LAND REHABILITATION

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Summary

Land rehabilitation is an intervention designed to make a geo-ecological improvement. In most contexts, this involves the mitigation or reversal of land degradation caused by poor land husbandry practices, especially agricultural practices. The key issues in land rehabilitation concern to what degree the land should be rehabilitated to self-sustaining natural control and to what degree to a sustainable economic after-use, where future land quality is sustained by careful management and repair.

In many contexts, land rehabilitation works involve countering the physical symptoms of land degradation, which include losses of soil quality due to soil or subsoil

compaction, and also accelerated runoff and erosion on hill slopes and in watercourses. In other contexts, the interventions involve the mitigation of wind erosion and pollution – especially by salts or industrial wastes, or military ordinance. The success of a land rehabilitation strategy, if it is not expressed in economic terms, is evaluated in the same terms as progress in ecological succession, commonly the integration, efficiency and resiliency of the geo-ecological system.

Rehabilitation treatments divide between those that treat the problems in the soil, usually by changes in land management, and those that treat the consequences of soil degradation, usually by engineering. In every case, since the fundamental causes of the land degradation are the social and economic processes that drive human societies to abuse the land, the long-term success of any land rehabilitation intervention depends upon the changes in land management.

1. Introduction

This section describes the ideas, strategies and methods currently employed for the rehabilitation of land that has become damaged by human actions. Many human activities cause land to become degraded to the point where it becomes unproductive or a negative factor in environmental quality. Across large parts of the world, human action has degraded the landscape to a condition where its productive potential is much less than in former times, at least allegedly. These include the eroded ravine lands of China, India and Pakistan, the barrens of the Mediterranean Basin, central Asia and the Sahel.

There are large areas damaged by soil salinization following misconceived irrigation, soil erosion following agriculture or deforestation, and tracts damaged by military, mining, and construction activities, especially surface mining and road construction. In some cases, the environment has been transformed to such an extent that recovery is unlikely to become a viable option. In others, there is a real potential for these damaged lands to be recycled to new uses or rehabilitated for nature. These processes, both natural and technological, that involve variously aspects of both ecology and engineering, are the focus for the notes that follow.

2. The Problem: Land Degradation

The driving force for land rehabilitation is land degradation. Land degradation is a composite term indicating the aggregate diminution of the productive potential of the land, including its major uses (rain-fed arable, irrigated, rangeland, forestry), its farming systems (e.g. smallholder subsistence) and its value as an economic resource. This term, which includes the subset of "desertification" refers to the decline of the biological productive potential of land, namely the entire geo-ecological system that includes soils, waters, climate, vegetation, topography, and land use.

Land degradation may be an inherent property of the natural system (e.g. some of the eroded ravine lands of South Asia may be due to tectonic uplift generated channel incision). In other cases, climatic change may be implicated. More usually, land degradation is caused by a mismatch between the land's self-sustainable biological potential, its quality in human terms, and the way the land is used. Simply, the way the land is used causes more damage to the land than its restorative systems can compensate. This chapter deals with the physical and technical processes of land rehabilitation but both land degradation and rehabilitation are driven by social and economic causes. Ultimately, land degradation and land rehabilitation are human processes that reflect the ways in which human societies use and value the land that feeds them.

Environmentalists occasionally protest that land degradation is “irreversible”. However, this chapter is devoted to the belief that most degraded lands can heal and, indeed, will heal themselves given sufficient time and the appropriate circumstances. It includes the belief that land degradation can be mitigated with the help of human intervention but also that most land degradation is preventable and that prevention is much better than any cure that rehabilitation work may aspire to provide.
However, the physical cause of land degradation is commonly a reduction in soil quality that fosters runoff and erosion ahead of soil formation and which reduces the biological productivity of affected lands. Soil degradation is a process that lowers the current and/or future capacity of the soils to produce goods or services. Soil degradation can be mitigated if land is left for sufficiently long periods “in fallow” which enables biological restoration of soil characteristics that have become degraded, notably its porosity and nutrient content. During this recuperation phase, biological processes can return the soil to a good condition for the growth of plant roots. However, land shortages are now reducing the time that land can be allowed to remain in fallow, with the result that the rate of degradation and loss of underlying productive potential during the cropping period increases.

