Chapter one

At the end of this chapter the student should be able to:

- Define land degradation, rehabilitation and vulnerability
- Understand components of land
- Explain trends in land degradation
- Understand processes in land degradation
- Define briefly the term risks of land degradation

1. Concepts and Definitions Land Degradation

- Soil Quality is defined as the capacity of a soil to function within ecosystem and land-use boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health.
- Or soil quality is defined from an environmental perspective as the capacity of the soil to promote the growth of plants, protect watersheds by regulating the infiltration and partitioning of precipitation, and prevent water and air pollution by buffering potential pollutants such as agricultural chemicals, organic wastes, and industrial chemicals.
- It also defined as the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation.
- Soil Fertility as the ability of the soil to supply essential plant nutrients and soil water in adequate amounts and proportions for plant growth and reproduction in the absence of toxic substances which may inhibit plant growth
- Soil productivity is defined as the capacity of a soil to produce a certain yield of crops or other plants under a defined set of management practices or a specific farming system
- Soil degradation is defined as a change in the soil health status resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries. Degraded soils have a health status such, that they do not provide the normal goods and services of the particular soil in its ecosystem.
    - ✓ Soil is one of the key ingredients of land and soil degradation is more precisely defined (Nkonya, et al., 2011). The Soil Atlas of Africa describes soil degradation as the “process that leads to a deterioration of soil properties and functions, often accelerated by human activities” (Jones, et al., 2013).
- Soil Erosion is a common term that is often confused with soil degradation as a whole, but in fact refers only to absolute soil losses in terms of topsoil and nutrients. This is indeed the most visible effect of soil

degradation, but does not cover all of its aspects. Soil erosion is a natural process in mountainous areas, but is often made much worse by poor management practices.

- ✓ Soil erosion is also more specific than both land and soil degradation. It refers only to the absolute loss of topsoil and nutrients, the most visible effect of soil degradation. Wind and water erosion are the main processes affecting soils. It is normally a natural process in mountainous areas, but poor management practices contribute to the potential for any soils to erode (FAO, n.d., Jones, et al., 2013).

- Nutrient depletion: The net loss of plant nutrients from the soil or production system is due to a negative balance between nutrient inputs and outputs. Major channels of nutrient depletion are nutrient removal through soil erosion, harvest, leaching, and denitrification (Lal 1994; Pieri 1995; Enters 1998).

1.1 What is land degradation?

The concepts under laying the use of the terms land and land degradation require definition to understand the subsequent discussions.

- Land refers to climate, water resource, land forms, soils, and vegetation (FAO 1980). It is comprised of the earth's surface including all elements of the physical and biological environment that influence land use. Thus, land resource refers not only to soil but also to land forms, climate, hydrology, vegetation and animals components of an ecosystem.
- Land degradation has a wider scope than both soil erosion and soil degradation in that it covers all negative changes in the capacity of the ecosystem to provide goods and services (including biological and water related goods and services – and in LADA's vision - also land-related social and economic goods and services).
  - ✓ UNCCD defines land degradation as "any reduction or loss in the biological or economic productive capacity of the land resource base. It is generally caused by human activities, exacerbated by natural processes, and often magnified by and closely intertwined with climate change and biodiversity loss" (UNCCD, 2014).
  - ✓ process has broadened to encompass all changes in the capacity of ecosystems affected by land degradation to provide biological, social, and economic services.
  - ✓ his is defined by the UNCCD (1994) in terms of reduction or loss of the biological or economic productivity. LADA has further developed this definition as "the reduction in the capacity of the land to provide ecosystem goods and services, over a period of time, for its beneficiaries". "Ecosystem goods" are products of land which have an economic and/or social value: they include land

availability, animal and plant production, soil health and water quantity and quality. "Ecosystem services" include biodiversity and the maintenance of hydrological, nutrient and carbon cycles. Land degradation is not necessarily confined to biophysical effects, nor is it limited to human-induced phenomena, but also includes natural impacts and effects

According to Blaikie and Brookfield (1987) land degradation is the reduction in the capacity of the land to produce benefits from a particular land use under a specified form of land management. On the other hand, according to Hurni (1993) the unhindered degradation of soil can completely ruin its productive capacity for human purposes and may be further reduced until steps are taken to stop further degradation and restore productivity. This definition embraces not only the biophysical factors of land use but also socioeconomic aspects such as how the land is managed and the expected yield from a plot of land. Agricultural use degrades soil in the long run and reduces its fertility if it is not accompanied by soil conservation measures.

Land degradation remains an important global priority issue for the 21st century requiring renewed attention by individuals, communities, and governments because of its adverse impact on agricultural productivity and the environment, and its effect on food security and quality of life. The phenomenon is a multifaceted and dynamic process that depends on biophysical, socioeconomic, cultural, and institutional factors, with strong negative effects on food security and quality of life. The land degradation process appears particularly severe in developing countries, which has significant implications for climate change mitigation and adaptation. This is because the loss of biomass and soil organic matter releases carbon into the atmosphere and affects the quality of soil and its ability to hold water and nutrients.

1.2 Trends in Land Degradation

GLADIS (Global Land Degradation Information System) is based on an assessment of the status and the trends of ecosystem goods and services:

Status: a representation of the situation as it is, a snapshot of the capacity of the land to provide ecosystem service, taken in a given moment in time. It can be used as baseline information.

Trend: a description of the direction of the actual or potential changes that is ongoing or potential in a given piece of land. It gives an indication of the stability or sustainability of the status. Trends can be either negative (degradation) or positive (improvement).

The combination of the two gives an idea of the overall level of land degradation, allowing for

The most important studies on land degradation designed for purposes of international comparison are the Global Land Assessment of Degradation (GLASOD) mapping exercise by Oldeman, Hakkeling, and Sombroek (1990) and the comparative study of drylands by Dregne and Chou (1992). Both depend on expert judgment. The GLASOD map was developed by asking teams of experts in 21 regions to evaluate human-induced soil degradation since World War II, using systematic criteria.

The GLASOD study defined degradation as a process that lowers either the current or future capacity of the soils to produce goods or services or both. Types of degradation included water and wind erosion, chemical degradation, and physical degradation. The Dregne and Chou study includes vegetation as well as soil degradation; conclusions were synthesized from a systematic evaluation of a large number of preexisting studies by different researchers. The Dregne and Chou study defined desertification as a human-induced process of land degradation that can range in severity from slight to very severe, and can cause effects including erosion, salinization, toxic chemical accumulation, or vegetation degradation, irrespective of climate. In their paper, however, desertification is confined to land degradation in the drylands of the world.

The: GLASOD study estimates that of 8.7 billion hectares of agricultural land, pasture, forest and woodland, nearly 2 billion hectares (22.5 percent) have been degraded since mid-century. Some 3.5 percent of the total has been degraded so severely that it is reversible only through costly engineering measures, if at all. Just over 10 percent has been moderately degraded, and is reversible only through significant on-farm investments. Another nearly 9 percent is lightly degraded and easily reversible through good land husbandry practices.

Globally, GLASOD indicates that nearly half of this vegetated area is under forest, of which about18 percent is degraded; 3.2 billion hectares are under pasture, of which 21 percent is degraded; and nearly1.5 billion hectares are in cropland, of which 38 percent is degraded (Figure 1). Water erosion is the principal cause of degradation. Wind erosion is an important cause, particularly in drylands and areas with landforms conducive to high winds. Chemical degradation, such as salinization and nutrient loss, is the result of cropping practices; it accounts for a smaller overall proportion of degraded lands, but more than 40 percent of cropland degradation. Physical degradation such as compaction accounts for a smaller proportion of degraded area.

The Dregne and Chou study shows that of global drylands, 89 percent is rangelands (of which 73 percent is degraded); 8 percent is rainfed cropland (of which 47 percent is degraded); and 3 percent is irrigated cropland (of which 30 percent is degraded).

Various sources suggest that 5 to 10 million hectares are being lost annually to severe degradation. If this trend continues, 1.4 to 2.8 percent of total agricultural, pasture, and forestland will have been lost by 2020. Declining yields (or increasing input requirements to maintain yields) can be expected over a much larger area.

