II. CATEGORIES OF WATERSHED DEGRADATION

A. The meaning of land degradation

The ecological diversity of the many thousands of watersheds to be found in the ESCAP region ranges across an extremely broad spectrum. Watershed conditions can range from wet tropical rain forest to arid desert and from equatorial heat to alpine cold. The richness of their natural resources of soil, water and vegetation varies enormously, ranging from the rich and fecund to the poor and barren. The past management of these resources, and the degree and nature of their exploitation, along with the stability and robustness of the ecosystems in which they occur, has resulted in a widely varying degree of land, resource and ecosystem degradation. Here again, the level of land degradation to be encountered also ranges over a very wide spectrum, ranging from the pristine to the very severely damaged.

The degradation of land is a multi-faceted phenomenon, which can be manifested in a variety of forms. It is generally accepted to mean deterioration of the land surface, either by the accelerated removal of soil, the progressive alteration of soil properties, or the loss of vegetative cover from soil. Some of the causes of land degradation are natural, being the consequence of disaster events such as floods, bushfires or drought, whilst others are the consequence of human activities, such as overgrazing, deforestation or poor agricultural practices. Land degradation can itself aggravate the damage caused by natural disasters, by such means as increasing flood run-off or increasing the potential for serious soil erosion. Land degradation is therefore the consequence of a multitude of causes and effects which all contribute to the reduction of the value of the land for human and ecological purposes.

In this publication, land degradation is classified into three major categories, each of which has a number of sub-categories, as listed below.

(a) Ecosystem alteration, including changes to vegetative cover and composition and the introduction of plant and animal pests, which can be classified into the following sub-categories:

  (i) Deforestation
  (ii) Land clearing
  (iii) Weed invasion
  (iv) Introduction of animal pests
  (v) Loss of wetlands

(b) Soil erosion and deposition, including processes which transport soil and deposit it elsewhere, which can be classified into the following sub-categories:

  (i) Water erosion
  (ii) Wind erosion
  (iii) Siltation and sedimentation
  (iv) Mass movement of soil
  (v) Coastal erosion

(c) Soil degradation, involving the alteration of soil properties *in situ,* which can be classified into the following sub-categories:

  (i) Soil salinity
  (ii) Degradation of soil structure

(iii) Soil fertility decline

(iv) Soil acidification

(v) Waterlogging

(vi) Soil pollution

Each of the sub-categories of land degradation listed above is to be found at various locations within the ESCAP region. At these locations, each of them is a consequence either of unsound or inappropriate watershed land use or of natural disaster occurrence, the effects of which may have been exaggerated or accelerated by land mismanagement. In particular, in the context of this document, land degradation can occur wherever the natural balances in the landscape are altered by development for agriculture, mining, forestry, industry or urban settlement, or for infrastructure such as roads, railways, dams, power stations, pipelines and transmission lines.

The most immediate and obvious *in situ* consequences of land degradation are evident as major changes to soil, vegetation and fauna populations, along with progressive and sometimes total loss of the productivity of the land itself. Within a watershed, land degradation also has *off site* effects, which will include sedimentation of streams, impaired water quality and increased severity of flooding and drought.

In a few words, degraded land can be defined as land which has lost some or all of its value for human use. This implies acceptance of the concept that land is a resource, requiring careful management if it is to retain its resource values. On the basis of this concept, we can enunciate a basic principle of conservation land use:

"to use the land according to its potential, yet conserve it according to its needs."

B. Ecosystem alteration

1. Deforestation and land clearing

Many forms of watershed degradation are evident as some form of direct damage to the soil. In the case of soil erosion and deposition, for example, the effects of degradation are manifested in the loss or transfer of soil, which has direct consequences in reducing the productivity of the site. In the case of soil degradation, the effects are manifested in a deterioration in the *in situ* properties of the soil, again with direct consequences in terms of reduced productivity. In the case of ecosystem alteration, however, the immediate consequence is a deterioration in the quality of the entire ecosystem which the land unit under threat supports. The effects will be manifested in a loss of vegetative biomass, a reduction in vegetation productivity and species diversity, and an impairment of habitat for native flora and fauna, as well as the secondary consequences of water and wind erosion and other forms of soil degradation that will be an eventual result of the reduced or impoverished vegetative cover.

Deforestation is here taken to mean the large-scale removal or partial removal of trees from forested areas, which may be deliberate or due to natural causes. Deliberate causes of deforestation include commercial logging, firewood production, clearing for agricultural or timber plantation purposes, "slash and burn" techniques of shifting agriculture, and clearing for such purposes as urban development or the development of infrastructure such as dams, road, railways or mining facilities. Natural causes of deforestation include wild fire, predation by a variety of pests and parasites, disease, damage by pest animals or grazing animals and human traffic or occupation.