2.1. Extent of Land Degradation

The question that arises, however, is how much of the land in the world is degraded and how much suitable for land rehabilitation treatment? The truth is that it is impossible to know. Produced during the late 1980s, GLASOD was the first systematic attempt to produce a global overview of soil and land degradation but since there is insufficient data for all but a tiny fraction of the earth's surface, much had to be based of guesswork and estimation. Nevertheless, GLASOD’s *“World Map of the Status of Human Induced Land Degradation”*, the second edition of which was published by ISRIC and UNEP in Wageningen in 1991 by Oldeman and colleagues provides a benchmark. GLASOD suggests that the globally land degradation affects about 15% of the world's dry land surface and 22% of its agricultural land base and 70% of the world’s dry land areas. Water erosion is the primary cause. The area where degradation is rated strong or extreme, where land rehabilitation is an issue, sums to around 3,050 m. ha. Water erosion is the main reason on 73% of this land and wind erosion on 8.5%. Human induced chemical soil degradation, mainly due to salinization and pollution is thought to affect more than 12% of the total degraded land area and 15% of that requiring rehabilitation.

Land use category	Total area (million hectares)	Area affected by land degradation (per cent)
Total land area	13,000	15

Total agricultural area	8,735	22
Total area of degraded land	1,965	100% from which:
Degraded by water erosion	1,094	56
Degraded by wind erosion	549	28
Degraded by soil structural damage	83.3	4
Degraded soil fertility – chemical degradation	135.3	7
Salinisation	76.3	4
Soil pollution (inclusive of industrial)	21.8	1
Acidification	5.7	0

Table 1: Estimated extent of land degradation

After loss of vegetative cover, soil compaction is often named as the major cause for land degradation by water erosion - because small changes in the soils architecture can result in large-scale changes in a soil's ability to absorb potentially erosive rainwater. Soil physical damage is an increasingly serious problem for agriculture. However, soil and subsoil compaction is difficult to estimate and official GLASOD estimates could be a huge under-estimation of the problem.

Recent years have seen a 3-4 fold increase in both the size of farm machinery and the frequency of trafficking across agricultural lands. This has placed more loading and more stress on their soils, both surface and subsurface. Studies undertaken in Scotland suggest that as much as 90% of cultivated arable land can suffer trafficking by heavy vehicles during an annual cycle of cultivation and, although reworking of the soil surface mitigates much of the compaction so caused, damage to the subsoil layer persists. The consequences of soil structural damage include reduced agricultural production and accelerated runoff and erosion from affected lands.

Before GLASOD, earlier estimates suggested that, worldwide, perhaps 12 x 10^6 ha of degraded arable land is abandoned annually due to unsustainable farming practices. In 1984, Brown and Wolf wrote an influential pamphlet called “Soil Erosion the Quiet Crisis in the World Economy” for Washington’s World Watch Institute. Here, they estimated that the world was losing around 28 bn. t. (25,400 million tons) of soil in excess of soil formation from its 1270 m. ha of cropland. Allowing each acre approximately 180 mm of topsoil, this suggested a decade loss rate of 7%, which if true would have eliminated half the world's productive topsoil before 2025. The mining away of the world's productive topsoil was called the “quiet crisis” because the changes involved may be imperceptibly tiny in the context of each annual agricultural cycle, but cumulatively disastrous measured across several decades.

Today, it has been suggested that, on the global scale, the loss of 75 bn. t. of topsoil to erosion each year represents a cost to each person on the planet the equivalent of $70 each year in lost production. Yield reduction in Africa due to past erosion is estimated as 8% overall. Many writers contest the link between erosion and yield reduction and soil loss, noting that biological productivity depends more on the quality of the soil that remains in the field than that lost in erosion. Nevertheless, the fact remains that the topsoils, which are lost to erosion or damaged by physical or soil chemical degradation, rank with the most productive and the most critical to people that depend on them for their livelihoods. Topsoil damaging processes create the lands that demand rehabilitation treatment.

2.2. Estimates of Areas needing Rehabilitation Treatment

The term "degraded land" contains an implicit value judgment. Some land has been in a degraded state for so long that the condition is now considered natural and normal - as in most of Western Europe and on the shores of the Mediterranean, much of which is technically deforested. Sometimes land degradation goes undetected because its symptoms are hard to see, as in the case of subsoil compaction and many forms of chemical and biological pollution. The trickiest issue is that most land that has been used by humans is degraded from its original condition. However, application of the term "degraded" involves a qualitative assessment that the land is sufficiently damaged to warrant being recognized as a human concern. Normally, degraded land is recognized because it is considered either wasteland, or wasted land, or occasionally, land that is rapidly wasting away from productive value.

Of course, collecting reliable information on either soil or land degradation at the national, let alone global scale, is a near impossible task. So, the inevitable conclusion must be that these estimates reduce either to educated guesswork or to political propaganda on the part of their authors. However, arguably, even these data are better than nothing.