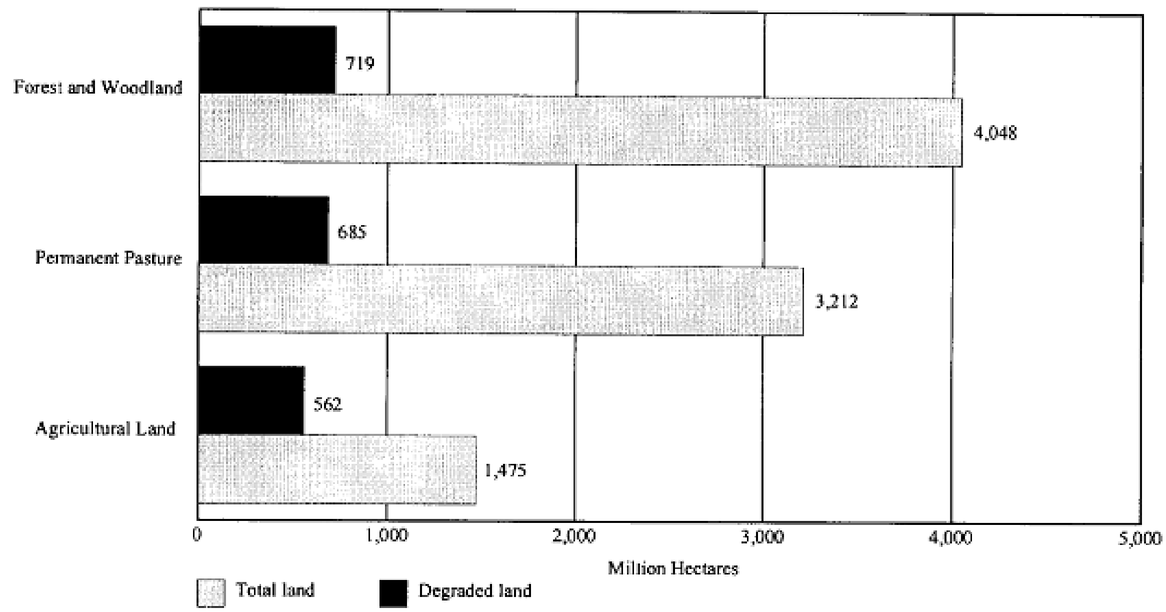
According to the GLASOD estimates, degradation of cropland appears to be most extensive in Africa, affecting 65 percent of cropland area, compared with 51 percent in Latin America and 38 percent in Asia (Figure 2). Degradation of pasture is also most extensive in Africa, affecting 31 percent, compared with 20 percent in Asia and 14 percent in Latin America. Forestland degradation is most extensive in Asia, affecting 27 percent of forestlands, compared with 19 percent in Africa and 14 percent in Latin America.

The magnitude of land degradation (and deforestation) by far exceeds the conservation activities being carried out in Ethiopia. The Ethiopian highlands are affected by deforestation and degraded soils, which have eroded the resource base and aggravated the repeated food shortages caused by drought.

Degradation of soil and water resources is a global threat. It is out of a total degraded land area of 1965 Mha, over 300 Mha are strongly degraded on a world scale.

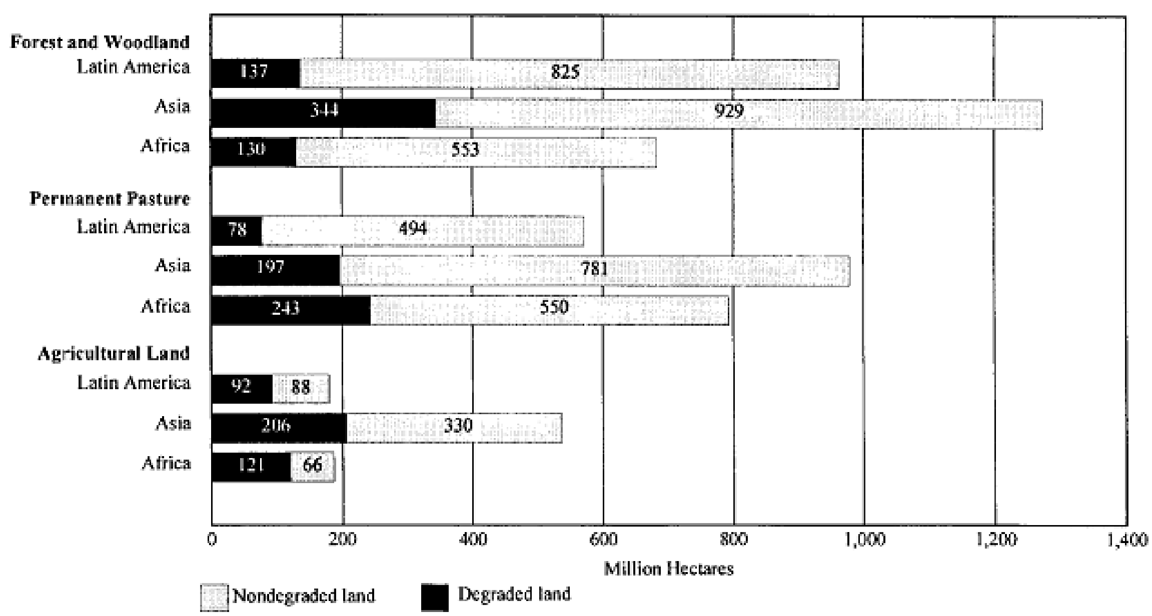
The speed and extent of soil degradation depend on different factors, such as soils, relief, climate and farming systems (intensity of use). Soil loss can be 20 to 40 times higher than the rate of soil formation, which means there is no hope of restoring destroyed soils within a time span that bears any relations to human history.

In the highlands of Ethiopia, the area of greatest livestock density and the area of major land degradation, recorded measurements of soil loss by water erosion range from 3.4 to 84.5 t/ha/yr with a mean of 42 t/ha/yr. This represents a loss of 4 mm of soil a year, which is twenty or more times replacement rates (Hurni, 1993).



Source: Oldeman 1992; Oldeman, Hakkeling, and Sombroek 1990.
Note: Figures are cumulative over slightly, moderately, strongly, and extremely degraded lands.

Figure1. Land degradation by type of land use: A global perspective



Source: Oldeman 1992; Oldeman, Hakkeling, and Sombroek 1990.
Note: Figures are cumulative over slightly, moderately, strongly, and extremely degraded lands.

Figure 2. Land degradation by type of land use: A regional perspective

1.3 Processes of land degradation

Detachment of soil from its original location and transportation to a new location is known as soil erosion. Mainly water is responsible for erosion although in many locations wind, glaciers etc. are also the agents.

In broad sense the erosion process can be classified into two types: geologic and accelerated erosion. They represent contrasting type of soil removal. Geologic erosion includes soil-forming as well as soil-eroding processes that maintain the soil in a favorable balance, suitable for the growth of most plants. Conversely, accelerated erosion includes serious deterioration (loss of soil productivity) and loss of soil due to human tillage or vegetation removal by animals or other natural events.

Geologic erosion is a normal process, which represents the erosion of soil in its natural condition without the influence of human being. Geologic erosion is sometimes also known as natural or normal erosion. This type of erosion has contributed to the formation of our soils and caused many of our present topographic features, such as canyons, stream channels, and valleys. Therefore, the geologic erosion is longtime eroding process. In practical course, the geologic erosion takes place by the action of water, wind, gravity and glaciers.

Accelerated erosion is in excess of geologic erosion. It is activated by the man's activates which have brought about changes in natural cover and soil conditions. The various forces involved in accelerated erosion are as follows:

1. Attacking force of water or wind which remove and transport the soil particles from one place to another, and
2. Retarding forces which resists the erosion.

Water erosion is a complex three-step natural phenomenon which involves *detachment*, *transport*, and *deposition* of soil particles. The process of water erosion begins with discrete raindrops impacting the soil surface and detaching soil particles followed by transport and deposition. The three processes of erosion act in sequence. Detachment and transport of soil particles are the primary processes of soil erosion,

There are three steps to accelerated erosion by water are listed below and shown in Figure 2.1:

1) Detachment or loosening of soil particles caused by flowing water, freezing and thawing of the topsoil, and/or the impact of falling raindrops.
2) Transportation of soil particles by floating, rolling, dragging, and/or splashing.
3) Deposition of transported particlesat some place lower in elevation.

Mechanics: detachment, transportation, deposition

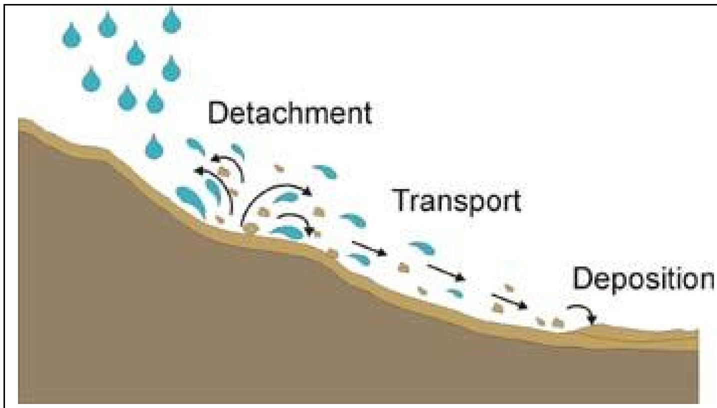


Figure 1.1 The three-step process of soil erosion by water starts with the impact of raindrops on soil.

Forms of erosion

Splash erosion: Splash erosion is the results from the impact of raindrops on the soil surface. The bombardment causes the displacement/detachment of soil particles. The impact can dislodge particles as far as 3 feet (7.6 cm). As they resettle elsewhere they block soil pores and lower infiltration capacity of the soil. Splash erosion also causes soil disintegration (destruction of soil structure).

Sheet erosion: This occurs when rain falls on bare or sparsely covered soil, loosening fine particles (silt, clay and humus) that are carried downhill in surface run-off. Sheet erosion lowers the fertility of the soil, because it removes the most productive layer, which has usually been enriched by fertilizer.

