1991). Agriculture is more productive near the lake due to higher annual rainfall, warmer temperature, longer growing season, and richer soils (Vacher et al. 1991). Population densities are highest near the lake, in particular the zones with extensive wetland resources, and have been high for thousands of years.

Lake levels are dynamic and have fluctuated 6.5 m in the past century. This, combined with the flat topography surrounding the lake, has important consequences for wetland and farmland distribution. A lake level change of 1 m can either inundate or expose 120,000 ha of land surface. Most human occupation, past and present, is within or adjacent to the area most affected by changes in lake level. Humans play an important role in the creation and management of the lake's resources. Totora is cultivated in areas affected by fluctuating lake levels where stands have been overexploited. The appearance of totora pollen in cores at 3500 B.P. has been interpreted as evidence of cultivation of totora (Binford and Kolata 1996). Most of the wetlands have archaeological evidence of intensive farming and occupation (raised fields, canals, and occupation mounds).

PAMPA. Large expanses of pampa or grassland plains are found adjacent to Lake Titicaca and the major rivers that feed the lake. These flat low-lying areas are subject to frequent flooding by the lake and rivers. Agriculture is considered risky in these areas because of the high water table, frequent frosts, and heavy soils. The pampa currently is used for grazing introduced sheep and cattle. Precolumbian farmers built raised fields and q'ochas and occupied the tens of thousands of artificial mounds distributed across the pampa.

CERRO. The most heavily farmed lands today are the slopes adjacent to the lake (3,800 to 4,200 m). Crops cultivated on lower slopes near the lake and on peninsulas and islands are less affected by waterlogging, frost, and the short growing season. The indigenous crops include potato, oca, ullucu, isañu, tarwi, cañihua, maize, and quinoa. In the immediate vicinity of the lake, stone-faced terracing covers the slopes from valley or lake edge to hilltop, and eroded terraced fields can be found many kilometers from the lake. Because of continuous farming, all natural vegetation has long been removed.

PUNA. The puna is the cold, high-altitude grasslands between 4,100 m to the base of the mountain glaciers (4,600 m and above). The puna of Lake Titicaca is classified as humid puna (800–1,200 mm of annual rainfall). The vegetation is predominantly low mats of herbaceous vegetation, tussock grasses, *Distichia* moors, and remnant groves of *Polylepis* spp. and *Buddleja* spp. This is also the habitat of guanaco, vicuña, deer, and viscacha.

Although the puna appears natural and devoid of human activity, humans have played an important role in shaping this landscape. Ephemeral sites representing 8,000 years of seasonal and permanent occupation are densely distributed throughout the puna (Klink and Aldenderfer 1996). Frost-resistant potatoes can be grown under certain conditions as high as 4,500 m, and herding settlements are found as high as 5,210 m (Bowman 1916:52, figure 24). The remains of agropastoral infrastructure such as residences, walls, corrals, and irrigation canals and large special-purpose sites (cemeteries and pukaras, or forts) are common west of the lake (Stanish et al. 1997; Flores 1979:45–50). Vegetation is annually burned off to improve grazing. T'ola shrubs (*Baccharis* or *Lepidophyllum*) and yareta (*Azorella*), cushion plants rich in resin, have long been harvested for fuel (West 1987; Wickens 1995). Vast wetlands, or bofedales, either anthropogenic or artificial, are found throughout the puna.

EARLY HUMAN MANIPULATION OF THE ENVIRONMENT

The human impact on the landscapes of the Lake Titicaca Basin began with the arrival of the first peoples to the area around 8,000 years ago (table 12.1). Hunter-gatherer settlements dating to 8000–9000 B.P. have been found in the Moquegua drainage southwest of the basin (Aldenderfer 1998). A total of 240 sites dating to the Preceramic period (8000–3500 B.P.) were located in a recent survey of the Ilave River drainage on the western side of Lake Titicaca (Klink and Aldenderfer 1996). Preceramic sites are rare in the immediate vicinity of the lake (Stanish et al. 1997; Albarracín 1996:78–79). By 4000–3500 B.P., hunters and pastoralists were living in permanent settlements in the Ilave River drainage (Klink and Aldenderfer 1996).

Based on elevation and latitude, the Lake Titicaca Basin is classified as moist mon-

TABLE 12.1. CHRONOLOGY OF THE LAKE TITICACA BASIN

Time Scale	*Culture*			*Period/Horizon*
1750				
1500				
		Inka		Late Horizon
1250		*Aymara Kingdoms*		Late Intermediate Period
1000		*Tiwanaku V*		
750		*Tiwanaku IV*		Middle Horizon
500		*Tiwanaku III*		
250				Early Intermediate Period
AD/BC	*Pukara*			
250				
500				Early Horizon
750		*Chiripa* *Sillamocco*		
1000	*Qaluya*		*Wankarani*	
1250				Initial Period
1500				
1750				
2000				
				Preceramic

tane forest. The stands of native trees (*Polylepis* spp.) are considered to be remnants of a once forested landscape (Ellenberg 1979; Budowski 1968; Winterhalder and Thomas 1978:77; Seibert 1983:265). Deforestation is attributed to long-term climate change (Morlon 1996; Cardich 1985), Precolumbian human degradation (Ellenberg 1979), and Colonial or modern degradation (Morlon 1996; West 1987; Seibert 1983). If the basin was indeed once forested, deforestation by humans for construction material, tool handles, and fuel probably began early and continued throughout prehistory. The early occupants probably burned trees and grasses to improve hunting and collecting. This tradition continues to the present. (During the Festival of San Juan, Aymara and Quechua farmers living near the lake systematically burn all t'ola shrubs and bunchgrasses near their communities.) Sediment cores show continuous presence of charcoal (presumably anthropogenic) from 6000 B.P. to the present (Binford et al. 1997). The trees found in the basin today are cultivated managed stands, not relics or remnants of natural forests (Gade 1981).

Vicuñas are territorial animals, and early hunters would have quickly realized the potential of improving natural wetlands or constructing artificial wetlands (bofedales) to increase populations. The fauna and flora near Preceramic base camps and settlements would have been gradually transformed by human disturbance and daily activities. The coevolution of agricultural and pastoral economies may have its roots in the early transformations of the puna by hunters and gatherers (Piperno and Pearsall 1998; Kuznar 1993). The domestication of camelids is dated to 4000–5000 B.P. in the neighboring upper Moquegua Valley (Aldenderfer 1998:295), although manipulation of wild herds extends further back in time. The impact of large herds of llamas and alpacas on the puna has been substantial since the Late Preceramic period.

Preceramic sites are rare in the wetlands and slopes adjacent to Lake Titicaca (Albarracín 1996; Steadman 1995; Klink and Aldenderfer 1996). Kolata and colleagues argue that the area was uninhabitable before 3500 B.P. due to "chronic drought." Preceramic wetland sites, analogous to the floating island settlements of the ethnographic Uru, would have low archaeological visibility and may be deeply buried under sediments or later occupation. Early hunter-fisher-gatherer populations would have been drawn to the rich resources of the wetlands (Erickson 1996, n.d.). Regular burning and the cultivation of totora may have been early forms of wetland management.

FARMING AND THE CREATION OF AN ANTHROPOGENIC ENVIRONMENT

At the time of Spanish conquest of the southern Andes, most of the Lake Titicaca landscape had long been converted into farm or grazing land. Detailed historical documents of the Lupaca kingdom located in seven major towns on the western shore report that political leaders owned huge herds of llamas and alpacas and exercised control over tens of thousands of human subjects. The Lupaca political organization was based on a hierarchy of leadership, towns divided into upper and lower moieties, dense rural populations, and colonies established in distant lands to exploit nonlocal resources (Murra 1968; Stanish et al. 1997; Graffam 1992). The Lupaca and their neighbors had inherited a rich landscape capital and sophisticated knowledge system from millennia of earlier farming peoples.

Cultivated plants appeared at 8000 B.P. or earlier in South America, and domestication and agriculture soon followed (Piperno and Pearsall 1998). The Lake Titicaca Basin and the south-central Andes have long been considered a "noncenter of domestication" (dispersed center) based on the distribution of wild and weedy species of important highland domesticates (Piperno and Pearsall 1998). Although the Preceramic of the Lake Titicaca Basin is poorly documented, the roots of early agriculture and herding are based in the gradual transformation of local and regional environments by hunter-gatherer-fisher peoples (Piperno and Pearsall 1998). By the time cultigens such as potatoes, quinoa, cañihua, and totora and domesticated animals appear in the archaeological record at 1500 B.C., the agropastoral economies are already well developed and widespread (Browman 1987; Erickson 1976, 1996; Hastorf et al. 1997). Many early farming settlements are located close to wetland resources, and the ethnobotanical records show that these resources played an important role in subsistence (Erickson 1976; K. Moore et al. 1999).

The adoption of farming and herding lifeways between 8,000 and 3,000 years ago must have had a profound and permanent impact on the landscapes of the Lake Titicaca Basin. The removal of vegetation cover increases erosion and evapotranspiration rates. The thick "homogeneous gyttija" in sediment cores, assumed to represent severe drought (Binford and Kolata 1996: 106; Binford et al. 1997; Abbott et al. 1997), may actually be the signature of anthropogenic transformation of the puna and cerro above the lake. The grazing of large herds, increased burning, and the harvest of shrubs and trees for building material and fuel permanently altered the puna and upper slopes. By 1000 B.C. farmers began constructing raised fields in wetlands and the pampa of the northern basin (Erickson 1993, 1996). The first evidence of terracing dates to the Early Intermediate period (200 B.C.–A.D. 600), and terracing is well established by the Middle Horizon (A.D. 600–1000) (Albarracín 1996). The initial construction of terraces may have actually increased soil erosion through the removal of slope vegetation and stones (Donkin 1979: 131). Dust peaks in the Quelccaya ice core dated to A.D. 920 and A.D. 600 and interpreted as evidence of intensification of raised field agriculture (Thompson et al. 1988) may represent a wider spectrum of anthropogenic activities.

THE TECHNOLOGY OF TRANSFORMATION

The traditional agricultural technology of farming communities in the Lake Titicaca Basin has been described as "hardware poor" (Donkin 1979; Denevan 2000). It is truly remarkable that the massive transformation and building of the landscape was done using simple manual tools without the help of animal traction or metal implements. Metal artifacts of late prehistory were rarely employed for mundane agriculture. The basic tool set for preparing, weeding, and harvesting fields includes the *chakitaqlla,* or Andean footplow, the *rawkana,* or hoe, and the *waqtana,* or clodbuster (Quechua terms) (figure 12.3). These tools have been used by Andean farmers for thousands of years. The modern distribution of the chakitaqlla closely maps Precolumbian terraces and raised fields and certainly played an important role in their evolution (Gade and Rios 1972; Donkin 1979: 13).