Total Area (3,050 million hectares)	**100%**
Water Erosion	73%
Wind Erosion	9%
Soil chemical degradation	14%
Soil physical degradation	4%

Table 2: Estimated extent of land area requiring rehabilitation treatment

3. Sustainability Concepts in Land Rehabilitation

There are aspects of land rehabilitation that affect every project. First, there is the decision concerning the nature of the after-use. Will the land be restored to nature or to human utilization?

If the land is to be restored to nature, then the focus of the project becomes the establishment of biological control of the environment. This means the generation of an autonomous, self-sustaining geo-ecological system. Here, the key indicators of success include the vitality, productivity and resilience of the system. Often measured are the system's capacity to recycle organic and mineral components, and its capacity to effect self-catalyzing environmental improvement, which is often manifested through the normal patterns of ecological succession.

If, however, the rehabilitation is to human use, then the key criteria become the sustainability of that after-use. This is measured in terms of the cost and benefits of maintaining environmental quality and the capacity of the local land management to preserve or enhance the productive quality of the land, howsoever defined.

In reality, this creates a huge problem. A major proportion of land reclaimed or rehabilitated for human use does not remain in a good quality condition. One common reason is that the land users do not have the will, the skill or perhaps the resources to sustain its quality. This is as much a problem for the reclaimed coalmine lands of Europe as it is for the agricultural lands in the developing world. For example, between 1969 and 1990, the Government of India invested around Rs16 billion in soil and water conservation. Evaluating the result, the Planning Commission's SWC Working Group agreed that land users had neither willingly adopted conservation measures nor maintained those installed for them.

Of course, these two circumstances, restoration to nature or reclamation for human use, are not absolutes but represent two ends of a spectrum. Many land rehabilitation schemes aim to incorporate both aspects of natural self-sustainability and sustainable human intervention, usually to preserve some aspect of the land that is favorable to human needs. The classic case of this is the ancient technology of long rotation forest fallow agriculture, better known to many as shifting cultivation, slash-and-burn agriculture, and taungya or jhum in Asia. This system uses trees as bio-accumulators and soil restoration agents. Several traditional systems are based on a two to three-year cycle of cultivation. In the first, the land is cleared by cutting down forest and burning. The burn destroys pests, weeds and diseases and it liberates nutrients that the forest had fixed from the atmosphere and mined from the subsoil. Crops, planted into the ash, thrive using this store of nutrients, which is often sufficient to sustain cultivation for two to three years and occasionally more. During this period, declining soil fertility and increasing competition from weed and pests, cause crop yields to decline. Ultimately, cultivation ceases, possibly after some useful trees are set into the land. The forest is allowed to reclaim the soil. Traditionally, the soil was fallowed under forest for perhaps 20-30-years – but, in present circumstances, it is often returned to crop cultivation within a decade.

4. Soil Rehabilitation

The soil is a key component in land rehabilitation. The soil controls what grows on the land and it determines what proportion of the rainfall that falls on the land infiltrates into the soil, runs off as surface or near surface flow, remains stored at the surface in ponds or in the soil attached to the soil particles, and how much is returned to the atmosphere through evaporation/evapo-transpiration. Directly or indirectly, through the vegetative cover, the soil also regulates the rate at which soil is removed by water or wind erosion.

Soil is a living resource; it is a living ecosystem, complex dynamic, evolving, biologically modulated open system. A soil that contains no life is not truly soil; it is *regolith* if it forms in place through physical and chemical weathering or *sediment* if it is moved to another location. Civil Engineers may use the word “soil” to describe any deposit that is not a rock but most other soil sciences include life in their definition.

The soil is defined as “a biotic construct favoring net primary productivity”. It is where the crucial links in most land-based biogeochemical cycles churn. Soil biological processes organize nutrient supply, chemical buffering, soil density, porosity, aeration, and water holding capacity. They affect soil structural stabilization, detoxification, and soil self-creation. Soil biology controls the quality of that soil and, in general, it makes the soil a better place for living things. This is why, in land rehabilitation, the central emphasis rests on the condition and vitality of the soil. Researchers recognize three key areas where improved understanding may help preserve that vitality. These are identification of those soil qualities that abet particular soil uses; that affect soil resilience in terms of the critical limits that define tolerance to particular types of usage; and that affect soil recoverability in terms of the ease with which it may be rehabilitated after degradation.