Rill erosion: On sloping land, particularly if cultivated, water run-off may gather in small V-shaped channels or rills. These are particularly evident in pumice soils or those formed from loess (wind-blown dust), but can occur on all hill soils.

Gully erosion: Gully erosion occurs on unconsolidated sub soils. These are generally deep and generate a lot of sediment, which often feeds into rivers. Gullies tend to erode at their head, eating back into the landscape. They are widespread throughout the country.

1.4. Risks and hazards of degradation

Risks of land degradation refers to the effects of land degradation to decline various land functions such as production, biomass, biological habitat, filtration and buffering, and source of raw material, etc. Land degradation hazards included wind and water erosion, loss of soil carbon, nutrient decline mass movement, soil structure decline, acid sulfate soils and soil acidification.

1.5. Vulnerability

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as: the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Although most scholars agree on the broad definition of vulnerability as “the capacity to be harmed,” the use of the term varies among disciplines and research areas.

Hazard is the potential threat to humans and their welfare while vulnerability is exposure and susceptibility to losses; together, hazard and vulnerability add up to risk. It is the probability to hazard occurrence or with disaster as the realization of a risk.

Another definition of *vulnerability* is “the characteristics of a person or group in terms of their capacity to *anticipate*, *cope* with, *resist* and *recover* from the impacts of natural hazards” and states that “vulnerability can be viewed along a continuum from resilience to susceptibility.”

The ordinary use of the word ‘vulnerability’ refers to the capacity to be wounded, i.e., the degree to which a system is likely to experience harm due to exposure to a hazard.

There are different perceptions of what “vulnerability” means, which in turn affect how vulnerability can be measured.

Vulnerability is the risk of being harmed by exogenous shocks which, in the case of LDCs, can imply a marked reduction of long-term average growth rates and impact on development prospects.

Vulnerability is a function of the magnitude and frequency of shocks, the exposure to such shocks and the resilience (i.e., the capacity to react to shocks).

The vulnerability of least-developed countries (LDCs) to climate change has been noted both by researchers and the United Nations. Many LDCs are located in parts of the world that are expected to be badly affected by temperature and precipitation changes. Moreover, climate-sensitive economic sectors, such as agriculture, are more important for the generation of output and income in LDCs than in other countries. Due to their low level of development, LDCs are also less resilient to negative external events and have lower capacity to adapt than other developing countries. This increased vulnerability is seen as unfair, as LDCs have contributed to climate change, by emitting greenhouse gases or by changing their land-use patterns.

1.6. Rehabilitation

Rehabilitation activities are applied on degraded lands in a watershed that produce excess sediments, excess run off and heavy pollutant materials. It requires land use adjustment measures that contribute to the reduction in the mentioned problems and simultaneously increases the productivity of the land and the income of farmers.

Rehabilitation activities include:

- Afforestation/ Reafforestation
- SWC
- Mulching
- Terraces
- Cover crops
- Agroforestry practice

Some terms related to rehabilitation activities at degraded sites are as follow briefly:

Rehabilitation: This refers to making the land useful again after a disturbance. It involves the recovery of ecosystem functions and processes in a degraded habitat. This does not necessarily reestablish the pre disturbance condition, but does involve establishing ecologically and hydrologically stable landscapes that support the natural ecosystem mosaic.

Restoration: This is an activity by which it returns an ecosystem as closely as possible to pre disturbance conditions and functions. The process re establishes the general structure, function, and dynamic self sustaining behavior of the ecosystem. It often done with indigenous species but may also involve exotic one.

Reclamation: This is recovering of productivity (but little of the original biodiversity) at a degraded site. The protective function and many of the original ecological services may be re established. This is often done with exotic species but may also involve native species.

Reforestation: This is the conversion of non forested land to forested land through planting, seeding and/or promotion of natural seed sources on land that was forested but that has been converted to non forested land.

Regeneration: This is growth or re-emergence of the native vegetation in a place after it has been destroyed or degraded, resulting protection of the area from interference.

Afforestation: This isthe conversion of bare land into forest land by planting of forest trees (on and that has never been forested before)

‘Chapter Two:

At the end of this chapter the student should be able to/ answer:

- List forms of land degradation
- Define what does mean Vegetation degradation implies
- The issue of climate change adaptation in context of Ethiopia.

2. Major Forms of Land Degradation

The following biophysical indicators of change in the state of the land and of land degradation can be defined:

2.1 Vegetation degradation

- Reduction in the available biomass, and decline in the vegetative ground cover, as a result of deforestation and overgrazing.
- Reduction is not in the quantity of biomass but also in quality
    - Bush encroachment into rangelands
    - Loss of palatable pasture grasses and their replacement with no palatable species.
- Annual rate of forest clearance (forests/ woodlands)

2.1.1 Land cover/use change:

Alteration of earth‘s land surface due to human action or/and modification of Earth's terrestrial surface. Humans have been modifying land to obtain food and other essentials.

Land cover is the observed cover of the land as seen on the ground or by remote sensing; it comprises the vegetation (natural or planted) and any human constructions which occur on the earth's surface. Open water bodies, ice, bare rock, mobile sands and similar surfaces are included

Land cover change refers to modification of the existing land, cover or complete conversion of the land cover to a new cover type.

Land use concerns the function or purpose for which land is used by the local human population and can be defined as "the human activities which are directly related to land, making use of its resources or having an impact on them".

Land use change is the conversion of land use due to human intervention for various purposes, such as for agriculture, settlement, transportation, infrastructure and manufacturing, parks, recreation uses, mining and fishery (Williams, 1994).

Another distinction to be made is between land characteristics, land properties and land qualities.

Land characteristics are those attributes of the land that help in identifying natural land units.

Land properties are single attributes of the land that connote certain behavior.

A land quality is a complex or compound attribute of the land which acts in a manner distinct, and largely independent, from the actions of other land qualities in its influence on the suitability of land for a specified kind of use. In order to define the degree of suitability, the requirements of potential uses need to be defined in the same terms. For example, an important land quality may be soil moisture storage capacity.

2.2 Soil degradation

Soil degradation is defined as decline in the quality and quantity of soil by several degradative processes including erosion, salinization, soil structure, depletion of soil organic matter and essential nutrients.

Physical, chemical and biological soil degradation

1. Physical soil degradation

- The displacement of soil particles
  - Water erosion
  - Wind erosion
- Internal soil physical degradation
  - Compaction
  - Sealing and crusting
  - Hard setting

Indicators for physical degradation

- ✓ Water logging
- ✓ Sealing and crusting of soil surface after storms
- ✓ Formation of massive structure,
- ✓ very compact when the soil is dry
- ✓ Poor workability,
- ✓ very hard consistence when dry
- ✓ Increased runoff as a result of high bulk density,
- ✓ Reduced infiltration rates and surface sealing.
- ✓ Poor germination of seed

2. Chemical soil degradation

The accumulated negative impact of chemicals and chemical processes that regulate the life processes in soil are;

- ✓ Loss of nutrients mainly as a result of erosion and loss of soil organic matter.

- ✓ Essential elemental imbalances with in the soil
- ✓ Base leaching and acidification: common in high rainfall areas with free draining soils
- ✓ Salinization and sodification.
- ✓ Soil Pollution

Indicators for chemical degradation

- ✓ Acidification (pH< 5.5)
- ✓ Lack of response to fertilizers
- ✓ Deficiency symptoms of K, Ca, Mg
- ✓ Lack of nodulation in legume crops
- ✓ Decrease in yield
- ✓ Salt crust formation at the surface
- ✓ Lack of soil aggregates stability
- ✓ pH > 8.5 indicates sodicity problem

3. Biological Degradation

- Reduction of vegetation cover: Increase of bare/unprotected soil
- Loss of habitats: Decreasing vegetation diversity
- Quantity/biomass decline: Reduced vegetative production for different land use
- Quality and species composition/diversity decline: Loss of natural species, and unpalatable species/weeds.
- Loss of soil life: Decline of soil macro-organisms (earthworms and termites) and micro- organisms (bacteria and fungi…,) in quality and quantity.
- Increase of pests/diseases: Reduction of biological control (e.g. trough loss or predators).

Indicators for chemical degradation

- Decrease or absence of soil macro fauna- earthworms, termites, etc
- Soil color becomes lighter as a result of decrease in organic matter
- Most of the indicators used for physical degradation

Types of soil degradation include:

1) Soil erosion by water: Removal of soil particles by the action of water.
2) Soil erosion by wind: Removal of soil particles by wind action. Usually this is sheet Erosion and wind erosion transport soil particle into three way:-
3) Soil fertility decline: The degradation of soil physical, biological and chemical

properties. Erosion leads to reduced soil productivity, as do:

A) Reduction in soil organic matter, with associated decline in soil biological activity; e.g. Decline of Earthworms, termites, bacteria and fungi …) in quality and quantity.

