Scientific Registration n° : 90
Symposium n° : 45
Presentation: oral

Steps toward soil care : ancient agricultural terraces and soils
Des marches vers le soin du sol : les terrasses et sols agricoles anciens

SANDOR Jonathan

Agronomy Department, Iowa State University, Ames, IA, 50011, USA

Insights into soil care through human history can be gained by studying agricultural terraces because of the storehouse of information they hold and their widespread use in time and space among many cultures. The stepped topography created by terracing is a characteristic feature of many of the world's cultivated sloping landscapes. Terracing constitutes some of humanity's strongest and most enduring efforts to manage geomorphic processes in agriculture and to conserve land resources. The array of terracing strategies among past and present agricultural societies reflects the high degree of indigenous knowledge of soil and landscape processes.

Although there is substantial information on aspects of ancient terracing, investigations into terraced soils are relatively few. The limited information on physical, chemical, and biological properties of terraced soils underscores the need for further pedological study. Environmental consequences of ancient and traditional terracing range from cases of successful soil care to circumstances that led to soil degradation.

Due to space limitations, only a few studies are cited in this review. More complete referencing and content are planned for a subsequent publication.

Terracing History and Geography

Ancient and traditional agricultural terraces encompass a broad range of forms and functions, occurring in diverse environments on five continents and Oceania (Table 1). The complex question of origins and spread of terracing through different regions is not addressed here, but likely centers of origin are southwestern and southeastern Asia, and the Americas (Spencer and Hale, 1961; Donkin, 1979).

Comparing earliest known ages for agriculture and terracing (Table 1) indicates that it is more difficult to date ancient agricultural land than crop remains, which can occur in several archaeological contexts. It is interesting that the earliest solid ages for terracing in most regions are similar at 2000-3000 yr B.P. While some direct dates for terraced fields have been obtained, most are inferred from archaeological association. A few researchers suggest older dates of 4000-5000 yr B.P. Spencer and Hale (1961) speculate that terracing began 5-9 millennia ago in the Near East.

Familiar forms of ancient terracing and their geographic association include wet-field terraces of southeastern Asia, bench terraces in mountainous terrain of the

Mediterranean, Himalayas, and Andes, runoff terraces in arid regions, and lynchet and rideaux fields in northwestern Europe (Table 2; Spencer and Hale, 1961; Nir, 1983; Wang and Wang, 1991; Treacy and Denevan, 1994). Functions of terracing for these major types include creation of a stable topographic base for crops, soil retention and erosion control, soil accumulation by sedimentation or hand filling, water control ranging from water spreading to runoff management, irrigation, and ponding, and other microclimate effects. Two basic elements in nearly all terracing are the retaining walls (risers) and interwoven fields (treads). Walls vary from very low to several meters high, from single walls to complex series. Wall construction materials range from in situ bedrock to stones, earth, and living vegetation or other organic materials. Some terraces are built as permanent structures whereas in some systems such as runoff agriculture, their design, placement, and use are more flexible.

Landscape Use and Modification

Landforms used for terracing are diverse at global to local scales, with underlying patterns relating to hydrology, soils, and microclimate. Common terraced landforms include hillslopes and mountainsides, valley margin landforms such a colluvial footslopes, alluvial fans, and stream terraces, and drainageways on upland slopes and in larger valleys. Diverse field placement is characteristic of many indigenous agricultural systems as part of a risk reduction strategy to offset climatic and other environmental uncertainty.

Agricultural terraces often conform closely to natural landforms and landscape features. In some areas they mimic and take advantage of natural stepped topography and geologic formations. Many terraced agroecosystems, with their mosaic of microenvironments among alternating contoured walls and small field segments seem to approximate natural ecosystems in terms of diversity. Aesthetic and religious significance has been ascribed to terraces such as those in the Andes.

Because terracing is done to manage geomorphic processes and land and water resources, landscape properties such as slope geometry, drainage patterns, and sediment transport processes are necessarily changed. The stepped topography resulting from terrace wall construction and sediment filling is generally characterized by reduced field slope angle and length. Direct geomorphic changes spark indirect changes in other landscape and ecosystem components through feedback, complex response, and cascading processes. The spatial extent of surficial change is confined in some terraced systems, while in others entire landscapes are altered, as in many mountain and wet-field terraces or in lynchet areas displaying subtle but pervasive anthropogenic colluviation. Many ancient agricultural terraces have been long abandoned and may be obscured or overprinted by later land use, while others remain intact.

