Building and Rebuilding Agricultural Terraces in the Colca Valley of Peru[1]

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A new search for appropriate agricultural technologies in the Andes is centering upon restoring pre-Hispanic terraces and raised fields (cf. Morlon et al. 1982; Portocarrero 1986; de la Torre et al. 1986; Guillet 1986). In Peru alone, indigenous farmers built more than one million hectares of agricultural terraces (Masson 1986, 208). Agronomically, terrraces are well adapted to mountain topography and soils and to the climatic variability of the Andean environment. In socio- political terms, the recent, intense preoccupation of both scholars and planners with aboriginal technology goes hand in hand with the popular conviction that Andean cultural achievements equal or surpass European ones. Restoring these abandoned production systems, proponents argue, will open new lands cheaply, stem coast-bound migration by offering rural employment, and lay the foundations of an ecologically sound, distinctly Andean political economy.

This article reviews some technical and political aspects of terracing based upon observation of a project to rehabilitate 30 hectares of abandoned terrraces in the village of Coporaque in the Colca Valley, Department of Arequipa, Peru (Figure 1). The Coporaque project is unfinished and the analysis here is preliminary. The point of departure is a brief background discussion of terracing in the valley, followed by a description of terrace construction and reconstruction. By observing a large-scale restoration effort, fieldwork employed ethnographic analogy to discover how pre-Hispanic terraces were made in the region. Colca Valley farmers themselves derive principles of terrace engineering by building or repairing them. Their teachers, they say, are the *machulas*, or ancestors, who built the walled fields that farmers today continue to plant and harvest. The closing section reflects on terrace research and its relationship with the politics of terrace restoration.

Fig. 1. The Colca Valley region, southern Peru.

AGRICULTURE IN THE COLCA VALLEY

The magnificently sculpted terrace landscape of the Colca Valley is a triumph of Andean engineering. The valley contains more than 14,000 hectares of fields (Denevan and Hartwig 1986, 104); two-thirds of them are walled, irrigated valley-side terraces (Figure 2); the rest are embanked, leveled bottomland fields on wide alluvial plains (Figure 3). Radiocarbon tests indicate that some of the fields may date from between 300 and 800 A.D. (Malpass 1986, 163-165); however, firm archaeological sequences for the region are lacking. Evidence of Inca occupation in the valley is widespread.

Farmers plant maize, broadbeans (*habas*), barley, alfalfa, quinoa, potatoes, and other minor crops in the Colca Valley. Any of these cultigens may appear **[end p. 51]**on terraces, often elaborately intercropped. Maize, however, is almost exclusively seeded on terraces. Cash cropping of barley and potatoes for the Arequipa market is expanding because purchases of bread, noodles, kerosene, clothes, and other goods are consuming a growing proportion of farmers' incomes.

Fig. 2. Valley-side walled terraces. Cultivated terraces line the slope below a contour canal. Abandoned and semi-restored terraces are above.

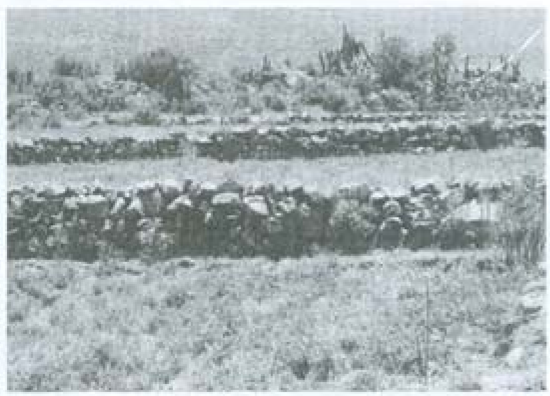

Fig. 3. Bottomland embanked terraces with alfalfa. The walls are 40 to 80 cm high.

Cultivated terraces are privately owned, but water is managed as a communal resource. Water is critically important for agriculture in the arid Colca region (annual precipitation is around 400 mm). Complex webs of canals channel water to fields from snow-capped peaks above the valley, or from widely distributed natural springs. Most local political disputes concern water rights, and the social dynamics within Colca Valley villages are largely concerned with water distribution.

Two-thirds of the valley's terraces are abandoned but many are recoverable. The causes of abandonnment, still under study, include depopulation folllowing the Conquest, colonial disruption of traditional land use, and water shortages (Denevan 1986,543-46). Abandoned fields are commonly located on slopes above cultivated fields and are usuually distant from settlement sites. Most abandoned lands are associated with unused, but reparable canal systems. Abandoned terraces, rubble-covered and weedy, are grazed only lightly by cattle. The legal status of abandoned lands varies from village to village. Local authorities are empowered to declare them communal grazing zones, private grazing parcels, or private plots for restoration and planting if water supplies are sufficient. Many unused fields, however, are in legal limbo, beset by competing claims. Farmers destroy relatively few abandoned terraces. Some dismantle terrace walls to make catttle pens, leaving the earthen backwalls exposed. Others seeking to widen fields for easier plowing have accelerated wall destruction on cultivated terrraces.