B) Degradation of soil physical properties as a result of reduced organic matter (structure, aeration and water- holding capacity may be affected); eg. Compaction, Sealing and crusting

C) Changes in soil nutrient content leading to deficiencies, or toxic levels, of nutrients essential for healthy plant growth; e.g. Fertility decline and reduced organic matter content, Acidification, Salinization/alkalinisation

D) Buildup of toxic substances e.g. pollution, incorrect application of fertilizers

4) Waterlogging: Rise In groundwater close to the soil surface or inadequate drainage of surface water,
   - Poor irrigation management
   - Water saturates the root zone leading to oxygen deficiency.
5) Increase in salts: Increase in salt in the soil water solution, or sodication, an increase of sodium cations (Na+) on the soil particles
   - Salinization often occurs in conjunction with poor irrigation management.
   - Mostly, sodication tends to occur naturally. Areas where the water table fluctuates may be prone to sodication.
6) Sedimentation or 'soil burial': Occur through flooding, where fertile soil is buried under less fertile sediments

2.3 Water (drought, water logging, salinity, water pollution)

Water degradation is change in quantity of (surface water, change in groundwater / aquifer level), decline of surface water quality, decline of groundwater quality, reduction of the buffering capacity of wetland areas. More fluctuations in river, stream and spring flows, with more frequent flooding in the rainy season and longer periods of water shortage in the dry season.

It is true that Ethiopia is endowed with water resources. However, there are some constraints that limit the use of water resources for irrigation and other purposes. The physiographic of the country where most of the population concentrated is undulating and not suitable for furrow irrigation, the simplest method of irrigation with greatest loss of water.

In the past 40 to 50 years, due to increasing population pressure in the high lands, fast deforestation took place that has exposed the land to severe water erosion. Hence, the valley bottoms, which could have been put to irrigation, are filled with sediments, making the construction of irrigation structures difficult. There are several examples of failed irrigation projects and structures as a result of filling up of canals or micro-dams by sediments that made maintenance expensive.

Another impact of deforestation in the development of irrigation is in irregularity in the supply of water to the canal. About forty or fifty years ago many of the Ethiopian streams in the highlands were perennial where the springs at the mountain foots and hills provided continues supply of water to the streams. At present however, the springs and streams are dry as a result of deforestation at upstream and the supply of irrigation water is at stake.

Water degradation includes:-

Change in quantity of surface water: Change of the flow regime: flood / peak flow, low flow, drying up of rivers and lakes.

Change in groundwater/aquifer level: Lowering of groundwater table due to over-exploitation or reduced recharge of groundwater; e.g. due to excessive irrigation

Decline of surface and ground water quality: Increased sediments and pollutants, pollutants infiltrating into the aquifers

Reduction of the buffering capacity of wetland areas: To cope with flooding and pollution.

2.3.1 Drought: Drought is a natural hazard originating from a deficiency of precipitation those results in a water shortage for some activities or groups.

- Associated with other climatic factors - such as high temperatures, high winds and low relative humidity.

2.3.2 Waterlogging: Refers to the saturation of soil with water. When the water table of the groundwater is too high

- Excessive irrigation on poorly drained soils, in poorly drained soils where water can't penetrate deeply
- When soils are water logged, air spaces in the soil are filled with water, and plant roots essentially suffocate

2.3.3 Water Pollution: Occurs when a body of water is adversely affected due to the addition of large amounts of materials to the water.

Causes of Water Pollution: Industrial waste, Sewage and waste water, Mining activities, Marine dumping, Accidental Oil leakage, Burning of fossil fuel, Chemical fertilizers and pesticides, Leakage from sewer lines, Global warming, Radioactive waste, Urban development, Leakage from the landfills, Animal waste, Underground storage leakage:

Sources of Water Pollution:

The sources of water pollution are categorized as being a point source or a non-source point of pollution

1. Point refers to the pollutants that belong to a single source. An example of this would be emissions from factories into the water, A pipe spewing toxic chemicals directly into a river
2. Non Point pollutants emitted from multiple sources. Contaminated water after rains that has traveled through several regions may also be considered as a Non-point source of pollution, fertilizer from a field is carried into a stream by surface runoff.

Water pollutants also include both organic and inorganic factors. *Organic factors* include volatile organic compounds, fuels, waste from trees, plants etc. Inorganic factors include ammonia, chemical waste from factories, discarded cosmetics etc. The water that travels via fields is usually contaminated with all forms of waste inclusive of fertilizers that it swept along the way. This infected water makes its way to our water bodies and sometimes to the seas endangering the flora, fauna and humans that use it along its path.

The current scenario has led to a consciousness about water preservation and efforts are being made on several levels to redeem our water resources. Industries and factory set-ups are restricted from contaminating the water bodies and are advised to treat their contaminated waste through filtration methods. People are investing in rain water harvesting projects to collect rainwater and preserve it in wells below ground level.

Water Pollution is common, and is an area of high alert. Water needs to be preserved and respected today, for us to live a tomorrow.

2.4 Climate change

Climate change will probably intensify the problem. Climate change is likely to affect hydrology and land use. Climate change, leading to higher average temperature and changing precipitation patterns, may have three direct impacts on soil conditions:

1. The higher temperatures cause higher decomposition rates of organic matter. Soil organic matter is important as a source of nutrients and it improves moisture storage.
2. More floods will cause more water erosion.
3. More droughts will cause more wind erosion

Climate change can affect multiple features of water resources, for instance, quantity and quality, high and low-flow extremes, timing of events, among others (Kim et al, 2008).

LULCC plays a major role in climate change at global, regional and local scales. At global scale, LULCC is responsible for Releasing greenhouse gases to the atmosphere, thereby driving global warming, especially methane (altered surface hydrology: wetland drainage and rice paddies; cattle grazing), and nitrous oxide (agriculture: input of inorganic nitrogen fertilizers; irrigation; cultivation of nitrogen fixing plants; biomass). Increase the release of carbon dioxide to the atmosphere by disturbance of terrestrial soils and vegetation, major driver of this change is deforestation. Vulnerability of water resources to climate change at a watershed level is crucial.

Human activities primarily burning of fossil fuels and changes in land cover are modifying the concentration of atmospheric constituents or properties of the Earth's surface that absorb or scatter radiant energy In particular, increases in the concentrations of greenhouse gases (GHGs) and aerosols are strongly implicated as contributors to climatic changes observed during the 20^{th} century.

According to the Intergovernmental Panel on Climate Change (IPCC), established by WMO and UNEP, ecosystems are subject to many pressures (e.g. land-use change, resource demands, population changes); their extent and pattern of distribution is changing, and landscapes are becoming more fragmented. Climate change constitutes an additional pressure that could change or endanger ecosystems and the many goods and services they provide. Soil properties and processes, including organic matter decomposition, leaching, and soil water regimes, will be influenced by temperature increase. Soil erosion and degradation are likely to aggravate the detrimental effects of a rise in air temperature on crop yields. Climate change may increase erosion in some regions, through heavy rainfall and through increased wind speed.

CO_2-induced climate change and land degradation remain inextricably linked because of feedbacks between land degradation and precipitation. Climate change might exacerbate land degradation through alteration of spatial and temporal patterns in temperature, rainfall, solar radiation, and winds. Several climate models suggest that future global warming may reduce soil moisture over large areas of semi-arid grassland in North America and Asia. This climate change is likely to exacerbate the degradation of semi-arid lands that will be caused by rapidly expanding human populations during the next decade. It is predicted that there will be a 17 per cent increase in the world area of desert land due to the climate change expected, with a doubling of atmospheric CO_2 content.

Water resources are inextricably linked to climate, so the prospect of global climate change has serious implications for water resources and regional development. Climate change especially changes in climate variability through droughts and flooding will make addressing these problems more complex. The greatest impact will continue to be felt by the poor, who have the most limited access to water resources.

Note: don't forget your assgnment that given in Chaper 3.

Chapter Four

4. Land Degradation Assessment

Land degradation is increasing in severity and extent in many parts of the world, with more than 20% of all cultivated areas, 30% of forests and 10% of grasslands undergoing degradation (Bai et al., 2008). Millions of hectares of land per year are being degraded in all climatic regions. It is estimated that 2.6 billion people are affected by land degradation and desertification in more than a hundred countries, influencing over 33% of the earth´s land surface (Adams and Eswaran, 2000). The decline in land quality caused by human activities has been a major global issue since the 20th century and will remain high on the international agenda in the 21th century (Eswaran et al.,2001).The immediate causes of land degradation are inappropriate land use that leads to degradation of soil, water and vegetative cover and loss of both soil and vegetative biological diversity, affecting ecosystem structure and functions (Snel and Bot, 2003). Degraded lands are more susceptible to the adverse effects of climatic change such as increased temperature and more severe droughts

Land degradation encompasses whole environment but includes individual factors concerning soils, water resources (surface, ground), forests (woodlands),grasslands (rangelands), croplands (rain fed, irrigated) and biodiversity (animals, vegetative cover, soil) (FAO, 2005).

Estimate for each physically-homogeneous mapping unit

Estimate for each physically-homogeneous mapping unit

- Type of degradation: (water/ wind erosion; chemical/ physical deterioration)
- Degree of degradation: (light, moderate, strong, extreme)
- Causes: (deforestation, overgrazing, agricultural activities, overexploitation of vegetation, industrial activities)

Land degradation Assessment

Land Degradation **A**ssessment in **D**ryland **A**reas (**LADA**)

LADA follows a **participatory, decentralized, country-driven and integrated approach** and makes

ample use of participatory rural appraisals, expert assessment, field measurements, remote sensing, GIS, modeling and other modern means of generation of data, networking and communication technologies for sharing information at national and international levels (Koohafkan et al., 2003; LADA project document, 2005).