Forests shield the soil surface from heavy rainfall, reduce the rate of run-off by increasing the rate of infiltration and as a consequence decrease the amount of flooding, mitigate soil erosion and limit the sedimentation of rivers. They can also act to control landslides and other forms of mass movement of the land surface.

On the other hand, deforestation of watersheds, especially around smaller rivers and streams, can increase the severity of flooding, reduce stream flows by lowering the watertable and increase sedimentation of rivers. Accelerated erosion, soil salinization and impairment of water quality are other common adverse consequences of deforestation. These secondary forms of degradation and ways and means for controlling or mitigating them will be discussed in some detail in later sections of this chapter.

The factors contributing to deforestation can all adversely affect land and water resources. The loss of protective tree cover has resulted in erosion, landslides and the silting of rivers and dams, as well as increased flooding downstream. The loss of trees also results in reduced organic matter and the loss of nutrients from the soil by leaching. This leads to further degradation of the quality and extent of forest cover. The destruction of trees on steep slopes and along the banks of rivers and streams can significantly increase erosion and sedimentation problems in the lowland areas of watersheds. In the ESCAP region, the rate of deforestation is a major factor contributing to watershed degradation and the increased severity of water related natural disasters. Until comparatively recently, the rate of deforestation in areas of tropical rainforest has been a cause for much national and international concern. There are also countries where the rate of removal of temperate forest and woodland is a matter for concern. Such concern has been heightened by a widespread community perception of the significance of forests in the mitigation of global Greenhouse effects, as well as increasing international concerns for nature conservation and the widespread adoption of sustainable development principles.

Land clearing is here taken to mean the large-scale removal of vegetation from woodlands, shrublands and grasslands in order to use them for such purposes as grazing, cropping or irrigation development. This form of activity is practised in low to marginal rainfall areas where the climatic and soil conditions are not suitable for forest growth but there is potential for large-scale crop or livestock production. As with deforestation, the removal of vegetation makes the land susceptible to water erosion and wind erosion, the latter in particular being a major potential problem in arid and semi-arid areas. Other associated adverse effects may be various forms of soil degradation as a consequence of cropping or irrigation practices, as well as potential invasion and damage by pest species. As is also the case with deforestation, extensive land clearing involves a loss of ecosystem productivity and diversity and the destruction of habitat for native flora and fauna.

Like the other forms of watershed degradation already discussed, land degradation due to deforestation or land clearing occurs as the direct consequence of poor or inappropriate land-use practices and can be avoided through the application of sound land-use planning and management principles. Good management implies sound overall ecosystem management, a process which requires the striking of a balance between economic objectives for productive land use and ecological objectives for the maintenance of ecosystem quality and diversity. Putting it another way, this kind of approach requires the adoption of an ethic of ecologically sustainable development, which in itself is the essence of the integrated watershed management approach.

2. Loss of wetlands

A wetland is an area of land which is partly or wholly inundated by shallow water for part or all of the time. The water in a wetland is normally slow moving or stationary and may be fresh, brackish or saline. In the context of this manual the concern is with natural wetlands, as distinct from artificial wetlands which have been constructed for a variety of purposes which might include water treatment and water quality management, flood control, fish breeding and production, waterbird breeding and production or the cropping of wetland plant species.

Until about twenty years ago, natural wetlands were often considered waste land of little value, which was frequently drained and "rehabilitated" for use in agricultural production or for urban and industrial development. Throughout the ESCAP region there has been a progressive loss of wetlands to such purposes. More recently, it has begun to be appreciated that natural wetlands possess a wide

range of valuable attributes and play a key role in many ecological, biological and environmental processes. Many Governments are now taking positive steps to manage existing wetlands more effectively and preserve and restore degraded wetlands. Application of the integrated watershed management approach involves an appreciation of the role of natural wetlands and the development and implementation of appropriate wetland management policies as an integral part of the overall catchment management programme.

Wetlands are the habitat for a wide and diverse range of animals including waterbirds, frogs, invertebrates and fish species, as well as a variety of water-adapted plants including grasses, rushes and tree species. As the border between aquatic and terrestrial environments, they become strategic refuge areas in times of drought, often providing a haven for endangered species. They provide important breeding and nursery areas for a large range of animals including birds, fish and invertebrates. Estuarine wetlands, including mangrove swamps and salt marshes, form an important link in the productivity of estuarine and offshore fisheries, a majority of coastal fish species spending part of their lives in such areas. Seasonally flooded inland wetlands provide major breeding grounds for water fowl.