TERRACE CONSTRUCTION, EROSION, AND RESTORATION

Analysis of data on how the Colca Valley terraces were originally made is incomplete; however, soil profiles, testimony from farmers, and close obserrvation of reconstruction methods during the Coporaque project reveal the basic procedures builders used. Most Colca slope soils are derived from weathering basalts and andesites or are alluvial deposits of these materials. Bottomland alluvial soils are deep and often poorly drained. The topsoil on high, steep slopes was originally at least 50 to 80 cm in depth. The original topsoil depth on a slope in the agricultural zone is difficult to calculate because unterraced but "terracable" slopes do not exist in most parts of the valley. Terrace fill was made from in situ material; no soils were transported from elsewhere (Sandor 1986, 245). A common pedological feature in the Coporaque area is an indurated Bt horizon, a possible incipient duripan, lying from 30 to 50 cm below the topsoil (Jon Sandor, pers. comm. 1987). Abundant colluvium, tumbling down from eroding rock cliffs, blankets most slopes. The hardened subsoil and abundant sources of cobble-sized stones were convenient pretations, so to speak, for terracing.

Aboriginal masons almost certainly planned or built canals before embarking upon large-scale terrrace construction or built canals and terraces conncurrently. In the Colca Valley, terraces are fundamentally hydraulic features for controling irrrigation water; there are, however, some unirrigated, segmented terraces high on steep slopes above the reach of canals. Farmers build terraces in the wet season because heavy, moist earth commpresses tightly, lowering the risk of waterlogging during heavy rains. Builders probably commenced **[end p. 52]** their labors by clearing or burning off vegetation, followed by gathering up large quantities of stone. Gravel-sized pieces are found packed into thick walls, called *sucwas* in Quechua, which run parallel to the slope forming terrace endwalls. People in Coporaque believe these pockets of gravel stem from builders literally sifting the topsoil and reemoving unwanted stone, an arduous process that indeed may have been carried out. Cobble-sized stones were collected for retaining walls and fill. Builders likely shattered boulders to make flat-sided stones for wall faces.

Fig. 4. Exposed cobble and gravel fill 50 to 80 cm deep. The base stones of a new wall are laid out in front.

Evidence suggests that on steep slopes builders began terracing from the bottom and proceeded upslope, using gravity to help move soil behind the walls. The terrace base is comprised of stones placed upon bedrock or, more commonly, upon the hard subsoil some 50 cm deep. Behind the base builders placed a cobble and gravel fill layer from 50 to 80 cm deep (Figure 4). There are four probable explanations for the fill: (1) it was a dump for excess stone and gravel; (2) it economized on the amount of earthen fill required to level the terrace; (3) it lessened the weight of material behind the wall, thus reducing the risk of wall failure; (4) it provided quick drainage when the terrace became saturated. Farmers today cite drainage as the primary reason for the fill, however, all the above explanations are plausible.

Leveling the terrace above the base and fill involved digging into the slope, moving soil down toward the wall, and packing it tightly while building the wall higher to retain the soil (Figure 5). As an irrigated terrace on a valley-side slope must be level, or nearly so, to economize on water, builders probably moved the soil themselves during construction, not waiting for natural erosion processes to fill the terrace slowly. In the Colca region, high, unirrigated, segmented terraces were self-filling, as were some of the less-sloping bottomland fields that lack artificial fills. Terrace walls feature indented vertical channels called *qhalchas* (Figure 7) and horizontal stone-embanked canals at the wall bases. These built-in devices indicate irrigation planning accompanied terrace construction. Terraces slope slightly forward or to one side to allow gravity flow of irrigation water over the platform. The degree of slope generally determines the height and width of terraces although variations in this relationship are common, probably because' of differences in topsoil depth. On places where the original topsoil was thin, terraces are low and narrow. The average height of the restored Coporaque terraces is 1.6 m and average platform width is 4.9 m. Vertical columns of terraces are bounded by long vertical irrigation channels, and irrigation methods probably deterrmined optimal terrace length. The restored terraces are 46 m long. Stone masonry style on original terraces follows no easily discernible pattern of rows nor displays stone size gradients from the base tooward the top. Stones 40 cm in diameter often nestle upon stones 10 cm in diameter. Some farmers believe the reason for the jig-saw like masonry is that, during construction, groups of stonelayers worked rapidly, spread out along slopes, each working on segments of a terrace. By working independently, masons could not match up long rows of stones. Gap repairs of damaged terraces, however, do display row-by-row masonry, called *estaquillado* (Figure 6). Experienced wall builders point out that it is not size nor pattern but the idiosyncrasies of stone fit and balance that determine wall strength. Walls also feature protruding stone steps (*takilpus*), which are handy for bounding up and down terraces during irrigation days (Figure 8).