- LADA considers both biophysical factors and socio-economic
- Intended to make an innovative generic contribution to methodologies and monitoring systems for land degradation
- The six main partner countries involved in the LADA project are
  - Argentina – for the Latin America region,
  - China – for the East Asia region,
  - Cuba – for the Caribbean region,
  - Senegal – for the West Africa,
  - South Africa – for the southern, central and eastern Africa region, and
  - Tunisia – for the Near East, North Africa and Mediterranean region (LADA project document, 2005).

They proposed that the causes, status and impact of land degradation and possible responses can be determined and assessed at the same time. The proposed LADA methodology was based on the DPSIR framework where D indicates the driving forces, P the pressures, S the condition of land and its resilience, I the impacts of the increased or reduced pressures, and R the responses by the land users to release or reduce the pressures on the land.

- Indicators on the biophysical condition of land, on how land is being managed, and the policy and social environment for instituting improvement in land management are discussed.
- Based on a review of existing land degradation indicators, data sources and methods, and expert consultation.
- Based on the list of potential indicators for uses at global, national, and regional, watershed or village and farm levels

Land Degradation Assessment Methods

The most common methods used to assess land degradation are:

- Expert opinions
- Land users‘ opinions,
- Field monitoring,
- Observations and measurement,
- Modelling,
- Estimates of productivity changes and remote sensing.

The methods have been applied to different approaches which use either qualitative or quantitative measures or both. The table (a – d) summarizes the systems assessed; assessment methods used; factors/processes/ and parameters of the land that is being assessed; and the units or values in which measurements were given for the different assessments of land degradation at different levels. Details are identified at the global, national, regional, and local and field/farm level. Below is a summary of the different assessment methods used in assessing land degradation processes in different systems at different levels.

Table. Summary of system of land; assessment method used; what was assessed and units/values at different levels

***(b)**: Regional level*

Systems assessed	Methods used	What was assessed	Units / values
Drylands, rangelands, grasslands, forests, deserts, etc., Soils, Rivers systems, etc.	**Expert opinion** (e.g. indicators, questionnaires, interviews, focus groups, etc..) **Remote Sensing and GIS** (e.g. NDVI, MODIS, etc.) **Modelling** (e.g CORINE, PESERA erosion models, etc.) (mainly for croplands) **Field monitoring and measurements** (measurements to verify models) -pilot areas **Grid System Monitoring (EU)**	Land/soil degradation: - severity, degree, extent, impact, causes, & risks - Soils (erosion, fertility, productivity, etc.) Vegetation change Land cover Land uses Slopes Climate (rainfall, temperature) for modelling Biodiversity loss Landscapes/ Ecosystem function	%, Classes (1,2,3,4,5 for light – very severe / excellent – very poor, etc..), t/ha/yr

***(a)**: Global level*

Units/Systems assessed	Methods used	What was assessed	Units / values
Full Cover Analysis	**Experts opinion** (e.g. indicators,	Land/soil degradation: (severity, degree, extent)	%, Classes

(c): National level

Systems assessed	Methods used	What was assessed	Units / values
Lands (agricultural lands, grasslands, forests, conserved area, deserts, etc.), Soils, Rivers, Rangelands systems	**Expert opinion** (e.g. indicators, questionnaires, interviews, focus groups ect.) **Land users opinion** (e.g. indicators, etc.) **Remote Sensing and GIS** (e.g. NDVI, MODIS, MSDI ect.) **Modelling** (e.g CORINE, PESERA models, etc.) **Field monitoring and**	Land/soil degradation: - severity, degree, extent, impact, causes, & risky - Soil (erosion, fertility, productivity, etc.) Vegetation change Land cover Biodiversity loss Land uses Rangeland health/conditions,	%, Classes (1,2,3,4,5 for light – very severe; extremely health – extremely unhealthy, etc.), t/ha/yr

(d): Local and Field/Farm levels

Systems assessed	Methods used	What was assessed	Units / values
Lands (cropland lands, grasslands, forests, conserved area, deserts etc.), Soils, Rivers, Rangelands, etc.	**Expert opinion** (e.g. indicators, questionnaires, interviews, focus groups, etc.) **Land users opinion** (e.g. indicators etc.) **Remote Sensing and GIS** (e.g. NDVI, MODIS, MSDI ect.) **Modelling** (e.g USLE/ RUSLE, CORINE, PESERA models, etc.) **Field monitoring and measurements** (verify models) - farm plots **Estimates of productivity changes**	Land/soil degradation: - severity, degree, extent, impact, causes, & risks;, Soil erosion (Sediment yields) Rangelands Health/ condition Soil condition (quality, salinity, stability, fertility, etc.), Crop yield & suitability, Soil condition, Landscape/ ecosystem function, Land cover, Biodiversity loss, Land uses, Climate (rainfall, temperature), etc.	%, Classes (1,2,3,4,5 for light – very severe; extremely health – extremely unhealthy, etc.), t/ha/yr Frequency of indicators

Assessment with land degradation indicators

Desertification and land degradation are complex processes with causes that range from climate change to change in land use or change in environmental protection legislation. The way in which an area responds to these pressures is determined by how resilient the landscape (soil, water, vegetation) and local economy are.

Indicators are often used as a tool to understand this complexity and to help answer questions such as:

How vulnerable is this area to desertification?

How rapidly is the land degradation progressing?

How effective are the actions that we are taking to mitigate it?

Land degradation indicators are

- ✓ An indicator is a parameter (or value derived from parameters) which provides information about a phenomenon.
- ✓ Indicators should not be confused with raw data from which they are derived.
- ✓ Indicators are quantified information which helps to explain how things are changing over time and space for decision making.
- ✓ An environmental indicator is a parameter which provides information about the situation or trends in the state of environment, in the human activities that affect or are affected by the environment or about relationships among such variables.
- ✓ Land degradation indicators are a sub-set of environmental indicators focusing on a particular trend in state of the environment and associated human activities. (additional sources: EEA 1998, USA EPA 1995)

Uses of land degradation indicators

To use indicators as the appropriate tool to provide operational support to a wide range of activities such as: **assessing mapping the extent of desertification as well as determining the causes; quantifying the impacts; justifying expenditure for mitigation measures and monitoring the efficiency of the measures undertaken.** Indicators that might be used for assessing land degradation in dry lands. Indicators on the biophysical condition of land, on how land is being managed, and the policy and social environment for instituting improvement in land management are discussed.

Indicators of land degradation are rills, water flows pattern, pedestals, bare ground, gullies, wind-scoured and depositional areas, litter movement, soil surface resistance to erosion, soil surface loss or degradation, plant community composition and distribution relative to infiltration and runoff, compaction layer, functional/structural groups, plant mortality/decadence, litter amount, annual production, invasive plants, and reproductive capability of perennial plants.

Available Models for Different Levels

Assessment of soil erosion and land degradation both by water and wind has been carried out using models designed for the purpose. The mathematical models are continually being improved and scientists from many countries have adopted them to meet the requirements of their local conditions (Arnalds et al., 2001). Many more models have now been developed and used by different countries in different regions. Below is a summary of several models for measuring soil erosion and land cover used in different environments

The Universal Soil Loss Equation (USLE) and its revised version RUSLE are two of the empirical models that have been most widely used and generally accepted by the natural resources community because they are relatively easy to use and its spatial distribution feasible with reasonable costs and better accuracy in larger areas (Saavedra, 2005).

The RUSLE model can predict erosion potential on a cell-by-cell basis (Shinde *et al*., 2010), which is effective when attempting to identify the spatial pattern of the soil loss present within a large region and it needs less input required data than other model. Now a day's, so many researches are using **remote sensing and GIS software with RUSLE model** to estimate the rate of soil erosion and mapping erosion risk areas. Other soil erosion models range in various degrees of complexity, they needs large input data, takes time and money, models like

EUROSEM (European Soil Erosion Model),

ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation),

CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems), and

MODANSWERS (modified ANSWERS), are basically conceptual and event based models.

INRA model Institute National Recherche Agronomique, which takes into account crust formation, land use and soil erodibility.

SLEMSA Model - the Soil Loss Estimation Equation, for Southern Africa

MMF Model - the Morgan-Morgan Finney model, to provide useful information on the source areas of sediment, sediment delivery to streams

WEPP Model - the Water Erosion Prediction Project

SWAT- Soil and Water Assessment Tool

The RUSLE model

The soil erosion assessment was estimated under ArcGIS environment using **Revised Universal Soil Loss Equation (RUSLE)** model for the study area. The five erosion factors cover management (C), rainfall erosivity (R), soil erodibility (K), slope steepness- length (LS) and conservation practice (P) were estimated and were used for the estimation of average annual soil loss.