Soils develop in a range of characteristic morphologies as the result of the vertical and horizontal movements of organisms, organic materials, water, chemicals, and soil particles. The self-creation and evolution of natural soils is conditioned by six factors:

- biological processes, the activities of organisms that grow on and in the soil, together with the chemical impacts of their secretions and waste products;
- geological conditions, which through weathering, determine the character, availability and amount of the material from which the soil skeleton is created;
- geomorphological and hydrological processes, determined by the position of the soil in the landscape system, which affect the amount of erosion, drainage or deposition it has experienced;
- climatic and microclimatic processes that control the activities of the soil biological system and that encourage physical processes through wetting/drying, freeze-thaw and the potential for erosion by wind, rain-splash and runoff;
- time, which determines how long all these factors have had to act, and which may allow the soil relict features created by environmental conditions in the past;
- human impacts, because most soils have been altered by land-use. In many cases, these human soil disturbing activities, including cultivation, forest farming and grazing, have been sustained for many decades or centuries. Most of the soils that are found on land scheduled for rehabilitation have been damaged by inappropriate land use – poor land husbandry.

Frequently, the solution to their problems and, by extension that of land degradation is simply to change the way they are managed. One new direction in soil conservation thinking, propounded by the Better Land Husbandry movement, works on techniques that seek to prevent and reverse land degradation by improving the way the soil is treated. These strategies, at a technical level, focus on improving the quality of the soil by improving its biological protection and structure, and at a socio-economic level, by treating the socio-economic problems that encourage or force land users to permit land misuse.

5. Soil Qualities to be Addressed in Land Rehabilitation

Seven soil quality factors may be tackled during land rehabilitation; many of them are detailed by Shaxson’s *“New Concepts and Approaches to Land Management in the*

Tropics" (FAO, 1999). These are the rate of soil formation, bio-productivity (soil fertility), rainwater infiltration, plant-available soil moisture, evaporative losses from the soil, soil rooting zone and soil chemical toxicity.

5.1. Enhance Soil Depth

Land rehabilitation requires the presence of a self-sustaining soil, which means that there should be a positive balance between soil creation and soil losses to erosion. This can be achieved in two ways, either by reducing the rate of soil removal by erosion, the traditional soil conservation approach, or by enhancing soil formation. Geo-physiologists emphasize the role of organic acids in accelerating the weathering of bedrock as plants mine for the minerals they need and, in the process, accelerating soil formation. Recently, there has been much success using *Mucuna beans* to regenerate soils in tropical steep lands. Mucuna is capable of generating 100 t. ha of green manure each year and has been used to rehabilitate lands that were almost devoid of cultivatable soil. However, increasing effective soil depth can be achieved in many ways besides the incorporation of organic matter. Changes in land management that reduce soil compaction or that lead to a reduction in soil packing density also enhance effective soil depth. Planting aggressively deep rooting crops or using subsoil tillage to break up compacted layers that impede root growth has the same effect.

Alternatively, soil depth can be changed by the physical collection of soils, as during the creation of agricultural terraces by cut and fill from hillsides. In industrial land reclamation, many sites are veneered with topsoil imported from other sites. The agricultural equivalent is to create a site, such as a check-dam, which collects the soil mobilized by erosion and converts it into a flat depositional terrace that can be cultivated. In Asia, farmers of loess-land ravine bottoms run ploughs against the ravine's steep walls, so bringing down new soil onto their fields.

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Journals and Magazines:

Land Degradation and Development [This expensive professional journal carries case studies from many of the key researchers and commentators in this field].

Erosion Control [This magazine features review articles and case studies amidst much material oriented to the erosion control industry, mainly in the USA. Some recent useful review papers have tackled turf, erosion control at the watershed scale, and soil stimulants and amendments. It is also freely available on the internet.]

Proceedings of the International Erosion Control Association [Valuable for case-study notes. However, much less readily available].

Bulletin Reseau Erosion [Edited by ORSTOM, Montpellier, France; is a major source of research, case study and policy information on soil and water conservation and also land rehabilitation work, principally in Africa].

Biographical Sketch

Martin Haigh is Vice-President (Europe) for the World Association of Soil and Water Conservation, and Professor of Physical Geography at Oxford Brookes University, the New University in Oxford, England. Professor Haigh's research and teaching focuses on the reconstruction of lands that have been damaged by human actions, especially surface mining, road construction, deforestation and agricultural extension, particularly in the headwater regions of Europe, South Asia and most recently Central America. Recent books include: Reclaimed Land: Erosion Control, Ecology and Soils (2000, Balkema) and Environmental Regeneration in Headwaters (2000, Kluwer/NATO) produced with J. Krecek for the International Association for Headwater Control.