The chakitaqlla is a simple yet remarkably efficient tool (Gade and Rios 1972; Morlon 1996; Donkin 1979). The footplow is very portable and can be used to turn tough sod of the lake plain and the rocky soils found on steep slopes. Fields are commonly prepared by teams of farmers; two men cut and raise a sod block with their chakitaqllas and a woman flips the sod over. Groups of farmers often line up in formation to turn the soil in community fields. The tool is primarily used today in the Lake Titicaca Basin to create wachos, 0.3 to 1.0 m wide sod lazy beds for planting tubers. The shape and size of the tool varies throughout the central Andes, and distinct forms are often linked to specific regions. A basic chakitaqlla consists of a long straight or curved shaft (1 to

FIGURE 12.3. Tools used to transform the landscapes of the Lake Titicaca Basin: rawkana (left), chakitaqlla (center), and waqtana (right). In the past, the blades would have been made of wood or ground stone.

2 m), with a cutting edge at the end of the shaft, a wooden footpeg, and an optional curved wooden handhold, all lashed together with leather bindings. Today, the blade is cut from a leaf spring of a truck. One end is hammered into a flat blade used for cutting sod, and the other end is hammered into a pointed blade for use in rocky soils. The wood comes from native trees specifically cultivated for tool parts. Traditionally, chakitaqlla blades were made of ground and chipped stone and hardened wood (Gade and Rios 1972; Morlon 1996; Donkin 1979).

The rawkana is a small hoe consisting of a metal blade and a short wooden handle hafted with leather bindings. In the past, the blades were made of wood, bone scapulae, ground and chipped stone, or tabular basalt. The all-purpose tool is used for preparing, planting, and weeding fields, banking tubers, and harvesting crops. The waqtana, a heavy malletlike tool, is used for breaking up clods of soil. It is usually made of a single piece of wood with a dense tree knot serving as the head. Others are made by hafting an oval stone or metal weight to the handle. In addition to these basic tools, wool carrying cloths are often used to transport soil and manure, and long wooden or metal levers are used to pry up and roll stones.

THE ARCHAEOLOGICAL SIGNATURE OF CULTURAL PRACTICES USED TO TRANSFORM THE LANDSCAPE

The cultural practices used by Andean farmers have been well documented in the historical and ethnographic record. Archaeologists often assume that traditional practices of Andean peoples recorded in historical and ethnographic accounts were the same used by their Prehispanic ancestors to shape, transform, and manage the landscape. The naive projection of historical and contemporary practices back into the Prehispanic period recently has been criticized. As Isbell (1997a) has pointed out, archaeologists should not assume continuities (or change, for that matter) in cultural practices, but rather should demonstrate them in the archaeological record. In this section, I will briefly discuss the archaeological signatures of some important Andean cultural practices that are linked to the anthropogenic landscape of the Lake Titicaca Basin.

AGROPASTORAL PRODUCTION ZONES

The rough mountainous terrain of the Andes is often characterized in the literature as stacked vertical ecological tiers determined by altitude and other natural factors, such as soils, rainfall, aspect, slope, elevation, temperature (Holdridge 1947; Tosi 1960; Troll 1968; Ellenberg 1979; Dollfus 1982). In this natural history perspective, environmental vertical zonation is taken as a given, something that humans adapt to. In contrast, Andean communities developed culturally defined land use categories or production zones for their holdings. According to Mayer (1985), production zones provide the structure or rules for the allotment of irrigation water, distribution of communal and individual land, regulation of land use, the scheduling of agricultural activities, definition of crop types, and the cycle of rotational fallow. Another strategy was the development and maintenance of high biodiversity in crops suited for a wide range of environments and culinary purposes (Zimmerer 1996). Prime examples are the land races of bitter potatoes (*Solanum juzepczukii*) and cañihua (*Chenopodium pallidicaule*) cultivated in the cold puna up to 4,450 m (Winterhalder and Thomas 1978 : 57). Altiplano maize grown on the islands and peninsulas of Lake Titicaca is another example of extending the range of a warm valley crop to a high-altitude environment. When the genetic limits of crop plasticity were reached, Precolumbian farmers often turned to technology to extend the limits of cultivation further. As Zimmerer (1996) has pointed out, Andean farming strategies stress flexibility, not microenvironmental specialization. Rather than adapting to specific ecological conditions, farmers transform nature through their settlement systems, production zones, and farming techniques.

Culturally defined production zones can be identified archaeologically (cf. Hastorf 1993; Goland 1991 : 514). The abandonment of farmland, and even entire agricultural strategies such as raised field agriculture, limits the direct projection of contemporary production zones back into the remote past. However, as Zimmerer (1996:20) has pointed out (following Murra and Mayer), the use of land is to assert political control over territory. Community territories and, by association, production zones are often defined by physical infrastructure (mojones, or boundary markers, walls, irrigation canals, dispersed seasonal residences, pathways, cemeteries). The major Precolumbian landscape transformations discussed below tend to map roughly onto contemporary production zones despite dramatic changes in the use and intensity of these zones (e.g., raised fields correspond to pampa and lakeshore wetlands, terraces to cerro or slopes, q'ochas to pampa and river valley plains).

THE ARCHAEOLOGY OF AGRICULTURAL LABOR

The basis of the transformation and creation of the cultural landscape of the Lake Titicaca region is raw human labor and its organization in time and space. Much has been written about traditional forms of mobilization and organization of labor at the level of the household (e.g., Orlove 1977; Morlon 1996; Aldenderfer 1993; Golte 1980), the community (e.g., Urton 1990; Winterhalder and Thomas 1978; Erickson n.d.; Golte 1980), the region (e.g., Zimmerer 1996; Masuda et al. 1985; Mayer 1979; Goland 1991), and the state (Albarracín 1996; Hastorf 1993; Kolata 1996). Andean labor institutions, from household to state, are rooted in the ideology of reciprocity. The delayed reciprocity of equal labor exchange between farmers (*ayni*) mobilizes labor for tight schedules demanded by intensive agriculture. Larger work parties, commonly for public works, are mobilized through the practice of *minka,* where a sponsor pays for labor in food and drink, or *faena,* where participants work communally for the good of the community. In later prehistory, Andean peoples paid a labor tax to the state under the *mit'a* system. Laborers working on public projects were housed, fed, and given gifts by the state. The ability to mobilize huge amounts of labor for transforming the land through agriculture and the built environment is the hallmark of Andean civilizations. The archaeological correlates of Andean labor and social organization have long been important issues in Andean prehistory (cf. Moseley 1992; Burger 1992; Isbell 1997a).

Settlement pattern is one index of reciprocal labor used in intensive agriculture. Stone notes that as agriculture becomes more intensive and labor demanding, "residences are 'pulled' towards the plot" and individual households are dispersed (1996:43). At the same time, the requirements of reciprocal labor for intensive agriculture encourage "gravitation" of households (ibid.:122). Linear landholdings provide the most efficient tenure system in the circumstances, which fits the general Andean pattern of agricultural land divisions, suyus and chutta. Another alternative to increase the labor pool involves multiple family residences, which may have been more common in the past (Isbell 1997b). The dispersed nature of rural settlement patterns in the Lake Titicaca Basin throughout prehistory suggests that farming households and communities attempted to locate residences near their fields (Albarracín and Mathews 1990; Stanish et al. 1997; Albarracín 1996). Because of the practice of field scattering, farmers often maintain multiple residences (Goland 1991; Erickson n.d.). The importance of labor reciprocity can be seen in the clustering of mound settlements on the lake plain (Erickson 1993, n.d.) and hamlets in the lower river valleys throughout late prehistory (e.g., Albarracín 1996). Experimental rehabilitation of terraces and raised fields also has provided valuable indices of labor and social units required for the construction of Precolumbian field systems (Ramos 1986; Treacy 1994; Erickson and Candler 1989; Erickson 1993). The physical patterning of field design reflects these labor and social units. The physical link of land and residence becomes stronger through time as agricultural improvements are accrued and inherited.

PREHISPANIC RURAL SOCIAL ORGANIZATION

Rural farming communities (*pueblos,* Spanish; *llaqta,* Quechua; *marka,* Aymara) of the Lake Titicaca Basin are traditionally divided into upper and lower halves or moieties (*saya* in Quechua and Aymara). The relations between moieties and their subdivisions are hierarchical (Urton 1990). These dual divisions often have spatial and physical components and thus can be identified in the archaeological record (e.g., J. D. Moore 1995; Hyslop 1990). These in turn are divided into ayllus, or local landholding groups that often have spatial integrity (Urton 1990; Wachtel 1990; Carter and Mamani 1982). Ayllus are made of numerous households with individual and communal landholdings dispersed across local territories that are often marked by physical structures on the landscape (figure 12.4; Urton 1990; Wachtel 1990). Traditional ayllus of the Aymara were segmental and hierarchical, ranging from multiple family groupings at the local level to macroayllus at the regional level (Albarracín 1996).