Soil Alteration

Geomorphic processes and agricultural management practices associated with terracing induce metapedogenic change in soil properties and development. The degree of soil change varies greatly, depending on particular processes and practices, duration of use, and environmental sensitivity and response. Some terraced soils differ slightly from their natural state while others are wholly anthropogenic. Soil changes and causal processes and practices documented for major forms of terrace agriculture are given in Table 2. Overlap in effects is evident, though each terrace system and environment tends to produce a characteristic set of soil changes. Changes resulting from terracing range from direct to indirect, deliberate to unintentional, and major to minor in impact. At the profile scale, some horizon changes are limited to the surface, while others extend well into subsurface horizons, and in some cases, soils have been completely reconstituted (e.g., van Breemen et al, 1970).

Perhaps the most visible form of terraced soil change is surface horizon thickening and the burial of original horizons, which follows sediment filling upslope of retaining walls. At the low end of the range are slight increases (few centimeters) found in many hillslope runoff terraces and lynchets involving low terrace walls and natural sedimentation. Substantial thickening of one to several meters is more characteristic of extensive bench and wet-field terraces filled by hand during terrace construction. Multiple fills and complex stratigraphy are found where agricultural terraces were rebuilt or incrementally filled, as is common in runoff agriculture (e.g., Bruins, 1990). Other common soil morphological changes involve texture and fabric. Soil chemical changes, such as in organic matter and phosphorus, have been reported in different kinds of terrace agriculture, but there are few biological studies except in terraced rice paddy soils.

Under long-term transformation, many terraced soils develop properties of anthropogenic horizons such as plaggen, anthropic, and agric, which are recognized in other agricultural and archaeological contexts. Cultural debris and artifacts (Courty et al., 1989) as well as elevated phosphorus levels (Sandor and Eash, 1991) can be found in a number of terraced soils. Wet-field terraces produce anthraquic soils.

Cases of Soil Conservation and Degradation

Some of the best examples known of long-term soil conservation involve terrace agriculture, which is significant given that successful care of land resources in the 10,000 year history of agricultural land use is rare relative to numerous cases of soil degradation. Yet if not properly maintained or if located in environments sensitive to disturbance, terracing can also lead to pronounced long-term land degradation. This is not surprising considering that terracing can involve a relatively high degree of landscape alteration.

Among the most vulnerable environments are slopes that become highly erodible following clearing of vegetative cover for cultivation. Examples of degraded terraced landscapes under these circumstances can be found in several geographic areas with a range of climate and geomorphology such as the Mediterranean, the loess region of China, the North American Southwest, and northwestern Europe. In the latter example, the lynchet form of terracing likely originated from accelerated erosion, but in the process more stable terraced land was achieved. In runoff agriculture especially, erosion plays an essential role in soil moisture and fertility, and actually may be encouraged.

Examples of long-term care of terraced lands are also diverse in geography, environment, and agricultural system, such as the Ifugao rice terraces in the Philippines (van Breemen et al., 1970) and Andean terraces (Sandor and Eash, 1991; Treacy and Denevan, 1994). Criteria for long-term soil conservation in the Andes are enhancement of soil tilth and nutrient status relative to corresponding uncultivated soils. Although more quantitative soil studies are needed, a number of terraced systems seem to have stood the test of time and are still productive under traditional management practices. Overall, it is likely that conservation was often preceded by soil degradation. Practices such as terracing may have evolved in response to land degradation when people were able to correct their mistakes in time.

Indigenous Knowledge Revealed in Terracing

Indigenous knowledge about soil and its care is implicit throughout this discussion of terracing. The placement, construction, and soil characteristics of agricultural terraces carry the tangible manifestations of what cultures have learned in working in their environments about resources and their conservation. A key element of indigenous knowledge is that it is time-tested, incorporating and linking the collected experience of people who have lived on the same land for many generations. This especially applies to traditional peoples who continue to farm and maintain ancient agricultural terraces built by their ancestors (e.g., van Breemen et al., 1970; Sandor and Eash, 1991).

Components of indigenous knowledge particularly relevant to the history of soil care are traditional soil classification and soil management practices. Among indigenous soil classifications that have been studied, two examples of the most developed and complex involve cultures relying on terrace agriculture: the Ifugao in the Philippines and some Andean farmers, whose ancient terracing systems are among the finest in the world. In the Andean example, over 50 names for soils in a four-tiered taxonomy are closely tied to an impressive terrace agriculture that incorporates several management practices conducive to maintaining soil quality.

Conclusions

Ancient agricultural terraces, their landscapes, soils, and farmers represent a library from which to learn about soil care, including both successes and failures. The long time perspective on soil quality gained by studying this venerable agricultural method can help guide efforts to conserve land resources for future generations.

References

Bruins, H.J. 1990. Ancient agricultural terraces at Nahal Mitnan. Atiqot 10: 22-28.

Courty, M.A., P. Goldberg, and R. Macphail. 1989. Soils, micromorphology, and archaeology. Cambridge Univ. Press, England.

Donkin, R.A. 1979. Agricultural terracing in the aboriginal New World. Univ. of Arizona Press, Tucson.