Most often, a terrace is destroyed or damaged when water-logged soil bursts the retaining wall and spills forth. Careless wall repair hastens further wall failure. Ruptures are usually localized to three- or four-meter breaches, but over time an unrepaired gap widens as water erosion enlarges the gap and soil creeps through. Terraces on relatively steep slopes tend to erode faster than those on gentler inclines. Builders blame poor masonry techniques **[end p. 53]** or dry soil construction for wall failure. Common mistakes cited include not fitting stones together tightly or failure to press stones tightly against the earthen fill behind. In the latter case, a gap forms between the wall and fill and the "floating" wall is liable to collapse. Failure to tamp down the earthen fill during construction also causes eventual collapse.

Terrace reconstruction essentially duplicates the labor techniques and sequencing of construction, except that soil spilled from ruptured walls has to be thrown back upslope and re-walled. Workers trench down to the original base, removing the fallen and buried wall and fill stones as they dig. The wall is rebuilt while fill stones and soil are carefully re- packed in behind the wall and tamped down. Guillet (1987) describes identical procedures of wall repair in the village of Lari, 12 km west of Coporaque.

Fig. 5. Farmer standing upon half-completed wall, moving earth downward to fill in behind the stones. Note the jig-saw masonry style.

Fig. 6. Reconstructed vertical water channel *(qhalcha)* used to vent water from one terrace to the next.

A critical consideration in large-scale terrace reconstruction is the labor requirement. The Coporaque project sample is small but suggests that 610 worker-days are required to build a terrace platform 2,781. 3 m2 with a retaining wall of 1,030.8 m2 (Table 1). Thus, just over 2,000 worker-days are required to rebuild one hectare (10,000 m2) of Cooporaque valley-side terraces. The figure is conservvative at best because it does not take into account canal rebuilding, careful platform leveling, and other tasks not completed when the above data were gathered. The per hectare figure is high compared to other projects finished or underway in Peru (Table 2).

A host of factors-terrace size and degree of erosion**[end p. 54]**, soils, organization of work, salaries--

account for the disparities in published figures on terrace restoration. Because most projects tally labor expended in terrace rebuilding--and not on canal reconstruction where irrigation exists--the high range of labor inputs is probably indicative of the requirements for restoring most fields. The Coporaque figures indicate no clear relationship between worker-days expended, male/female worker combinations, and the progress of the work. Men, in general, are more productive earth movers and masons than women, although some older women excel at those tasks. Women normally gather and stack stones next to masons as they fill and raise terrace walls. Differences in terrace size and degree of erosion, as well as labor efficiency, determine the rhythm of work.

Table 1. Progress of the Coporaque terrace project after six weeks.

Week	Men	Women	Worker-days	Platform (m^2)
1	17	4	108	clear veg.
2	19	13	177	1,239.4
3	11	10	88	350.5
4	12	1	65	420.5
5	11	7	96	444.4
6	8	9	76	326.5
	78	44	610	2,781.3
			(1,030.8 m^2 new wall)	

Table 2. Reported per hectare labor requirements for terrace restoration in Peru.

Project	Worker-days per Hectare	Source
Puno (Pusalaya)	2,499	Coolman 1986, 223
Coporaque	2,000	
Puno (Asillo)	622	Ramos 1986, 236
Porcon	500	Araujo 1986, 282
San Pedro de Casta	350	Masson 1986, 213

Analysis of labor requirements and the speed at which heavily eroded terraces are restored can shed light on the efforts that were needed to construct the original terraces. Assuming that constructing terraces on virgin slopes is twice the work of resstoring even heavily eroded ones, then 4,000 workerrdays were needed in pre-Columbian Coporaque to terrace one hectare. In that hypothetical case, 200 people could conceivably terrace one hectare in 20 days, or 2,000 people-less than the pre- Colummbian population of Coporaque--could have terraced 100 hectares in 200 days. Pending further data anallysis, current observations suggest that large-scale terrace construction in the valley could have prooceeded fairly rapidly, keeping in mind that the nootion of speed is highly subjective. If this is so, then questions regarding the agricultural evolution of the Colca Valley arise. Did farmers irrigate bottomlands first, moving upslope later? Did farmers cultivate unterraced slopes or "rustic" terraces during faavorably wetter climatic periods before intensive irrrigated terracing? Were large areas of valley-side terraces built or rebuilt only under the aegis of Inca rule? Archaeological surveys and reconstructions of past climatic regimes may eventually provide annswers.