The household, ayllu, and community organization also have archaeological correlates. The rural settlement pattern, past and present, in the Lake Titicaca Basin is highly dispersed. Throughout the archaeological record, regional settlement has fluctuated between weakly and strongly hierarchical, dispersed and agglutinated (Stanish et al. l997; Albarracín 1996; McAndrews et al. 1997; Albarracín and Mathews 1990). Precolumbian households have been identified in the archaeological record for the basin (Aldenderfer 1993; Bermann 1994; Janusek 1994). The plot where households maintain their primary residence (a house compound often around a patio) and infields (*sayaña,* Aymara) tends to have many physical improvements such as stone walls, corrals, infield gardens, and canals for irrigation and drainage. Each year, individual households were assigned a topo (or *tupu*) of communal land of the ayllu, enough farmland to support a family for a year. The size of a topo would vary according to the productive potential of the land. I have argued that the modular patterning of the smallest units of raised fields reflect topo divisions (Erickson 1993). "Compressed verticality" (Brush 1977) and "field scattering" (Goland 1991) within different environments are household, ayllu, and community strategies to reduce risk. This also is an important factor in determining Prehispanic rural settlement patterning. Multiple residences for individual households or multiple agglutinated settlements for single communities throughout production zones make it difficult to define precisely all components of the individual households through traditional site survey. Local labor units may be reflected in house compounds (Isbell 1997b; Bermann 1994; Janusek 1994),

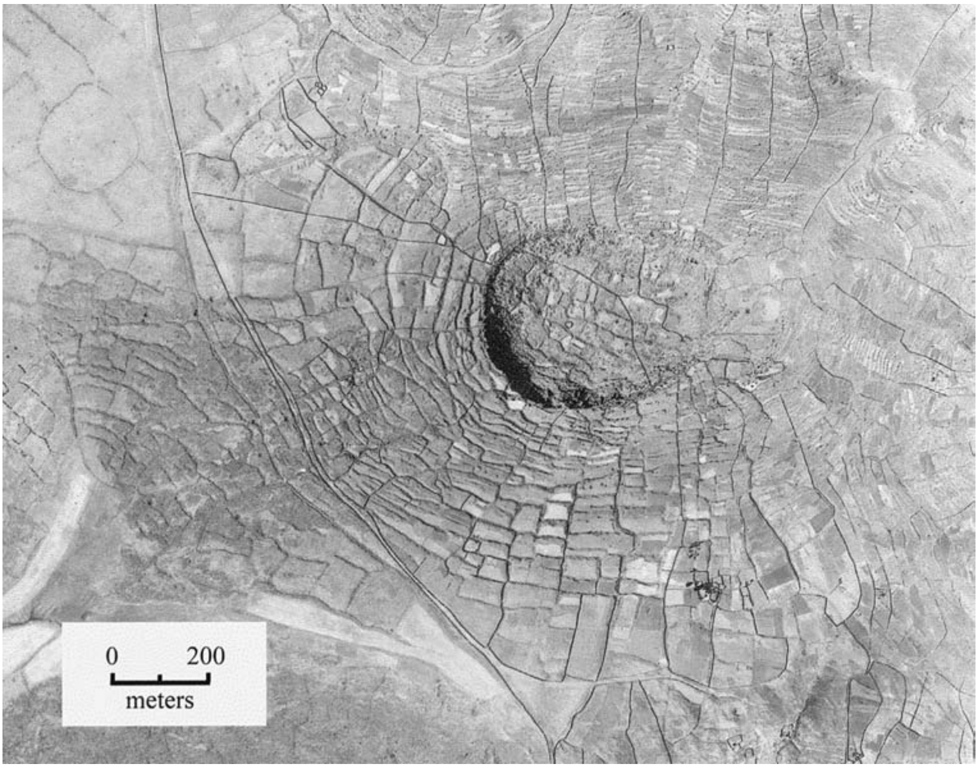


FIGURE 12.4. Highly patterned fields, field walls, pathways, roads, and dispersed farmsteads on gentle slopes between Hatuncolla and Lake Umayo, Puno, Peru. The walls of a community's sectorial fallow system radiate from the top of a hill (left of center).

settlement patterning in relation to intensity of agriculture (e.g., Stone 1996), residence location in reference to fields (Stanish et al. 1997; Erickson n.d.), or the formal patterning of Precolumbian fields (Erickson 1993).

The community and ayllu levels of social organization have a much clearer archaeological signature than individual households and household infields. Traditional community and ayllu lands within production zones are often organized under rotational or sectorial fallow systems (Orlove and Godoy 1986; Wachtel 1990; Goland 1991; Morlon 1996; Mayer 1979, 1985; Carter and Mamani 1982). In ideal cases, communal land is divided into spatially discrete segments, often long linear strips or pie-shaped wedges, called *chutta, suyu, laymi, muyuy,* and *manda* in Quechua and *aynoqa* in Aymara (figure 12.5). Each year, a number of segments are designated to be left in fallow, and the rest are assigned a specific crop. A common cycle is two to three years of cropping followed by two to twelve years of fallow (Winterhalder and Thomas 1978:68). A community's rotational fallow system is often physically defined by stone walls radiating from ridges or tops of hills. Irrigation canals feeding terraced fields often map and bound the social structure of communities (e.g., Treacy 1994; Zuidema

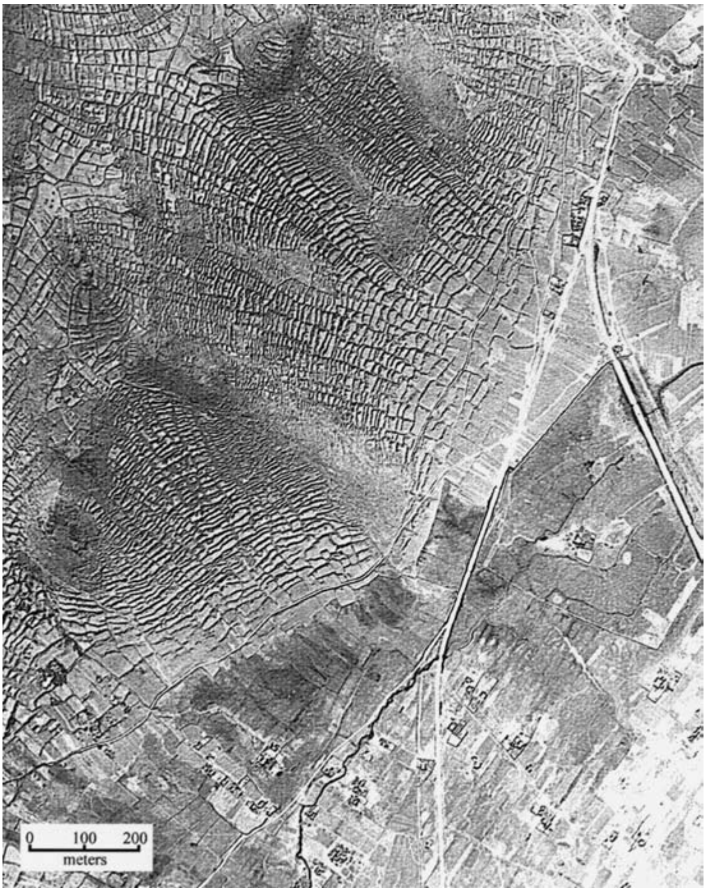


FIGURE 12.5. Massive terraced hillside near Pomata, Puno, Peru. Vertical walls dividing terraces into long strips run from the hill crest (upper left) to the pampa (lower right) several hundred meters below. Faint traces of raised fields can be seen between dispersed farmsteads in the lower right.

1985). Terrace infrastructure (facing walls, pathways, and walls running up and down slopes) often reflects land tenure at the household, ayllu, and community levels. Some grazing lands, raised fields, and q'ochas were also managed by rotational fallow systems and incorporate physical structures such as boundary markers, canals, and walls (Palacios 1977; Erickson n.d.; Flores 1987; Rosas 1986). Ayllus often maintain shrines and "altars" on hilltops overlooking their territories (Candler 1993; Wachtel 1990). Isbell (1997a) has recently argued that the ayllu can be identified in aboveground multiple burial towers (chullpas) that are distributed throughout the Lake Titicaca landscape, often on high ground overlooking community fields. Even natural aquatic resources such as totora reed swamps and fishing grounds are physically marked by ditches or stone cairns to define ayllu and community territories (Levieil and Orlove 1990; Nuñez 1984; Erickson n.d.).

The origins of these cultural institutions remain elusive and debated (Moseley 1992; Kolata 1993; Isbell 1997a). Social and technological institutions are dynamic, and these institutions certainly evolved and transformed over time. Some of the material correlates from these institutions are identifiable in the landscape and built environment by 1000 B.C. Through the practice of everyday life over generations, these structures have been expanded, enhanced, and formalized (Erickson 1993, n.d.). The cultural construction, modification, and improvement of land over long periods of time has been called "landscape capital" (Blaikie and Brookfield 1987b; Netting 1993). The agricultural resources at any point in time represent a history of labor invested by previous generations of farmers. Farmers inherit the improvements (and environmental degradation) of preceding generations, which tends to tie each new generation more tightly to the land. The thousands of years of efforts to demarcate individual and community lands physically through the built environment are now part of the permanent landscape record.

TERRACING

The most striking aspect of the Lake Titicaca Basin for the visitor is the patterned landscape of terraces (*terrazas* or *andenes* in Spanish; *pata,* Quechua; *takha, takhana,* Aymara) on nearly all of the hill slopes (see figure 12.5). Although raised fields (waru waru, suka kollas, or camellones) and sunken gardens (q'ochas) have received the most research attention, the agricultural terraces of the Lake Titicaca Basin are much more impressive in terms of overall labor input and areal extent. Massive conversion of slopes, some quite steep, into productive platforms for agriculture was done at a monumental scale (figure 12.6). There is a nearly continuous distribution of terracing on slopes of both the northeast and southwest shores of Lake Titicaca from the Tiwanaku Valley in the south to the towns of Pukara, Azángaro, and Ayaviri in the north and on slopes rising from all of the river valleys of the basin. Terracing continues unbroken on the adjacent eastern Amazonian watershed of southern Peru and Bolivia (Donkin 1979; Denevan 2000; Goland 1991). I estimate that Precolumbian terracing in the immediate vicinity of the lake and the major river valleys of the basin alone covers 500,000 ha.

Archaeologists, agronomists, soil scientists, and geographers have made detailed studies of Precolumbian and contemporary terrace agriculture in the central Andes (Donkin 1979; Denevan 2000; Treacy and Denevan 1994; Goland 1991; Torre and Burga 1986; Zimmerer 1996) and more specifically in the Lake Titicaca Basin (Morlon 1996; Ramos 1986; Coolman 1986). The functions of terracing have been summarized in numerous publications (Treacy 1994; Treacy and Denevan 1994; Donkin 1979; Ramos 1986; Coolman 1986; Morlon 1996; Torre and Burga 1986).

Treacy and Denevan (1994:93–96) conveniently summarize the functions of terracing as:

- Soil deepening: The soils of Andean slopes tend to be thin and full of stone. Improving the depth of soil increases the retention of water in addition to providing a deeper medium for crop growth (Donkin 1979:131).

FIGURE 12.6. Agricultural terraces, linear land boundaries, pathways and dispersed settlement near Chisi, Copacabana, Bolivia. Precolumbian terrace walls and platforms are still used but are rarely maintained.

- Erosion control: The control of erosion is believed to have been a secondary function of terracing. Andean soils are highly susceptible to erosion, much of which is due to human activities. Informal terracing (lynchets, cross-channel walls) may have been an early response to loss of topsoil. As I will argue below, soils used to fill terraces were often removed from farther up the slopes during construction or through intentional erosion.
- Microclimatic control: The local topography created by terrace walls and platforms provides microclimates that are more favorable for crops. Frost damage can be reduced as terraces interfere with the flow of cold air down slopes and create turbulence, protecting crops. Terraces also modify slope aspect and sun angle for improved growth conditions and reduction of radiant heat loss at night (Donkin 1979:131; Morlon 1996).
- Moisture control: The primary function of Andean terraces may be to control water by artificially flattening surfaces. Irrigation was often combined with terracing in the south-central Andes. Precolumbian terraces in the Lake Titicaca Basin appear to be primarily rainfed, not irrigated. Whatever the source of moisture, terracing improved moisture retention by reducing runoff and providing a deeper soil medium to store moisture.