A = R. K. L.S. C. P

where: -

A = spatial average soil loss rate (t/ha /year),

R = rainfall-runoff erosivity factor [MJ mm/ (ha h year-1)],

K = soil erodibility factor [t ha h/ (ha MJ mm)],

L = slope length factor,

S = slope steepness factor,

C = cover management factor, and

P = conservation support practice factor

The study produced maps that show the rate of soil erosion by water in the watershed.

- Calculates the actual sediment loss by soil erosion
- To evaluate the different scenarios of land uses
- To assess landscape soil erosion susceptibility with scenario analysis
- To develop adaptation strategies for future climate change scenarios such as modification in land management techniques.
- To assess the risk of land degradation on large scale agricultural lands as well as the techniques used for continuous monitoring.
- Capable of predicting soil loss from fields or hill slopes

Identification of areas with high degradation risks will allow for better soil conservation plans to reduce the sediment load to the rivers and lakes in the region of interest

1. Rainfall erosivity factors

Rainfall erosivity defined as the aggressiveness of the rain to cause erosion. The numerical value used for R in RUSLE and USLE must quantify the effect of raindrop impact and must also reflect the amount and rate of runoff likely to be associated with the rain. The rainfall erosivity factor quantifies the effect of rainfall impact and also reflects the amount and rate of runoff likely to be associated with precipitation events. The soil loss is closely related to rainfall partly through the detachment power of raindrop striking the soil surface and partly through the contribution of rain to runoff. This applies particularly to erosion by overland flow and rills for which intensity generally considered the most important rainfall characteristics.

2. Soil erodibility factor

The susceptibility of soil to erosion agents is known as **soil erodibility**. Soil erodibility is the manifestation of the inherent resistance of soil particles for the detaching and transporting power of rain fall. This factor quantifies the cohesive character of a soil type and its resistance to dislodging and transport due to raindrop impact and overland flow shear forces. Those soil erodibility factors refer the effect of soil on erosion through the resistance of soil to both detachment and transport. Due to a function of a range of soil properties such as soil texture, structure, soil moisture, roughness, organic matter content and chemical and biological characteristics, soils are different in their resistance to erosion. In general, soils having faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion.

3. Topographic factors

The effect of topography on soil erosion is accounted for by the LS factor, which combines the effects of a slope length factor (L) and a slope steepness factor (S). Wishmeier and Smith (1978) defined slope length as the distance from the point of origin of overland flow to the point where the slope decreases enough that deposition begins or the point where runoff becomes concentrated in a defined channel. Slope steepness reflects the influence of slope gradient on soil erosion. It is known that the amount of runoff increases due to the continuous accumulation down the slope as the slope length (L factor) increases; the velocity of runoff increases as the slope steepness (S factor) increases.

4. Cover factor

The C-factor is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding clean-tilled continuous fallow. To account for the effect of vegetation in erosion assessments, a cover and management factor (C-factor) has often been used. Land use classification is often used to map vegetation types that differ in their effectiveness to protect the soil Vegetation reduces soil erosion by: protecting the soil against the action of falling raindrops, increasing the degree of infiltration of water into the soil, reducing the speed of the surface runoff, binding the soil mechanically, maintaining the roughness of the soil surface, and improving the physical; chemical and biological properties of the soil.

5. Conservation practice factor

The management practice factor P indicates the effect of conservation practices on soil erosion, wherein the land which has adequate conservation interventions. Specific cultivation practices affect erosion by modifying the flow pattern and direction of runoff and by reducing the amount of runoff. Especially in agricultural areas, conservation practices such as contouring, strip cropping, or terracing, reduce soil losses.

For instance, in areas where there is terracing, runoff speed could be reduced with increased infiltration, ultimately resulting in lower soil loss and sediment delivery. The effectiveness of such practices is often analyzed with a support practice factor (P-factor).

CORINE model

CORINE methodology is a standard method used by the countries of the European Community to determine the erosion risk and qualities of the land being studied (Doğan et al., undated). Countries of the European Community sharing the Mediterranean region have completed their erosion maps and classification of their lands using CORINE methodology (Doğan et al., undated).

- Determines the actual erosion risks for vegetative cover, land slope, meteorological condition and soil properties.
- The model consists of 6 steps, each of which uses different overlaying combinations of soil texture, depth, stoniness; climatic data, land use and land cover information.
- Consequences of land cover changes on soil erosion distribution
- Provided complete and appropriate assessment of land degradation and can be used to improved degradation assessment in other semi-arid areas

Chapter Five

5. Rehabilitation and/or Restoration of Degraded Land

Rehabilitation: Repair damaged or blocked ecosystem functions, with the primary goal of raising ecosystem productivity for the benefit of local people. It attempts to achieve such changes as rapidly as possible. Rehabilitation and restorations, they aim at recreating autonomous or self-sustaining ecosystems, which are characterized by biotic change or succession in plant and animal communities, and the ability to repair themselves following natural or moderate human perturbations.

Thus, restoration and rehabilitation projects must also share as explicit or implicit working goals the return to former paths of energy flow and nutrient cycling, and the reparation of conditions necessary for effective water infiltration and cycling throughout the ecosystem.

Restoration invariably seeks a direct and full return to the indigenous, historic ecosystem,

restoration sense late and, particularly, rehabilitation may settle on one of many possible alternative steady states, or a synthetic simplified ecosystem as an intermediate step in their long-term goals. The alternative steady states might or might not have occurred in the process of degradation of the original, pre disturbance ecosystem.

5.1 Vegetation

The principle of agronomic and vegetative measures is to maintain a high vegetative cover, which serves two purposes: production and protection. An improved crop management can involve improved seeds, appropriate varieties, and diverse varieties, optimal timing of planting, appropriate spacing of plants, fertilization, integrated pest and disease management, etc. In addition to improved ground cover, the roots improve soil structure, and thus aeration, infiltration and biological activity in the soil.

Plant residues build up soil organic matter and thus improve stability of the soil structure and aggregates. Mixed cropping, inter-cropping, sequential cropping, relay cropping agro-forestry, cover crops, and last not least fallow aim at an optimal plant cover over a longer period of time.

Vegetation Rehabilitation:

- Recreate healthier ecological conditions
- Re-establish more open landscape
- Recreate historic balance between grassland and woodland
- Along streams, gullies and ravines
- Along boundaries as screening plantings
- In areas of high soil erosion hazard
- In places where woodlands occurred historically

5.1.1 Area closure

Enclosing and protecting an area of degraded land from human use and animal interference, **to permit natural rehabilitation**, **enhanced by additional vegetative and structural conservation measures.** Area closure involves the protection and resting of severely degraded land to restore its Productive capacity.

There are two major types of area enclosures practiced in Ethiopia:

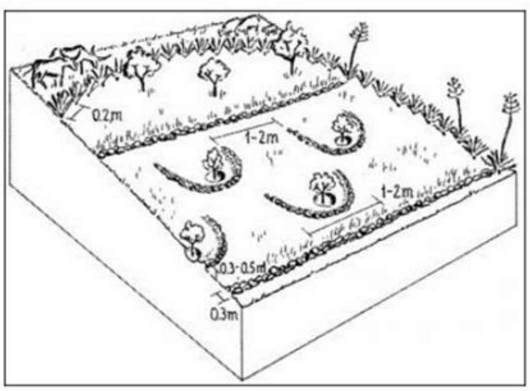
1) The most common type involves **closing off an area from livestock and people** so that natural regeneration of the vegetation can take place;
2) The second option comprises **closing off degraded land** while simultaneously implementing additional measures such as planting of seedlings, mulching and establishing water harvesting structures to enhance and speed up the regeneration process.

The selection of measures chosen for rehabilitation depends mainly on the land use type, and to a lesser extent on climate, topography and soil type. Degraded croplands with individual land use rights are normally treated with additional structural measures to retain soil moisture and trap sediment, and with agronomic measures to restore soil fertility. Open access grazing lands are closed for natural regeneration while partly treated with additional measures, and open access woodlands are simply closed.

Structural measures such as micro-basins, trenches, and bunds that enhance water infiltration and soil moisture may be constructed to increase survival rate of vegetative material planted.

The maintenance of area enclosures involves activities such as replanting, maintaining of fences, pruning of trees and weeding. After one year, cut-and-carry of grass for stall-feeding can be partly practiced, which is of economic benefit to the farmers.

Rehabilitation normally takes about 7-10 years depending on the level of degradation and intensity of management. Land use is limited to selective cutting of trees, collection of dead wood and cut-and-carry of grass for livestock fodder. On individually owned enclosures land users start cutting trees after three years (for eucalyptus) and after 7–8 years (for other trees), while on communal land farmers are allowed to collect dead wood after 3-–4 years, and the community decides about the use of trees.



Technical drawing

Rehabilitation of degraded land based on enclosure with live fence. Natural regeneration of vegetative cover is supported by water harvesting structures and planting of nitrogen-fixing/multipurpose shrubs and trees as well as local grass species. On steeper slopes hillside terraces may be established.(Mats Gurtner)

5.1.2 Reforestation and/or Afforestation

Afforestation:- It is the establishment of forest or stand of trees in area where there was no forest.