Wetlands can have a major effect on water quality downstream, acting as sediment basins, filters and sinks for nutrients that would otherwise cause river and lake eutrophication and trigger algal blooms. Because of their ability to absorb nutrients from water and promote nutrient cycling through plant take-up, wetlands can become highly productive ecosystems, characterized by seasonal changes in plant mix and grazing patterns for a variety of wildlife and domestic animals.

Natural wetlands may have significant effects on the hydrology of a watershed and its river system. They can be effective flood detention storages, reducing flood peaks downstream and attenuating the floodwave pattern. Wetlands may also act as groundwater recharge areas, particularly in upland areas where water is retained in wetland storage for long periods and can gradually percolate into underlying aquifers.

If properly managed, natural wetlands can provide valuable opportunities for agricultural, pastoral and forestry production. In drought periods, wetlands can provide grazing when other areas are depleted. Ephemeral wetlands, often dry for long periods, can provide opportunities for extensive grazing and intermittent crop production. Wetland timbers may provide sawlog and firewood sources. Both inland and estuarine wetlands are extensively used by indigenous peoples as sources of food and water and centres of cultural activity. In urbanized and industrialized regions, natural wetlands provide important sites for a variety of recreational and cultural activities.

The loss or degradation of wetlands may be due to a variety of causes, which may be natural or man-made and direct or indirect. Direct losses are principally the result of deliberate decisions to divert water away from wetlands and drain them so that they can be used for agriculture or for urban and industrial development. Such decisions are driven either by population pressures or by profit motives and stem from a lack of appreciation of the intrinsic ecological and environmental values of wetland ecosystems. In recent years there has been a growing recognition by governments of the importance of wetlands, accompanied by the introduction of regional, national and international policies and agreements requiring the preservation and proper management of natural wetland areas.

Whilst these changes have retarded the rate of loss of wetlands through development pressures, loss and degradation of wetlands still occurs through indirect causes which largely relate to poor management of wetland catchments. Extensive soil erosion on such catchments, as a consequence of the use of inappropriate farming practices, overgrazing or deforestation, causes progressive siltation of wetlands downstream and is a major source of wetland degradation. Both point and non-point pollution sources on wetland catchments, introducing excessive quantities of nutrients or toxic substances, can also be major causes of wetland degradation. On larger river basins, upstream diversion of water for purposes such as domestic or industrial supply, and particularly large-scale irrigation, can also be a major

cause of wetland degradation. Regulation of streamflow for such purposes, or the construction and operation of large upstream reservoirs for flood control, can also be highly damaging to wetlands, interfering with the cyclic sequence of flood periods and drought periods on which many wetland ecosystems depend.

Effective protection of wetlands from these indirect forms of degradation or loss requires the adoption of an integrated watershed management approach in which the various beneficial values of wetland systems are recognized and appropriate control measures are developed and implemented. In particular, land-use planning and control and the general adoption by land users of appropriate land-use management techniques are all essential tools for effective wetland preservation and management.

3. Other forms of ecosystem alteration

Other forms of ecosystem alteration which are an indirect consequence of human activity or inappropriate land use include invasion and damage by a variety of pests, which may include diseases, insect predators, weed species or feral animals. These pests, in their turn, may produce secondary effects of soil erosion and deterioration and ecosystem degradation.

An outstanding example of this form of degradation is the case of the rabbit pest in Australia. Introduced in the mid-nineteenth century for sporting purposes, the rabbit bred explosively and soon spread throughout the southern part of Australia and subsequently through arid and semi-arid areas across the continent. It has since caused enormous damage through overgrazing and burrowing, being a major factor in the initiation of water and wind erosion as well as the degradation of grassland ecosystems and the destruction of the habitat of many small native animals. It has been classified as the cause of the most serious and widespread land degradation in Australia and many billions of dollars has been spent on attempts at its control. Despite the partial success of the disease *Myxomatosis*, introduced in the 1950's, and more recently the *Calicivirus* virus, in achieving large-scale biological control, the rabbit remains a major threat and a potential cause of continuing and widespread land and ecosystem degradation.

Throughout the ESCAP region, a variety of other exotic and feral animals, including feral goats, pigs, buffalo, horses and camels, cause problems of overgrazing, vegetation removal, soil disturbance and consequential water and wind erosion. In many areas, a wide variety of weed and pest species of exotic plants cause very substantial ecosystem alteration and impairment and indirectly result in serious land degradation, loss of habitat and significant reduction in agricultural productivity.