Most, if not all, slopes adjacent to the lake or lake plains in the Lake Titicaca Basin are terraced. The exception would be rock outcrops with no soil or extremely steep faces. The slopes of all the islands and peninsulas of the lake are completely covered with terracing from the top of the hills to the lake edge. These terraces, categorized as bench terraces, are also the most formal in design and construction (and the most costly in terms of labor). In some cases, the wall height is equal to or greater than the width of the cultivation platform created.

Precolumbian terraces are used by contemporary farmers, but little effort is devoted to their maintenance. Most terraces are in a poor state of preservation, and many walls have been removed to enlarge the fields. With the exception of a few rural development projects, new terraces are not being constructed. Terrace fields are generally farmed using the traditional fallow system of two to three years of cropping followed by two to twelve years of fallow, often combined with grazing (Winterhalder and Thomas 1978:68; Morlon 1996). Because only a portion of the land is in cultivation in any year, much of the landscape covered with terraces appears abandoned (Donkin 1979: 121–122).

Although diverse in form and size, the majority of the terraces of the Lake Titicaca Basin can be classified as bench terraces, contour terraces, and valley floor terraces (Treacy 1994; Treacy and Denevan 1994; Donkin 1979). Walls are constructed of local stone, most often found on the surface of the slope or encountered during construction of the walls and platforms (figure 12.7). Simple terraces without stone walls or facing are found on upper slopes and at the base of slopes. The more formal, stone-faced terraces 5 to 100 m long and 2 to 20 m wide are most common (Ramos 1986; Donkin 1979:120–122; Morlon 1996). Stone retaining walls of 0.5 to 3.5 m tall are either dry-laid or cemented with mud, and most have foundations set in a shallow trench

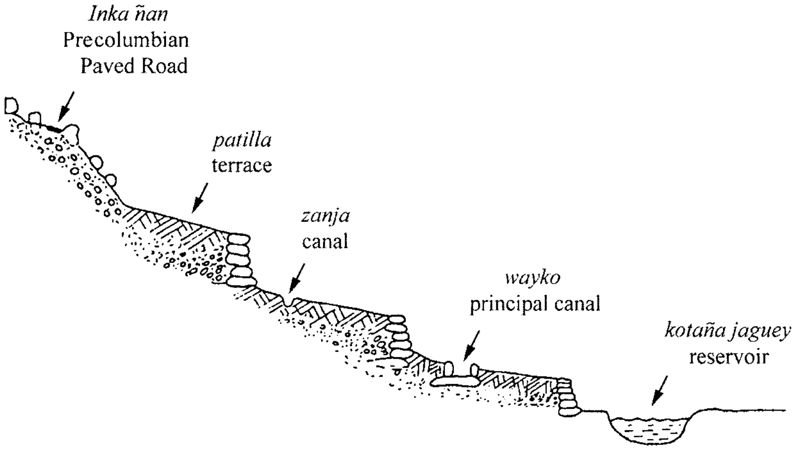


FIGURE 12.7. Profile of terrace infrastructure. *Source:* After Ramos 1984.

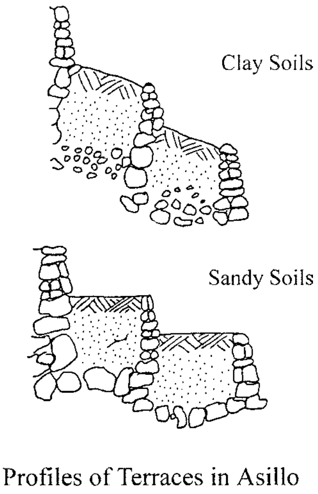


FIGURE 12.8. Profiles of terraces in different soil types. *Source:* After Ramos 1984.

(Donkin 1979:120; Ramos 1986; Coolman 1986). The lower interior fill of walls is generally composed of small stones that provide drainage and prevent blowouts of terrace walls during heavy rains (figure 12.8). The upper fill of terraces is topsoil. Terraces generally receive treatments of dung fertilizer during the cultivation of potatoes.

Terrace construction is labor intensive. Ramos (1986) calculates 225–2,270 person-days/ha (an average of 600 person-days/ha) for terrace rehabilitation in Asillo in the northern basin. Coolman (1986) reports figures of 2,500 person-days/ha for new terrace construction in Puno. The labor for terrace construction was certainly spread out over many thousands of years, and terraces grew through accretion as farmers made improvements on the land.

Terrace design tends to be highly patterned. Discrete blocks of identical terraces are often delineated by vertical walls, canals, and pathways. Many of these features run from the top of the hill to the valley floor (see figures 12.5 and 12.6). A block of stacked terraces is often linked by stairs of stones projecting from the terrace face and vertical and lateral channels. In the Lake Titicaca Basin, these walls and channels serve to (1) control and distribute runoff within and between field platforms and provide drainage for excess water, (2) organize sectorial fallow cycles, and (3) mark individual, ayllu, and community field boundaries (Ramos 1986).

Terracing is often attributed to the Inka, who incorporated the region into their empire in the mid-1400s. The most elaborate terraces are associated with maize production for the Inka located on the Copacabana Peninsula, Isla del Sol, and the Isla de la Luna (Donkin 1979). The Inka were responsible for major landscape engineering feats, which included long causeways, ritual baths and fountains, monumental carving in living rock, and ceremonial centers, in addition to impressive blocks of terracing near state installations (Stanish et al. 1997; Hyslop 1990). Many of these terraces appear overconstructed or overengineered and may have had ritual functions that served to promote the power of the Inka state.

Settlements within and adjacent to the terraced zones of the lake show continuous occupation from 1800 B.C. to the present. The earliest direct evidence of terracing in the region is the massive stone-faced platforms at the site of Pukara (200 B.C.–A.D. 600). These structures provided bases and retaining walls for the monumental buildings at the site. Stone-faced terraces used for agriculture and occupation in the lower Tiwanaku Valley have been securely dated to A.D. 600–1000 (Albarracín 1996). The earliest terraces were probably lynchets, simple barriers of earth, stone, and vegetation constructed to trap soil eroding from slopes. These ephemeral structures would have been erased as more formal, stone-faced terraces were constructed in later prehistory.

RAISED FIELDS

Raised fields (*camellones* in Spanish; *waru waru,* Quechua; *suka kollas,* Aymara) are the best studied of the major technologies of landscape transformation (Smith et al. 1968; Lennon 1983; Erickson 1988, 1993, 1996, 1999; Kolata 1993, 1996). Raised fields are large elevated planting platforms constructed in areas of waterlogged soils or soils prone to annual flooding (figure 12.9). The platforms are accompanied by canals or ditches on one, two, or all sides that were created during the process of raising the field (figure 12.10). Raised fields are highly variable in size and shape. Platforms range from 4 to 10 m wide, 10 to 100 m long, and 0.5 to 3 m tall. Canal size is generally

FIGURE 12.9. Prehispanic raised fields (waru waru, suka kollas) near Huatta, Puno, Peru.

FIGURE 12.10. Rehabilitated raised field platforms planted in potatoes alongside water-filled canal (center) in the community of Viscachani Pampa, Huatta, Puno, Peru.

in proportion to the size of the platform. Bundles of fields are organized in regular patterns, possibly reflecting the social organization of agricultural labor and land tenure, specific functions or crops, or stylistic preferences (figures 12.2 and 12.11; Erickson 1996). Abandoned raised fields are found in most of the seasonally inundated plains and river valleys surrounding Lake Titicaca. A conservative estimate of area of Prehispanic raised field agriculture is 120,000 ha (Erickson n.d.).

The functions of raised field agriculture have been determined through the rehabilitation of Precolumbian fields, ethnographic analogy, and agronomic experiments (Smith et al. 1968; Erickson 1988, 1996; Garaycochea 1986b; Ramos 1990; Kolata 1996). The functions include:

- Soil improvement: The construction of raised field platforms involves increasing the depth of topsoil, aeration, and drainage of heavy and often waterlogged soils.
- Water management: The canals adjacent to the platforms receive water from runoff, lake and river flooding, and the rise in water table during the rainy season. The ability of the cultivated soil to absorb moisture is improved through construction of the platforms. Canals and spillways permit some control over water levels within canals and the water table within fields.
- Capture, production, and recycling of soil nutrients: Soil and nutrients eroding from raised field platforms or carried by floodwaters are captured as sediments in the canals. Mature canals have higher levels of organic matter and nitrogen than nonraised field contexts. Organic matter from harvest stubble and aquatic vegetation growing in the

canals can be incorporated as green manure or muck to renew soil fertility of field platforms for sustained production.

- Improved microclimate: The water in the canals, functioning as a solar heat sink, reduces the daily fluctuation in temperature in the canals and the risk of frost damage by increasing local temperatures. The topography of platform-canal decreases heat loss during frosts by blocking and reflecting radiation back to the fields.
- Aquaculture: The construction of canals and fields substantially expanded the area of wetland conditions. Important wetland resources such as fish, totora, and aquatic birds were enhanced and possibly controlled through raised field agriculture.

Like the terraces discussed above, the construction of raised fields caused a major transformation of the Lake Titicaca Basin landscape. Raised field agriculture involved reworking the soil profile to a depth of 1–2 m. Biodiversity and carrying capacity of pampa and wetland ecosystems are improved by artificially expanding the terrestrial-aquatic interface or ecotone. The microtopography of fields and canals and the standing water in canals may have increased the overall temperature of the basin during the growing season.

Most of the raised fields were abandoned at the time of or before the arrival of the Spanish, although some may have remained in cultivation until the last century (Erickson 1993, n.d.). Raised field agriculture probably began as early as the Initial period

FIGURE 12.11. Raised field platforms (light linear features) and canals (dark linear features) on the edge of Lake Titicaca (lower right) near Huatta, Puno, Peru. Note the long straight canals that subdivide the raised field landscape into wedges or strips.

(1800–900 B.C.) or Early Horizon (900–200 B.C.) along the lake edge (Erickson 1993). By the Early Intermediate period (200 B.C.–A.D. 600), raised fields were being farmed throughout the basin. Many fields were buried under larger raised fields that were constructed during the Middle Horizon (A.D. 600–1000) and Late Intermediate (A.D. 1000–1475) (Erickson 1993, n.d.; Seddon 1994; Binford et al. 1997; Kolata 1996). Climate change, in particular a long-term drought, has been proposed as the cause of raised field abandonment (Kolata 1996; Kolata and Ortloff 1996a; Binford et al. 1997). I have argued that raised field construction and use continued and actually flourished during the period of presumed drought conditions (Erickson 1993, 1996, n.d.).