Reforestation:- It is the reestablishment of forest cover either naturally by natural seeding, coppice or root suckers or artificially by direct seeding or planting

According to FAO the term **forest plantation** includes all forests established by planting or seeding in the process of afforestation and reforestation. It relates to **indigenous** and **introduced** species, but must have a minimum area of 0.5 ha, a minimum crown cover of 10% and a potential minimum height of 5 m at maturity. Young natural stands and all plantations, which have yet to reach a crown density of 10% or tree height of 5 meters, are included under forest.

The particular features of forests among terrestrial ecosystems

Forests are characterized by a tree cover of a **specific density**. A distinct feature of forests among the terrestrial ecosystems is the longevity of their most important structural elements, the trees. The long lifespan of trees allows for accumulation of high stocks of biomass, together with a wealth of structural properties. These assets bear the potential for high permanent carbon storage, and high biodiversity of many natural forest communities. The structural richness does not only extend aboveground there is usually also high belowground biomass and soil biological activity as well as belowground biodiversity.

Structural complexity of forest ecosystems entails complex processes and self-regulating feedback loops, which eventually provide highly desired ecosystem services such as soil protection, water flow control and water resource generation, as well as filtering and buffering functions of the soil with respect to numerous chemical constituents.

In many of the terrestrial biomes of the Earth, forests of different composition and eco-physiological characteristics form the potential natural vegetation, and they remain as greatly appreciated quasi-natural ecosystems even in the densely populated and industrialized regions of the world, where planted and managed forests have commonly replaced natural forest ecosystems.

5.2 Soil Restoration

Soil restoration (SR) is the technique of enhancing compacted **soils** to improve their porosity and nutrient retention. It includes biological (worms) and mechanical aeration, mechanical loosening (tilling), planting dense vegetation, and applying **soil** amendments.

Healthy and fertile soil is the foundation for land productivity. Plants obtain nutrients from two natural sources: **organic matter and minerals**. Reduced soil fertility undermines the production of **food, fodder, fuel and fiber**. Soil organic matter, nutrients and soil structure are the main factors influencing soil fertility. Soil organic matter is a key to soil fertility. Organic matter includes any plant or animal material that returns to the soil and goes through the decomposition cycle. Soil organic matter (SOM) is a revolving nutrient fund: it contains all of the essential plant nutrients, and it helps to absorb and hold nutrients in an available form.

Soil organic matter has multiple benefits; it is also fundamental for good soil structure through the binding of soil particles, for water holding capacity, and it provides a habitat for soil organisms.

Soil texture also influences soil fertility. The presence of clay particles influences the soil's ability to hold nutrients. sandy soils usually have a lower nutrient holding capacity than clay soils, and hence need particular attention in terms of soil fertility management.

Declining soil fertility: The reason for a decline in SOM and the closely linked nutrient content is simply that the biomass and nutrient cycle is not sustained, meaning more material in the form of soil organic matter and / or nutrients (especially the macro-nutrients of nitrogen, phosphorous and potassium) leaves the system than is replenished.

This results from various causes:

- ✓ removal of crop products and residues (plant biomass),
- ✓ loss through soil erosion,
- ✓ leaching of nutrients (below the rooting depth),
- ✓ volatisation of nutrients (e.g. nitrogen),
- ✓ Accelerated mineralization of SOM through tillage.

The gains or replenishments are derived from residues of plants grown or nutrient accumulation (e.g. nitrogen fixing), external input of organic matter, manure and fertilizer, and nutrients through the weathering and formation of the soil.

Soil fertility can improve through:

Maintain or improve a balanced SOM–nutrient cycle, meaning that net losses should be eliminated and organic matter and / or nutrients added to stabilize or improve the soil fertility. Replenishment of soil nutrients is a major challenge. Replenishment and reduced loss of soil nutrients can be achieved through the following options:

1. **Improved fallow-systems:** The deliberate planting of fast-growing species - usually leguminous - into a fallow for rapid replenishment of soil fertility. These can range from forest to bush, savannas, grass and legume fallows.
2. **Residue management:** A practice that ideally leaves 30% or more of the soil surface covered with crop residues after harvest. It requires residue from the previous crop as the main resource (thus burning is discouraged) it also helps reducing erosion, improving water infiltration and moisture conservation.
3. **Application of improved compost and manure:** Compost (mainly from plant residues) and manure (from domestic livestock) help to close the nutrient cycle by ensuring that these do not become losses to the system.

4. **Tapping nutrients:** This takes place through the roots of trees and other perennial plants when mixed with annual crops (e.g. in agroforestry systems). Trees act as nutrient pumps: that is they take up nutrients from the deep subsoil below the rooting depth of annual crops and return them to the topsoil in the form of mulch and litter. This enhances the availability of nutrients for annual crops.
5. **Application of inorganic fertilizer:** Inorganic fertilizers are derived from synthetic chemicals and / or minerals.
6. **Minimum soil disturbance:** Tillage systems with minimum soil disturbance such as reduced or zero tillage systems leave more biological surface residues, provide environments for enhanced soil biotic activity, and maintain more intact and interconnected pores and better soil aggregates, which are able to withstand raindrop impact (and thus reduce splash erosion). Water can infiltrate more readily and rapidly into the soil with reduced tillage, and this also helps protect the soil from erosion. In addition, organic matter decomposes less rapidly under these systems.

5.3 Wetland Rehabilitation

A wetland is a land area that is saturated with water, either permanently or seasonally. The return of a wetland and its functions to a close approximation of its original condition as it existed prior to disturbance on a former or degraded wetland site.

Common Wetland Rehabilitation Techniques

Backfill Ditches. Ditches are usually dredged through wetlands to promote irrigation and move water. The dredged material is often piled along the edge of the ditch in piles, known as spoil banks. These can block sheet flow (The movement of water across a surface in a sheet like mass instead of within channels or streambeds). Backfilling can help restore the natural topography and hydrology, which can lead to at least partial rehabilitation of wetlands affected by ditch construction.

Construct Berms. Constructing small dikes or berms can protect adjacent property from the natural flooding of a restored wetland.

Control Weeds. Thousands of plant species have been transported beyond their natural ranges, both intentionally and unintentionally. Many introduced species spread prolifically in environments where predation and competition are limited, pushing out the native flora.

Excavation. Excavation can restore natural topography and elevations in order to intercept groundwater, to reach an intertidal level or to establish wetland hydrology. In some cases, sediment previously deposited in a wetland can be removed to rehabilitate the wetland. When landowners strive to create artificial wetlands, they can displace other habitat (i.e., upland habitat). Excavation and removal of excavated material can be expensive. In some circumstances, it is difficult to predict appropriate excavation depths. Excavation to subsoil leaves poor substrate for plant growth.

Install Water Control Structures. Restoring natural hydrology is important on wetland projects. A landowner may wish to artificially alter water levels with a water control structure where bullfrogs or other invasive species need to be controlled, or when the natural hydrology cannot be reestablished. Risers or stop log structures made of plastic or metal help manage the normal flow of water. If excess water is expected during flood events, a wide trough like opening in the side of the dike called **an emergency spillway** should be designed into wetland projects.

These spillways allow water to pass through without damaging the retention structures during a high-water event.

Reconnect Floodplains and Restoring Backwaters, **Channels and Bends**. Restoring a stream to

its natural channel, and reconnecting channel and floodplain, can reduce sediment load and flooding downstream; raise the water table; lower water temperature; and restore fish and wildlife habitat.

Remove Culverts. Removing or repairing culverts can be an effective way to increase fish habitat. Culverts can block fish passage by constricting flows; collecting debris that plugs passage; and forcing the water to find another path, often one that a fish cannot follow.

Remove Tile. Tile breaking during wetland projects involves removing a section of underground agricultural tile that drains a wetland basin. Drain tile or field tile is usually made of clay or perforated plastic, and buried at a depth of two to six feet.

Conditions Where Practice Applies

Applies to natural wetland sites with hydric soils which have been subject to the degradation of hydrology, vegetation, or soils.

This practice is applicable only where the natural hydrologic conditions can be approximated by actions such as modifying drainage, restoring stream/floodplain connectivity, removing diversions, dikes, and levees, and/or by using a natural or artificial water source to provide conditions similar to the original, natural conditions.

5.4 Monitoring and evaluating of rehabilitation practices

Monitoring and evaluation are providers to work towards providing the best care possible, with the available resources, methods and skills.

Monitoring is used to describe systematic, **continuous assessment** of progress to inform
managers and other stakeholders. As it is conducted regularly and is ongoing, there is an internal element.

The purpose is to help identify goals, problem areas, progress towards achieving results and to initiate change. It may be performed at the level of the individual, programme or local community. The information collected includes inputs and outputs of the programme and the processes employed. The information obtained from monitoring can inform and strengthen an evaluation and form an essential basis for establishing efficacy and effectiveness

Evaluation focuses on the **outcomes** from a programme and aims to objectively assess progress
and the achievement of results towards an agreed goal or to answer certain questions and provide guidance to decision-makers. Evaluation may have a broader or more general focus than the specific programme, for example considering policy, systems or national level implications although it is typically linked to outcomes and not only outputs. Evaluation is usually conducted on a one off‛‘ basis. The desire for objectivity means evaluation often has an external element
and so is typically conducted by people or organizations external to the programme, including funding agencies and international researchers.