This form of land degradation may not necessarily be the result of poor or inappropriate land use; as in the example of the Australian rabbit, it may be a consequence of the accidental introduction of a pest species or even direct introduction for what seem at the time to be perfectly valid reasons. Frequently, however, land-use decisions have led indirectly to the creation of conditions which greatly favour the establishment and flourishing of various pest species and lead subsequently to various severe forms of land degradation and ecosystem impairment. Such decisions would include the adoption of changed land-use practices, such as extensive deforestation or shrubland clearing to permit cropping or grazing activities, which may provide augmented potential for the establishment and spread of pest species. Land-use policy changes therefore need to be made with careful consideration of their likely adverse environmental and economic consequences

C. Soil erosion and deposition

1. Erosion processes

Erosion is the wearing away of the earth's surface by natural or artificial processes. Under natural conditions it occurs at a spasmodic but slow rate, under the influence of water, wind or gravity. This process is termed "geological erosion" or "natural erosion". Throughout history, human activity has

from time to time caused disastrous erosion and consequential land degradation and loss of land productivity, sometimes over very extensive areas. This process is called "accelerated erosion" or simply "soil erosion".

Within the ESCAP region, soil erosion is the most widespread and most serious problem of land degradation It is particularly extensive in the more arid countries of the region, affecting vast areas of Northern China and Australia. It also occurs at many locations throughout the humid and tropical areas of the region, wherever extensive deforestation, land clearing or agricultural development occurs or where steep land has been cleared for mining or urban development. Its most serious consequence is a reduction in the productivity of agricultural land, potentially a major problem because the population of the region depends upon agricultural production for its food and fibre needs.

2. Water erosion

The most widespread form of soil erosion is water erosion. Water erosion is a complex process involving the detachment of particles from the soil, followed by their transportation and subsequent deposition. The process is an intermittent and episodic one, occurring principally at times of heavy rainfall, overland flow and stream flooding. The rate at which it occurs depends upon many factors, which include climate, weather, soil characteristics, topography, plant cover and land use.

There are several forms of water erosion which include raindrop splash erosion, sheet erosion, rill erosion, gully erosion, tunnel erosion, and streambank erosion. The initiating mechanism for surface erosion is heavy rainfall, during which the impact energy of raindrops breaks up soil aggregates and causes detached particles to move laterally by splash action. On sloping land, there is a net movement of soil particles downhill, which is then further aggravated as overland flow begins and promotes particle transport further downslope. The extent of the erosion is greatly affected by the size and impact energy of the raindrops, the soil structure, the steepness of slope and, particularly, the nature and amount of plant cover available to shelter the soil surface from raindrop impact. Without plant cover to reduce impact energy and assist in binding soil particles together, the rate of erosion will be greatly accelerated.

If heavy rainfall continues, the further detachment and transportation of soil particles downslope will develop through the processes of sheet and rill erosion. Sheet erosion is the comparatively uniform removal of surface soil across a significant area and involves the processes of separation, entrainment and lateral movement both by raindrop splash and by turbulent overland flow. It is usually associated with rill erosion, a process which develops when overland flow becomes concentrated into small channels or rills, as is usually the case except on the very smoothest of surfaces. The term is appropriate when the erosion channels are so small that they can be obliterated by tillage practices; larger erosion channels are called gullies and these are formed by different mechanisms, which are further discussed below.

Rill erosion involves the entrainment and transport of soil particles from the rill channel walls and floor and is caused predominantly by the erosive force of the run-off flowing down the rills. It occurs on comparatively uniform slopes as well as slopes which are uneven and variable in slope and micro-topography. It is usually combined with sheet erosion, the latter occurring on the inter-rill surfaces and transporting detached material into the rill channels, where further transport and additional erosion occurs. Rill erosion is usually the most obvious form of upland surface erosion and the bulk of the downslope movement of eroded soil occurs through transport by rill flow. The factors which determine the rate of rill erosion are complex, but include the rate of surface run-off, the depth of overland flow, the structure and physical characteristics of the eroding soils, and the length and steepness of the eroding slope.

Sheet and rill erosion have the direct effect of removing topsoil and causing the loss of nutrients and organic matter, leaving an unproductive surface which is difficult to cultivate and substantially impairing agricultural productivity potential. These forms of erosion occur most commonly on cropping

Photo 3: For intensively developed urban areas and floodplains, land-use planning and control measures have an important role to play in flood mitigation strategy (Moosan City, Kyungkido Province, Republic of Korea)

Photo 4: Drought may have devastating social and economic consequences for both local and national communities (Kyungkido Province, Republic of Korea)