Raised field agriculture denotes a substantial modification of the land surface, and thus considerable amounts of labor were invested in construction and maintenance. Based on our experiments, a single farmer can construct 1 m^3 of field/hour or 5 m^3/day (a 5-hour workday). The total of labor dedicated to raised field agriculture is impressive. I estimate that 75.8 million person-days were required to construct the 120,000 ha of raised fields of the Lake Titicaca Basin (Erickson n.d.). Archaeological (Lennon 1983; Seddon 1994; Erickson 1996) and experimental research (Garaycochea 1986b; Erickson 1996) indicates that raised fields were constructed over 2,000 or more years, and thus construction costs were spread out over a long period. Experimental construction suggests that raised fields were built at the beginning and end of the rainy season when conditions are optimal. Initial construction involved the removal of the A horizon of the canals to provide fill for the field platforms. As canals matured, a new organic-rich A horizon formed over time and sediments accumulated in the canals. This was periodically removed during field maintenance and canal cleaning. These rebuilding episodes are clearly recorded in stratigraphic profiles of excavated Prehispanic fields (Seddon 1994; Erickson 1996). A sequence of small fields being replaced by larger fields has been documented in excavations of raised fields. Many generations of farmers were responsible for this growth through accretion.

Experiments showed that major highland Andean crops (potatoes, ocas, ullucus, isañus, quinoa, cañihua, tarwi, and altiplano maize) can be successfully grown on raised fields. Potato yields on experimental raised fields ranged from 5 to 20 MT/ha; traditional agriculture on the slopes yields 2–5 MT/ha (Erickson 1996; Kolata et al. 1996). Based on potato production between 1981 and 1986, I calculate a carrying capacity of 37.5 persons/ha of raised field cultivation platform or 2.25 million inhabitants for the entire raised field system. Of course, the raised fields were not all constructed or all in use at the same time.

Based on the hierarchical settlement patterns and agricultural infrastructure (river canalization, dikes, and aqueducts), Kolata and colleagues (Kolata 1993, 1996) have argued that raised fields on a regional scale could have been constructed only under the direction of a state society, in this case Tiwanaku of the Middle Horizon. Based on the experimental construction of raised fields and archaeological evidence for the patterning of rural settlement and associated field systems, I have argued that farming communities were capable of constructing and maintaining the raised fields of the Lake Titicaca Basin (Erickson 1993, 1996, n.d.).

The networks of canals and platforms increase both the area of wetlands and the rich ecotone or interface between terrestrial and lacustrine habitats (see figure 12.11; Erickson n.d.). These earthworks also function to capture topsoil and important nutrients eroded from the slopes (Carney et al. 1996).

SUNKEN GARDENS

Sunken gardens, or q'ochas (Quechua for "container of water"), *q'otanas, cotaña, cota* (Aymara), *chacras hundidas, pozas, ojos de agua* (Spanish), are the third major element of landscape transformation in the Lake Titicaca Basin (figure 12.12; Flores 1987; Rosas 1986). Q'ochas were first defined in the densely populated pampa of the northern basin between the Río Azángaro on the east and the Río Ayaviri (Pukara) on the west at an elevation of 3,850–3,900 m. Q'ochas and raised fields coexist in the lower Tiwanaku Valley and the Huatta pampa (Albarracín 1996; Erickson n.d.). The total number and areal extent of these features in the Lake Titicaca Basin is unknown, but Flores estimates that the complex of q'ochas in the northern basin covers 530 km^2 (Flores 1987). A density of over 100 q'ochas per km^2 has been reported for Mataro Grande (figure 12.13). In the 256 km^2 area of functioning q'ochas, Flores estimates there are more than 20,240 structures (ibid.:284). Q'ochas are still being maintained and cultivated by the Quechua farmers in the northern basin. The following discussion

FIGURE 12.12. A contemporary sunken garden (q'ocha) in fallow cycle near Llallahua, Puno, Peru. Note the patterns of eroded lazy beds (wachos) in the depression.

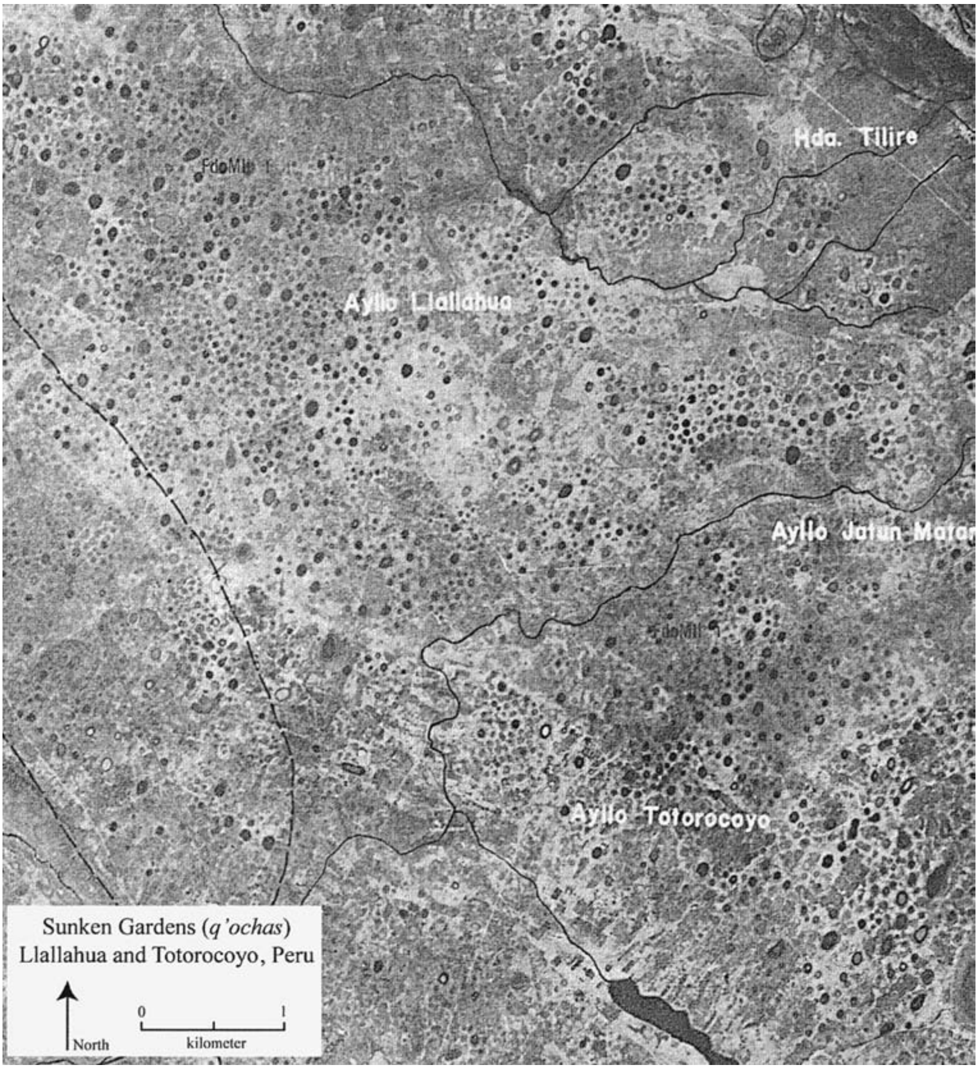
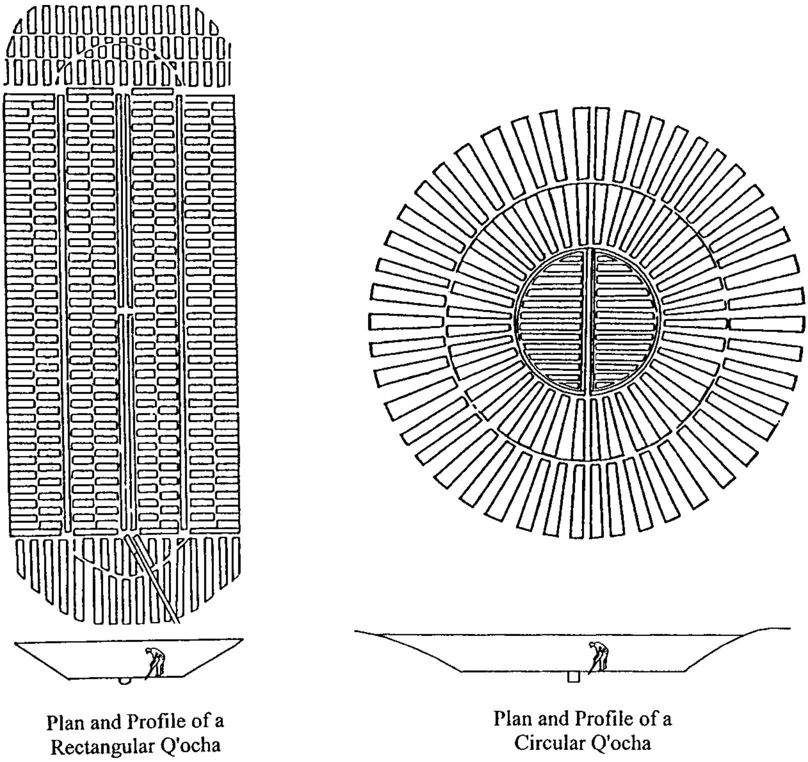


FIGURE 12.13. Aerial photograph of the sunken gardens (dark circles) near the communities of Llallahua, Jatun Mataro, and Totorocoyo, Puno, Peru. *Source:* After ONERN 1965: Hoja 4a.

is based on the well-studied q'ochas of the northern basin that are still in use (Flores 1987; Rosas 1986).

Q'ochas are large shallow depressions ranging from 0.1 to 4 ha and 1.5 to 6 m deep (figure 12.14). They are nearly always located in areas of poor drainage. The forms are highly standardized; round and oval shapes are the most common. The structures are ranked according to size and shape: (1) large and round are most common (*muyu q'ocha*), (2) medium-sized and oval (*suyt'u q'ocha*), and (3) small and rectangular (*chunta q'ocha*) (figure 12.15). The elaborate canal networks that link q'ochas are clearly artificial. It is still not clear whether the depressions themselves are completely artificial or natural formations. The lack of spoil piles of earth at the edges of the northern q'ochas suggests natural formation. Even so, q'ochas show considerable artificial enhancement of their shape, in the formal symmetry of the depression and in the patterning of canals and lazy beds (wachos). A central canal (yani) divides the q'ocha in half and extends beyond the borders of the depression. These canals (0.5–1 m wide and up to 5 m deep) provide a means of capturing runoff to fill the q'ochas and of draining excess water into the river. Other canals encircle the depression to distribute


Plan and Profile of a Rectangular Q'ocha

Plan and Profile of a Circular Q'ocha

FIGURE 12.14. Plans and profiles of two forms of q'ochas north of Lake Titicaca, Puno, Peru. *Source:* After Flores 1987.