Nir, D. 1983. Man, a geomorphological agent. Keter Publishing House, Jerusalem.

Sandor, J.A., and N.S. Eash. 1991. Significance of ancient agricultural soils for long-term agronomic studies and sustainable agriculture research. Agron. J. 83: 29-37.

Spencer, J.E., and G.A. Hale. 1961. The origin, nature, and distribution of agricultural terracing. Pacific Viewpoint 2: 1-40.

Treacy, J.M., and W.M. Denevan. 1994. The creation of cultivable land through terracing. p. 91-110. In N.F. Miller and K.L. Gleason (ed.) The archaeology of garden and field. Univ. of Pennsylvania Press, Philadelphia.

van Breemen, N., et al. 1970. The Ifugao rice terraces. p. 39-73. In N. van Breemen et al. (ed.) Aspects of rice growing in Asia and the Americas. H. Veenmen and Zonen N.V., Wageningen, The Netherlands.

Wang Xing-guang, and Wang Lin. 1991. On the ancient terraced fields in China. Tools and Tillage 6: 191-201.

Keywords: anthropogenic soils, soils and archaeology, agricultural history, terracing, indigenous knowledge, ethnopedology

Mots clés : sols anthropiques, sols et archéologie, histoire de l'agriculture, mise en terrasse, savoir indigéne, éthnopédologie

Table 1. Geography and approximate early ages for agriculture and terracing.

Location		Early Ages (yr B.P.)		
Continent/Region	**Subregion**	**Agriculture**	**Terracing**	**Comments on Terracing Ages**
Eastern Asia	China	8500-11,500	3000	Uncertainty about older age
	Japan/Korea	3000-5000	?	
Southern to SE Asia and Oceania	India/Indochina	5000-7000	2300-3100	3100 yr B.P. Pakistan
	Philippines	3400-5000	2000	
	Papua New Guinea	9000	?	Ancient but uncertain age
	Polynesia	1000-3600	1100	
Southwestern Asia	Near East	10,000	3000-5000	Possible 5000 yr B.P. age for gabarbands in Baluchistan. 5000-9000 yr B.P. speculated for origin of terrace agriculture.
Europe	Mediterranean	8000	2500-4000	4000 yr B.P. Italy, 3700 yr B.P. Crete
	Eastern Europe	5000-7000	?	
	Western Europe	5000-7000	2000-3500	Early ages for lynchets
Africa	North Africa	6500	3000	Runoff terraces; 2450 yr B.P. Ethiopia.
	SubSaharan Africa	3000-5000	500	Uncertainty about older age.
MesoAmerica		5000-10000	2500	
South America		4000-5000	2500	
North America		3000-5000	1000	Uncertainty about older age

Table 2. Examples of common processes, soil management practices, and soil property changes documented in different kinds of ancient and traditional terrace agriculture.

<u>Mountain</u> Geomorphic processes: slope decrease/leveling, some colluvial sedimentation. Soil practices: relatively large walls, construction filling, fertilization, some irrigated. Morphology: thickened A horizons, buried horizons, plaggen, anthropic, agric horizons; horizon reshaping, texture and rock fragment changes, structure and pore changes. Chemistry: cases of organic C, N, P increase; CEC change, pH variable change. Biology: soil fauna, enzyme activity changes.
<u>Wet-Field</u> Geomorphic/pedogenic processes: paddy soil proc., anthraquic conditions, slope leveling. Soil practices: water impoundment, puddling, green manure, fertilization, soil additions/emplacement (e.g., hydraulic filling). Morphology: new soil materials, constructed texture with clayey surface, soil thickening to several meters, plow pan, agric horizon. Chemistry: inverted gley, ferrolysis, altered clay minerals, some organic matter increases. Biology: aquatic, anaerobic organisms.
<u>Runoff</u> Geomorphic processes: fluvial/colluvial episodic sedimentation, slope decrease. Soil practices: relatively small walls/dams, sometimes deliberate watershed erosion. Morphology: some A horizon thickening, buried horizons, increase in soil moisture and potential water retention. Chemistry: examples of both increase and decrease in organic C, N, P, pH. Biology: organic debris and microbial input via sedimentation.
<u>Lynchet/Rideaux</u> Geomorphic/pedogenic processes: mainly colluvial sedimentation after land clearing, especially intrafield erosion in humid climate; eolian additions, agric processes (slaking, mobilization, translocation of fine sand, silt and clay), sediment mixing. Soil practices: relatively small field boundary walls, tillage. Morphology: some A horizon thickening, buried horizons, homogenization from plowing/mixing but also heterogeneous fabrics, agric horizons (e.g., dusty clay coatings, crust fragments), extrinsic additions (e.g., charcoal, ceramics). Chemistry: examples of lower to higher organic matter and P. Biology: common increase in biological activity if organic additions.