THE SOCIAL AND POLITICAL CONTEXTS OF TERRACING

Understanding the patterns of pre-Columbian social organization and irrigation management is of utmost importance for understanding how people transsformed the natural environment into a vast productive landscape. The argument that tightly centralized planning is necessary to control irrigation water and thus terrace construction does not necessarily apply in all cases, including the example of the Colca Valley. Padi terraces on a large scale in the Phillippines were made by gradually melding the individual fields of families into an irrigated system (Conklin 1980). In Coporaque, field areas are defined as irrigation sectors, each with independent or semi-independent canal systems, suggesting that work groups (some form of the Andean *ayllu*) may have been responsible for the construction and maintenance of each sector. Careful analysis of pre-Columbian settlement patterns and the local geography of canal systems may allow us to abstract some principles of social structure from the landscape, and ethnohistorical research may disclose how local authorities distributed scarce water reesources.

Yet the most pressing question regarding terraccing is not historical but contemporary: under what conditions will campaigns to restore terraces succceed? Terrace reconstruction projects are on the development agendas of several Peruvian state agencies, among them the *Proyecto de Acondicionamiento Territorial y Vivienda Rural* (PRATVIR), the *Programa para el Apoyo del lngreso Temporal* (PAIT), and the *Programa Nacional de Conservación de Suelos en Cuencas Hidrográficas* (PNSACH). Other state and privately funded agencies are also involved. These groups pinpoint terrace areas, elicit requests from communities for projects, and provide foodstuffs or cash to local farmers to reconstruct crumbling fields and canals.

The enthusiasm to rebuild ancient systems stems, in great measure, from archaeological and geographic research that influences a new breed of development planners. However, most terrace research has dealt with technological and historical issues. The trajectory of terrace research largely began with works on the discovery and classification **[end p. 55]** of terrace landforms (cf. Spencer and Hale 1961; Field 1966; Donkin 1979; Denevan 1980). Besides focusing on the physical attributes of terraces, these papers often advanced historical theories of population pressure and intensification to explain terrace genesis. More technically sophisticated papers on agronomic functions, temperature gradients, and modeling have appeared (Koloseike 1974; Earls 1986). The trajectory has peaked recently by placing terracing within a framework of "eco-development" where terracing is deemed the most correct form of Andean land management as well as a symbol of the vindication of Andean technology.

Fig. 8. Finished terrace with *takilpus* in foreground. Note inward inclination of wall for strength.

The difficulty is that planners have tended to lift terracing from the contemporary social and perceptual context of the Andes by emphasizing the technological virtues and historical roots of terraces. In Coporaque, terraces are, above all, land, and land is inextricably linked to concepts of tenure, water rights, social and family obligations, and economic well-being. The fact that land is terraced does not influence the fundamental constellations of meaning attached to land and property. Restoring abandoned land in Coporaque opened up a Pandora's box of problems: redistributing scarce water, establishing land titles, finding new markets for new production, and resolving land access and control disputes among families competing for prestige. Agencies involved in reconstruction projects in Peru are only now beginning to pay close attention to these issues.

Regarding terracing as an example of an approopriate, recoverable technology and not land with social definitions fails to ask why communities do not bring abandoned terraces under the plow spontaneously. Part of the answer lies in the particular dynamics of local politics and the legal basis of abandoned lands. For example, people in Coporaque had restored and parceled out terraces during the 1950s, primarily to head off legal claims on unused lands by outsiders (under Peruvian law, some abandoned but cultivable lands may be "denounced" and occupied). On other occasions, town political figures seeking popular support have parceled land to townspeople for restoration. Labor requirements and scheduling can mitigate against rapid reconstruction. While people in Coporaque claim labor is abundant, it may not always be availlable. Families tend their own fields first, rebuilding terraces on the few free days they have during the planting and harvesting seasons. During the wet season favorable for terrace reconstruction, many household heads descend to the coast to work as wage laborers on rice plantations. Other restoration projects may face similar scheduling restraints. Terrraced lands may also be a low priority for modernizing farmers: they fall down, they may fail to retain moisture, they are hard to plow with oxen or tractors, and they may be poor environments for some cash crops. Subsistence maize may thrive on terrraces, while marketable barley does less well.

In development planning, a focus on terraces alone is inadequate. Planners should ask whether expansion of the land frontier in the highlands is a solution for out-migration and low production, and what role the cultivable terrace surfaces can play in augmenting rural well-being. Applied research on terracing requires an expanded vision encompassing sociological and local political considerations. Wheatley (1965, 143) mentioned that "cultural geographers have not normally given much attention to the selection of their categories "of investigation," and he questioned the appropriateness of terrrace research leaving aside the "exigent question" of context. There has been a tendency to ignore social issues in recent discussions of the role of terracing in development; discovering social and economic contexts in which terracing can again succceed in the Andes is a new research frontier. **[end p. 56]**

NOTE

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