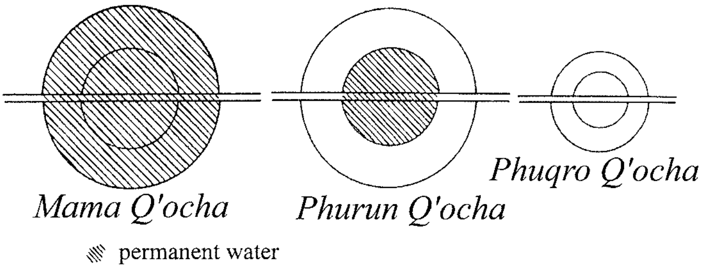


FIGURE 12.15. Three forms of q'ochas. *Source:* After Flores 1987.

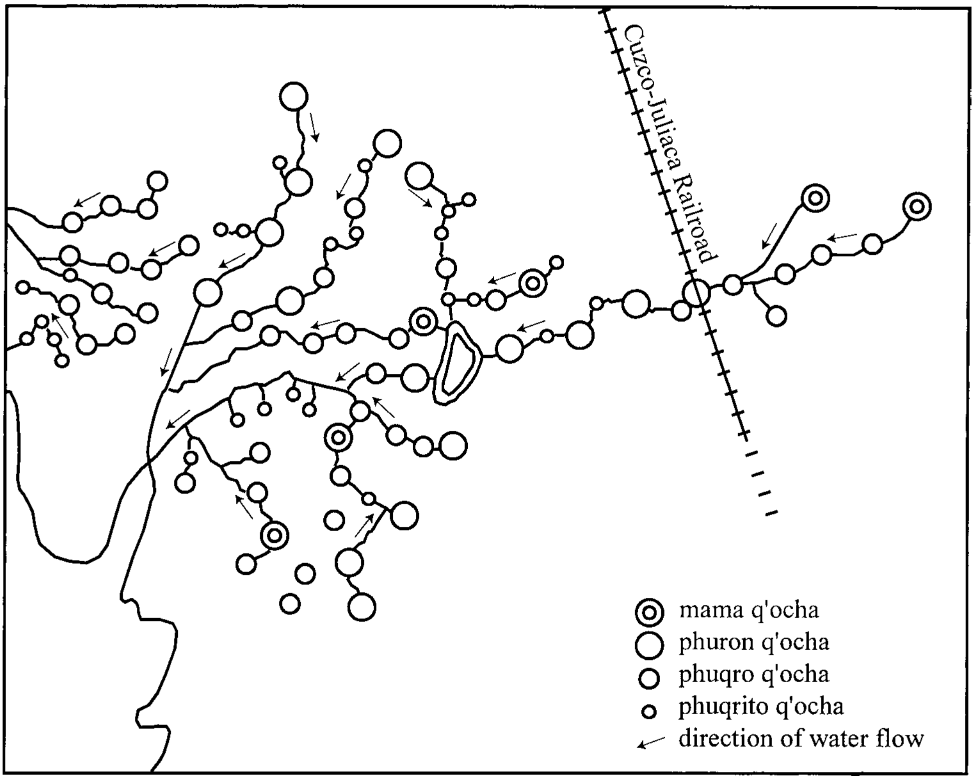


FIGURE 12.16. The interconnected networks of q'ochas and canals of the community of Llallahua, Puno, Peru. *Source:* After Angeles 1987.

water. The central canal connects up to twelve or more individual q'ochas in complex hydraulic webs (figure 12.16). Q'ochas are farmed using a three-year cycle of cultivation followed by four to five years of fallow. The sectorial fallow system described above is used to organize the rotation of potatoes, quinoa or cañihua, and barley or wheat (one year each). The fallowed fields are allowed to fill with water and aquatic vegetation. During the years of fallow, animals are allowed to graze on vegetation growing in the depression. The functions of q'ochas include:

- Water management: The depressions function as microcatchment basins to collect and store surface runoff year round. The q'ochas near the lake plain also provide access to the water table during the dry season and droughts.
- Nutrient capture, production, and recycling: The depressions capture organic sediments and topsoil eroded from higher ground. During the fallow stage, the flooded field accumulates organic matter from decomposing aquatic plants.
- Production of forage for domestic animals: During the fallow period native grasses and aquatic plants flourish in the depressions. Domestic animals are allowed to graze on this forage during the dry season.

- Aquaculture: During the fallow stage, the flooded depressions support edible fish and aquatic vegetation such as totora and llachu used as forage during the dry season. Totora is often cultivated for forage, matting, and roofing material in q'ochas on the Huatta pampa.
- Sod construction material: The q'ochas of the Huatta pampa produce thick mats of sod that are cut into blocks and used for the construction of walls, corrals, and temporary shelters on the pampa.
- Source of drinking water: When in the fallow phase, q'ochas are an important source of drinking water for humans and their domestic animals during the dry season. Q'ochas also provide water for making adobes.
- Improved microclimate: The humid depressions improve the climate conditions for crops and reduce the risk of frost damage.
- Preparation of freeze-dried tubers: In Huatta, q'ochas are excellent locations to freeze-dry potatoes and other tubers during the dry season. The base of the depression is colder than the surrounding pampa during nights of frost.

Q'ochas are owned by individual families today. They can be sold only to other members of the community. Each family controls an average of six to seven q'ochas. Compared to nonq'ocha fields in the northern pampas, crop yields from q'ochas are higher and more consistent. During the droughts of 1982–1983, the q'ochas produced 10 MT/ha of potatoes and 3,600 kg/ha of cañihua (Angeles 1987:69–70, in Morlon 1996:253).

The origins and history of q'ocha cultivation are unknown. References to q'ochas as valuable land appear in early Colonial documents involving land disputes (Flores 1987). The largest concentration of q'ochas is adjacent to the large Early Intermediate (200 B.C.–A.D. 600) site of Pukara. Association with Pukara culture has been suggested, but no q'ocha has been directly dated. The q'ochas of the Huatta pampa (Erickson n.d.) and those of the lower Tiwanaku Valley (Albarracín 1996) are associated with multicomponent occupation sites dating from the Initial period (1800–900 B.C.) to the present. It is quite probable that construction and use were contemporaneous where the distribution of q'ochas and raised fields overlap.

IRRIGATED PASTURE

The high-altitude grasslands, or puna (4,000–4,800 m), have been shaped by human activities over many millennia, first by hunter-gatherers and later by the herders of the native camelids. The llama can survive on the dry tough grasses of the puna, but the alpaca (highly valued for its wool and meat) requires forage that is more succulent. Pasture for herds of alpacas during the dry season can be found only in the *Distichia* moors or bofedales (*oqho* in Aymara). Natural bofedales are not sufficient to support large herds of alpacas. Herders have improved natural pasture and constructed vast artificial bofedales through irrigation (figure 12.17; Palacios 1977, 1984). A hectare of irrigated pasture can support 3 alpacas during the dry season, thus large bofedales are

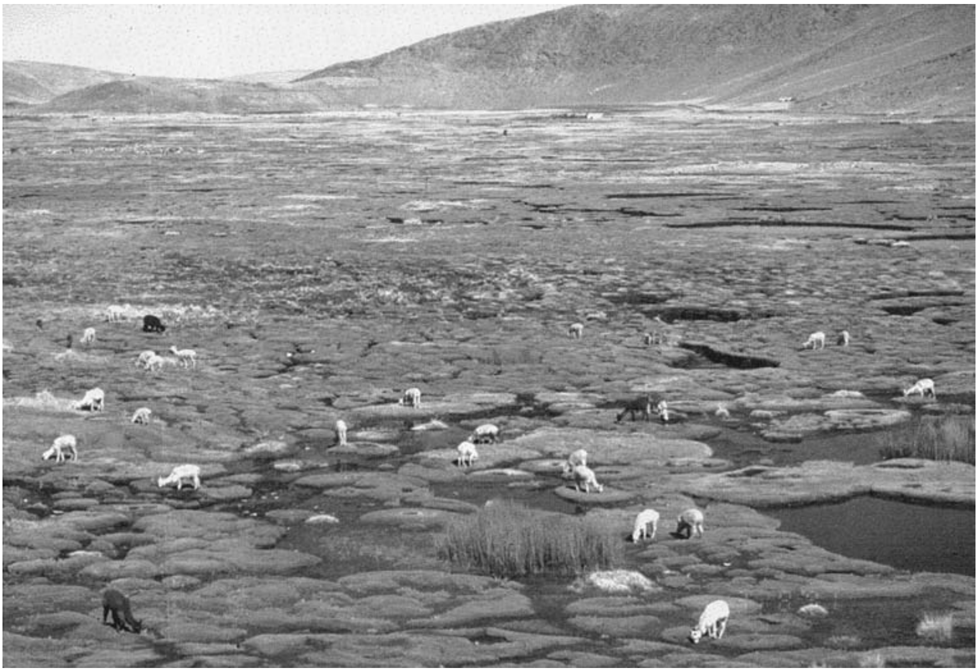


FIGURE 12.17. Alpacas grazing in a large irrigated pasture (bofedal) near Sandia, Puno, Peru (photograph courtesy of Lisa Markowitz).

necessary to support the 30,000 head of alpaca owned by herders in communities such as Chinchillapi, Peru (Palacios 1984:49). Water, tapped from rivers, streams, and springs, is often brought from long distances in two large feeder canals (*hach'a irpa*) of up to 2 m wide and 0.8 m deep and 17 km long (figure 12.18). Canals are reinforced with sod blocks that take root, forming living walls. These, in turn, supply smaller networks of canals (*hisk'a irpa*) used to create the bofedales. One of the larger bofedales covers 2,200 ha and can support 3,000–4,000 head. It generally takes herders many years of hard work to create mature bofedales capable of supporting large alpaca herds. The sustained addition of nutrients from organic sediments carried by the irrigation water and camelid dung would greatly improve the potential carrying capacity and value of these features.

Bofedales are fragile and require regular maintenance. If allowed to dry out, it can take years to bring them back into production. Canals are cleaned and repaired once a year after the rains. Families are responsible for the canals that cross their property. Each of the four sections of the community of Chinchillapi control separate bofedales. Ownership of a residence near an irrigated bofedal gives a herder grazing rights. When canals pass property lines, owners can tap into the canal to create their own bofedal. Inheritance of access to bofedales is patrilineal, and residences tend to be clusters of related families. Bofedales are foci of subcommunity solidarity and identification. Conflicts are usually resolved at the local level.

Bofedales are mentioned in the early Colonial documents for Puno. The technology was probably an important element in herding economies of the Precolumbian period and apparently has a long history. Vast extensions of bofedales, many more than are in contemporary use, would have been necessary to support the large camelid herds documented in the early Colonial tax records for the Lupaca who occupied the same region in the mid-sixteenth century. Based on these documents, Graffam (1992:889) estimates that the Lupaca controlled a total population of 1.9 million llamas and alpacas. By late prehistory, the nonpuna landscape was dedicated almost entirely to crop production; thus, pastoralism was restricted to the puna (with the exception of grazing in fallowed fields and the lake-edge wetlands). Numerous Late Preceramic (4000–3500 B.P.) occupation sites, possibly associated with herding, have been found near bofedales in the Ilave and upper Moquegua River drainages (Klink and Aldenderfer 1996; Aldenderfer 1998). Because of the physical infrastructure of bofedales (canal

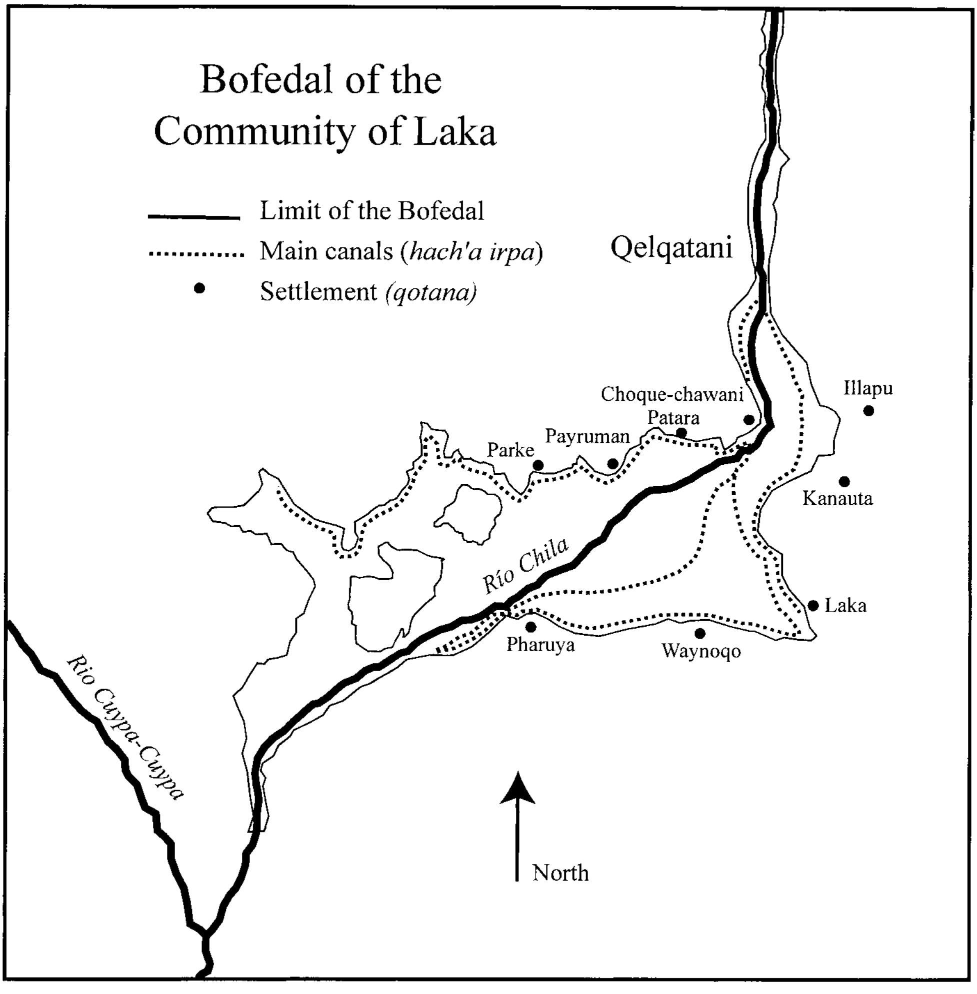


FIGURE 12.18. The irrigated artificial pasture of the community of Laka, Chinchillapi, Peru. *Source:* After Palacios 1977.

networks) and associated residences, it should be possible archaeologically to investigate the social organization of Prehispanic bofedales and the origins and evolution of the technology (e.g., Aldenderfer 1998).

MISCELLANEOUS ARTIFICIAL LANDSCAPE FEATURES

Thus far, I have discussed the major Precolumbian agricultural technologies that were used to transform the Lake Titicaca Basin into a cultural landscape. There are a number of other physical features created by humans that, although less grand in geographical scale, approximate the labor and environmental impact of the major technologies when considered in their entirety. These include modified rivers and streams, artificial canals, improved springs, roads and pathways, causeways, ponds, reservoirs, stone piles, corrals, cemeteries, burial towers, temples and shrines, residences, and settlements.

MODIFIED RIVERS AND STREAMS. Artificially straightened and canalized river and stream channels are found throughout the region. The rerouting of natural channels and the construction of sod walls or dikes on natural levees to reduce flooding are apparently old practices. A 14 km section of the Río Catari was straightened and reinforced by dikes, possibly during the Middle Horizon (Kolata 1993). In recent years, farmers have constructed massive sod walls of many kilometers for flood control along the Illpa, Azángaro, Ramis, and Coata rivers.

ARTIFICIAL CANALS. In addition to the water channels associated with terraces, q'ochas, and raised fields, there are numerous artificial canals in the pampas of the Lake Titicaca Basin. Kolata and Ortloff (1996b) report on the canals of Koani Pampa and the Tiwanaku Valley that were constructed to provide irrigation and drainage for raised fields. In Huatta, artificial canals of up to 5 km long are still used today for poling reed boats through the lake shallows and pampa. One canal network radiates from a large occupation site dated to the Early Intermediate period (figure 12.10; Erickson 1993). Parallel and radial canal networks are used today by communities and individual farmers to mark the boundaries of their wetland resources (Erickson n.d.). These features, combined with raised fields, substantially expanded the wetland ecosystem in the basin.

IMPROVED SPRINGS. Most springs in the Lake Titicaca Basin show modification by humans. These include deepening and enlarging the source into collection tanks. Water is distributed to dispersed farmsteads and villages in networks of open canals. Near springs and along streams, thousands of artificial ponds are dedicated to tunta production, tubers that are water leached and freeze dried.

CAUSEWAYS. Precolumbian causeways of earth, sod, and stone were constructed to cross low-lying pampa and wetlands (Kolata 1993; Smith et al. 1968; Hyslop 1990; Albarracín 1996; Julien 1988). Causeways were often segments of interregional road networks that may date to the Middle Horizon and Late Horizon (Kolata 1996; Hyslop

1990). In addition to transportation, these features may have had a flood control function (Smith et al. 1968; Kolata 1996). Causeways may have also served as aqueducts in the southern basin (Albarracín 1996; Kolata 1996).

ROADS AND PATHS. Elaborate networks of roads and paths cover the landscape of the basin. Formal roadways connect Precolumbian urban centers, administrative sites, and cemeteries (Hyslop 1984; Julien 1988). Many are stone paved and include features such as drains, bridges, gates, curbs, and parallel walls. The Inka constructed a northern and southern road around Lake Titicaca to connect regional centers to Cuzco (Hyslop 1984; Julien 1988; Stanish 1997).

Networks of pathways wind across the agricultural landscape, connecting dispersed fields, farms, villages, and urban centers (see figures 12.4 and 12.5). Paths in densely populated areas show improvements such as stone paving, staircases, and walls to prevent animals from entering fields. Paths often define boundaries between fields. Although difficult to date precisely, paths are associated with some of the earliest agricultural settlements of the basin.

PONDS AND RESERVOIRS. Most contemporary and archaeological settlements in the pampa are associated with artificial ponds. In addition to providing water for humans and livestock, ponds are used to raise fish and totora. Many of these ponds were formed in the process of making adobes and cutting sod for construction of residences and walls.

WALLS. Stone, sod, and adobe walls are ubiquitous features of the built environment (see figure 12.4). Walls tend to be elaborate near farmsteads and within villages. Walls keep domestic animals in or out of fields, depending on the stage of the fallow cycle. Walls are important markers for individual, ayllu, and community lands. Straight walls radiating from the peaks of hills mark Precolumbian land tenure and possibly the practice of sectorial fallow (see figures 12.4, 12.5, and 12.6). Maintenance of walls is often enforced at the level of the community. Walls protect crops and animals from the elements and often shelter important medicinal and wild food plants.

STONE PILES. Stones encountered during agricultural activity are tossed onto piles (a formation process spanning thousands of years). These stone piles and walls may play a significant role in mitigating frosts. The heat absorbed by the stones is released at night, raising the local temperature and reducing the daily fluctuation of temperature (Morlon 1996).

CORRALS AND GARDENS. Contemporary and Precolumbian corrals are ubiquitous features in the basin. Herders and farmers bring their animals into corrals at night. The dung that accumulates is collected as fuel and fertilizer (Winterhalder and Thomas 1978). Corrals are periodically turned into house gardens. Corral walls help protect bitter potatoes and quinoa from frost at higher elevations. The symbiosis between herding and farming is old, and corrals may have played a role in the domestication of Andean crops (Kuznar 1993).

CEMETERIES, BURIAL TOWERS, TEMPLES, AND SHRINES. Cemeteries were often located far from settlements on the tops of hills, mesas, and crests of ridges (Stanish et al. 1997; Hyslop 1977). During late prehistory, cemeteries enclosed by high walls covered hundreds of hectares (Stanish et al. 1997). Stone and adobe burial towers, or chullpas, are prominent features of the landscape (Hyslop 1977, 1984; Stanish et al. 1997). Most date to the Late Intermediate (A.D. 1000–1475) or Late Horizon (A.D. 1475–1532). Chullpas are linked to ancestor worship and the rights of community and ayllu to farmland. The tall towers physically dominate the landscape as symbolic markers of the lands controlled by ayllus and communities (Isbell 1997a). Stone-walled semisubterranean courts dating to the Early Horizon (1800–900 B.C.) through the Middle Horizon (A.D. 600–1000) are found on natural and artificial promontories (Chávez 1988). Landscape shrines, or huacas, are identified by stone altars, hearths, and offerings of fine potsherds, shell, and exotic stones. Most shrines have evidence of long continuous use to the present. Today, these locations are often marked by wooden crosses or stone platforms used in Catholic and traditional rituals (Candler 1993).

RESIDENCES AND SETTLEMENTS. The Lake Titicaca Basin was densely occupied at the time of European contact and has probably been so since the Early Intermediate period (200 B.C.–A.D. 600). Intensive surveys located close to 500 sites within 360 km^2 of Juli-Pomata (Stanish et al. 1997) and more than 1,000 sites within an area of 400 km^2 in the Tiwanaku Valley (Albarracín and Mathews 1990). The cycles of population aggregation and dispersion in settlement have been attributed to changes in total population size, political economy, the fortunes of polities, agricultural intensity, and climate (e.g., Stanish et al. 1997; Albarracín 1996; Binford et al. 1997; McAndrews et al. 1997). The largest site, Tiwanaku, covers an estimated 8 km^2 (Kolata 1993). Although centralized states and urban centers were present at certain times in prehistory, the predominant rural settlement pattern in the basin could be characterized as dispersed.

Precolumbian houses were constructed of adobe, sod, stone, and thatch (Bermann 1994; Janusek 1994). Walled house compounds with sleeping, kitchen, storage, and workshop structures were often arranged around a patio. As structures age and deteriorate, they are often leveled for new construction. Continuous occupation of certain locations in the wetlands and pampa produced huge mounds that dominate the flat landscape. These settlements are surrounded by thousands of smaller mounds that represent small towns, hamlets, and individual family residences. Farmers still choose these locations for settlement. Archaeological excavations of mounds document intense and continuous occupation beginning as early as 1500 B.C. (Stanish and Steadman 1994; Erickson 1988).

THE ANTHROPOGENIC LANDSCAPE LEGACY: LONG-TERM HUMAN-ENVIRONMENT RELATIONSHIPS AS HISTORICAL CONTINGENCY

Traditional perspectives on the relationship of humans and the environment in the Andes assume a separation of culture and nature. According to the nature-centric perspective, the Andean environment since the Pleistocene is viewed as a fragile ahistorical ecosystem in equilibrium, as long as it remains undisturbed by humans. Humans are viewed as forces impacting on and degrading the natural environment. In the human adaptation perspective, people adapt to, respond to, and map onto the structured and ordered Andean environment perceived as discrete ecological tiers. In the neoenvironmental determinism perspective, humans adapt to a limited range of climatic variation but are helpless in the face of extreme climatic fluctuation that surpasses the limits of human adaptation, such as long-term drought (Binford et al. 1997). All three perspectives are limited in their ability to understand the long-term transformation of Andean landscapes.

In contrast, a human-centric perspective assumes that the Andean environment is dynamic, historically contingent, and at times chaotic. Andean peoples did not simply adapt to vertically stacked ecological tiers and influence or impact that natural given environment. Nor were humans helpless in the face of climatic variation, as argued by the neoenvironmental determinists. Humans were and are active agents who shaped, transformed, and created the Andean environment. The Lake Titicaca Basin is a built environment, and the evidence of human presence is continuously distributed across the landscape. The temporal dimension of the human transformation is documented in a palimpsest of material correlates to human activity. I have argued that it would be difficult or impossible to define a wild, natural, pristine environment or climax ecosystem in the Lake Titicaca Basin because of the long-term effect of anthropogenic processes.

The role of native peoples in creating the Andean environment should not be underestimated. Much of the early transformation involved deforestation and burning of grasslands, and the replacement of natural fauna and flora with domesticated crops and animals, weedy species, and cultivated trees. The environment was recreated as a highly patterned built environment of fields, walls, settlements, roads, paths, and canals. Soil structure was reworked to a depth of 2 m or more on a massive regional scale during the construction of raised fields, terraces, and q'ochas. Incidental and induced erosion of soils and nutrients from overgrazing, burning, and deforestation in the upper basin was captured behind terrace walls or in raised field canals below (Carney et al. 1996; Erickson n.d.). Hydrology and temperatures were also modified on a regional scale through construction of raised fields, terraces, and q'ochas. Raised fields permanently transformed and artificially expanded the natural wetlands, increasing biodiversity and overall biomass (Erickson 1996).

ANTHROPOGENIC VERSUS NATURAL CAUSATION

Does a human-centric perspective overemphasize the anthropogenic processes over natural processes of environmental formation and change? Can natural disturbance be distinguished from anthropogenic disturbance (Bray 1995; Stahl 1996)? Proponents of the other perspectives argue that both short- and long-term variations of climate (mega–El Niños, cataclysmic drought, global climate change) have a greater role than humans in determining the past and environment of the Andes. The dynamics of the

Andean environment and Precolumbian societies are attributed to climate fluctuation or climate change. The processes of adoption, expansion, and abandonment of specific farming systems and the rise, flourishing, and collapse of civilizations are reduced to responses to favorable and unfavorable climatic conditions. In the human-centric perspective, climatic fluctuation and change are expected and become a background to human activities. The best evidence for cultural resilience and flexibility in the face of short- and long-term climatic change is the continuity and longevity of rural households and settlements distributed across the landscape and the continued expansion of agricultural production and human population throughout prehistory. The series of short-lived states and urban centers in late prehistory are the best evidence of clear discontinuities in the archaeological record.

DEGRADATION VERSUS ENHANCEMENT OF THE ENVIRONMENT OF THE LAKE TITICACA BASIN

Accepting for a moment the idea that the environment of the Lake Titicaca Basin is dynamic, historically contingent, and a result of human activities over the long term, does this human landscape represent environmental degradation or environmental enhancement? We would also have to ask, at what temporal and spatial scale? I have argued that there is no pristine or original benchmark for comparison. To argue whether human activities are environmental enhancements, sustainable land use, or environmental degradation requires subjective value judgments (Stahl 1996:118–119; Denevan 1992:381; Kirch and Hunt 1997). Quantitative measures of biodiversity through time are not available for the basin. Contemporary studies show that biodiversity and biomass are high in the wetlands of Lake Titicaca despite the high altitude and harsh climatic conditions (Dejoux and Iltis 1992; Levieil and Orlove 1990). I have argued that these wetlands have been maintained and enhanced by humans for thousands of years. Another measure of the health of a landscape could be the sustained human carrying capacity over the long term. Archaeological surveys show that the Lake Titicaca Basin was densely populated during the 2,000–3,000 years before the arrival of the Spanish (Stanish et al. 1997; Albarracín 1996; Albarracín and Mathews 1990). The basin is still one of the most densely populated agrarian landscapes in the Andes.

Numerous scholars suggest that Prehispanic peoples of the Lake Titicaca Basin caused environmental degradation (Winterhalder and Thomas 1978:77–79; Richarson 1991; Seibert 1983; Ellenberg 1979; ONERN 1965; Budowski 1968). Environmental degradation is difficult to define, document, and measure (Blaikie and Brookfield 1987a; Richarson 1991; Botkin 1990; Stahl 1996). As pointed out by Spriggs (1997), environmental degradation of one part of the landscape can actually be landscape enhancement, improvement, management, and sustainable development in another part. Prehispanic deforestation and topsoil erosion at higher elevations reduced the fertility and moisture-holding ability of soils on slopes to the point that the land lost its ability to produce crops, support camelids, and sustain natural faunal and floral communities. At the same time, the earth, organic matter, and nutrients eroding from these slopes were trapped and deposited on river and lake plains to be recycled by farmers using raised fields and q'ochas for intensive crop production, which in turn sustained large urban populations and state-level societies. Increased nutrient input to the lake may have enhanced the overall biomass of wetlands resources. The tensions and conflicts between competing and often spatially overlapping pastoral and farming activities have a long history (Browman 1987; Winterhalder and Thomas 1978). Terracing, raised fields, q'ochas, and bofedales, considered to be ecologically sound and sustainable strategies, involved massive disturbances of soils, hydrology, and vegetation, replacing nature with artificial ecosystems. From the perspective of smallholders, who pass down improvements made to the land and management techniques (fallowing, crop rotation, soil management, and agricultural infrastructure) these disturbances could be considered long-term conservation strategies (Netting 1993; Blaikie and Brookfield 1987a; Hames 1996).

ARCHAEOLOGY AND THE STUDY OF THE ANDEAN LANDCAPE

Environmental change brought about by introduction of Old World species of domestic plants and animals and farming practices, Colonial economic policies, and contemporary urban and agricultural development has occurred at a scale and intensity far greater than at any comparable span of time in prehistory (Denevan 1992; Zimmerer 1996; Gade 1992; Donkin 1979; Mayer 1979). Despite these transformations, the Andes have not suffered the tragedy of the commons to the degree experienced in other parts of the Americas (Denevan 1992:376; Guillet 1981). Guillet (1981:149–150) believes this is due to the intensification of agriculture, sectorial fallowing, risk management, and strong communal ethic still found in Andean communities. Andean farmers have done a good job of adjusting to changing environmental, economic, political, and social conditions through flexibility, diversification, maintenance of heterogeneity in land races, and adoption of techniques and crops that they find useful (Gade 1992; Zimmerer 1996; Morlon 1996). Zimmerer (1996) has argued persuasively that crop biodiversity and indigenous knowledge systems can best be encouraged and maintained at the scale of regional landscapes.

Many of the Precolumbian technologies, landscapes, and indigenous knowledge systems discussed here are abandoned, underutilized, or forgotten. Their physical imprint on the landscape and built environment is enduring. Despite dramatic changes in land tenure, demography, social organization, and economic systems during the past 500 years, the Precolumbian structures of everyday life (fields, pathways, walls, canals, and other features of the built environment and landscape) still shape contemporary rural life in the region. This valuable record of Andean environmental history is now at risk as terrace walls are removed for pasture and raised fields are erased by mechanized plowing and urban expansion (Garaycochea 1986a; Erickson and Candler 1989).

Archaeology can contribute to our understanding of the relationship between humans and the environment and the long-term dynamics that created the Andean landscape. Many of us have argued that what we learn from the material record of human activities on the land could provide viable models for contemporary land use (Morlon 1996; Denevan 2000; Erickson 1998; Kolata et al. 1996). Significant issues that need to be addressed include justice for all segments of society, land reform, adequate wages, access to capital and markets, and fair prices for agricultural produce if there is any hope for a truly sustainable rural development. The environment of the Lake Titicaca Basin has been shaped by human activities, intervention, and management over many millennia. Botkin (1990: 93–201) points out that the future of the environment will depend on similar human input. This future must be informed by a long-term history of the environment that seriously considers the role of humans.

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