5.4.1 Natural regeneration

Natural regeneration relies on older pine trees left on the land to provide seed to regenerate the site. This practice can only be employed if the site has not yet been harvested. Plans are then made for harvesting the present forest stand and leaving some trees to provide the seed.

Mostly pine stands grow best where all trees are of the same age and receive the same amount of sunlight. Therefore, once the seedlings are established the large seed trees must be removed.

Methods of natural regeneration

A. ***Natural regeneration (NR) from seed***

When regeneration obtained from seed forms a crop, it is called a seedling crop. It is neither planted nor of coppice or root-sucker origin but originating in situ from natural regeneration. When this seedling crop grows into a forest, it is called a high forest. NR from seed depends on the followings:

1) **Seed Production:** The most important consideration for natural regeneration from seed is the production of adequate amount of fertile seeds by the trees of the area or in the vicinity. The production of seed depends on the following: **species, age of trees, and size of crown, climate, and other external factors.**

2) **Seed Dispersal:** The seed produced by the trees is dispersed by the agency of wind, water, gravity, birds and animals. Some examples of seed dispersal by various agencies are given below:

- Wind: Conifers, Acer, Betula, Populus, Alnus , Salix, Terminalia, Dalbergia, Acacia, Adina , Bombax, etc.
- Water: Most mangrove species, Dalbergia, Teak, etc.
- Birds: Prunus, Mulberry, Diospyrus, etc.
- Animals: Acaica arabica, Prosopssis juliflora, Zizyphus, Anthocephallus, etc.
- Gravity: Oak, Juglans, Asculus, etc.

3) **Seed Germination**: After dispersal, insects, birds and rodents destroy a lot of seeds. The others germinate provided they are deposited on suitable soil. Germination of seeds depends upon several internal and external factors listed below:

- **Internal Factors:** Permeability to water, permeability to O2, development of Embryo, viability of seeds, size of seeds, germination capacity, germination energy
- **External factors:** Moisture, air, temperature, light, seed Bed.

4) **Seedling Establishment:** Even if germination is good, it does not mean that natural regeneration would be good because a large number of seedlings die at the end of rains or as a result of frost during winter or drought during summer. In addition, there may be other factors such as weeds, grazing, fire, which may kill the seedlings. Thus, establishment is defined as the development of new crop naturally or assisted' to a stage when the young regeneration natural or artificial' is considered safe from normal adverse influences and no longer needs special protection or tending operation other than cleaning, thinning and pruning.

The following factors affect establishment of seedlings:

- Development of roots
- Soil conditions – Moisture, Aeration, Nutrients
- Light

- Other Climatic Factors- high or low temp.
- Rainfall
- Drip (Slash erosion)
- Condition of grasses and other competing weeds
- Grazing, Browsing and Fire
- Composition of the crop

B. Natural regeneration from vegetative parts

When regeneration obtained by coppice forms a crop, it is called coppice crop and when it develops into a forest, it is called coppice forest to differentiate it from the high forest.

Natural regeneration by coppice can be obtained either by:

1) **Seedling coppice**: Coppice shoots arising from the base of seedlings that have been cut or burnt back. This method of obtaining natural regeneration is used for cutting back woody shoots and established reproduction which is not making any progress so that they may produce vigorous shoots and soon develop into saplings.
2) **Stool coppice**: Coppice arising from the stool or a living stump of a tree is called stool coppice. In this method, regeneration is obtained from the shoots arising from the adventitious buds of the stump of felled trees. The coppice shoots generally arise either from near the base of the stump or from its top. The shoots arising from near the top of the stump are liable to be damaged by the rotting of the upper portion of the stump as well as by wind, etc.

Vegetative reproduction can be obtained by any of the following methods:

1) **Coppice:** Vegetative reproduction in which the tree, plants or the seedlings of a species when cut near the ground level produce shoots.
2) **Root Sucker** (A shoot rising from the root of a woody plant): Vegetative reproduction in which a root of a plant is partially or wholly cut to produce a shoot called root sucker.
3) **Cutting:** Vegetative propagation in which a portion of the stem, branch or root is placed in the soil or other medium, in order that it may develop into a plant. Depending on the part of the plant used, cuttings may be classified into stem cutting, branch cutting, root cutting and root and shoot cutting. Root and shoot cutting is a young plant with pruned taproot and severed stem used for planting.
4) **Layering:** Inducing development of roots on branches while they are still attached to

the trees is called layering. Layering may be done in soil or in air and so layering is of two kinds: air Layering and soil Layering

5) **Grafting**: Vegetative propagation in which a portion called scion (any uprooted portion of a plant used for grafting or budding on a rooted stock), of one plant is applied to stock (a rooted plant on which a scion is grafted), usually rooted, which is another plant, with the object of securing vegetative union between the two, when the scion is detached from the parent plant and the shoot of the other plant is severed, to produce a new plant to be planted out. Attempt is made to transport the scions to the grafting place within 24 hours.
6) **Budding:** A vegetative reproduction in which, a bud with some portion of the bark of a genetically superior plant is grafted on an inferior plant so that it can produce shoot when the old shoot of the stock is cut off. Bud is grafted on the stock in the form of a patch after removing the bark of the stock in that portion or by making an incision in the bark of the stock in the form of T and then fixing the scion inside it.

Natural regeneration steps

1. Selecting the seed trees. Before the site is logged, seed trees must be selected and marked with paint. Selection means choosing the best-looking trees for seed trees – trees which are the straightest and tallest and have large crowns (lots of green needles) and no disease. The number to leave on the site will vary according to species. More seed trees are required for longleaf pine because it is not a prolific seed producer and its large seeds are often eaten by animals (Williston and Balmer 1974). Trees should be well-spaced over the site to allow even distribution of seed.

2. Planning for a good seed crop. The frequency of good seed crops varies from year to year and species to species. To insure successful natural regeneration, the site should be logged just prior to a good seed crop. You can observe the seed crop by looking through binoculars in the spring or early summer and counting cones to determine the crop for the fall or looking at conelets to predict next year's crop. Conelets resemble small pink or light green cones and are located near the ends of the branches; cones are green and are located further in on the branches. Both conelets and cones are in the top 2/3 of the tree crown.

3. Logging. The landowner should supervise the logging operation especially to insure that the seed trees are not damaged by the logging. Damaged trees may die or not produce a good seed crop.

4. Preparing the site. The site must be prepared to first incorporate the forest litter (organic matter) and then expose mineral soil -- seeds need soil to germinate and grow. Some site preparation options are to burn, mechanically scarify, and/or spray with herbicides.

5. Logging the remaining trees. When an adequate seedling stand is established and about 1-2 years old, the seed trees should be harvested (Boyer 1979). If you wait too long, seed trees may affect the growth of the seedlings and logging may damage the seedlings. For Longleaf pine the seed trees may be left.

6. Controlling unwanted vegetation. Shrubs, small trees, and herbaceous vegetation will compete with small seedlings for nutrients, water, and sunlight causing mortality or slower growth. For the first few years, the planting site should be observed to see if this unwanted vegetation is affecting seedling growth and survival and measures should be taken to control the weeds. Chemical control, hand-cutting, and mowing are threepossible methods of control.

Advantege and disadvantage of natural regenration

Advantages

- The initial costs of establishing a forest stand may be lower especially if site preparation is not necessary.
- Less heavy equipment and labor is required.
- The seedling has a naturally shaped root system unlike seedlings which have been grown in a nursery.
- Chance of tip moth damage is reduced (Beaufait and others 1984).
- For aesthetic reasons, the landowner may prefer to see a forest stand which is unevenly and naturally spaced versus a stand which is in rows.

Disadvantages

- A seed crop must be available and seed dispersal must be timed correctly with site preparation so that a suitable seedbed is available for the seed germination.
- Moisture in the soil is necessary for the seeds to germinate; exceptionally dry years or sites may result in poor germination or seedling mortality.
- Insects and other small seed-eating animals may consume all or most of the seed.
- Competing vegetation may be a problem for survival and growth for a longer time period than with planting because seedlings are smaller or seed may not be disseminated in the first year.

5.4.2 Soil Seed Bank

Soil seed banks include all living seeds in a soil profile, including those on the soil surface. In the beginning, Soil seed banks are also composed of dispersal units, which are seeds or fruits surrounded by structures serving for dispersal and sometimes contain other plant parts such as bracts or stems. Over time, the dispersal structures, as well as seed coats, can decompose, leaving only germination units. For example, Ranunculus arvensishas a thick seed coat and spikes which both decompose after burial in soil after a few years, leaving coatless seeds (A. Saatkamp, 2009, unpublished data).

Soil seed banks resemble other biological reservoirs, such as invertebrate eggs, tubercles and bulb banks, spores of non-spermatophyte plants and fungi, or seeds retained on mother plants (serotiny).

Soil seed banks vary much according to seed proximity, seed persistence and physiological state. Living seeds have been found in or on the soil for different durations, different seasons, at different depths, in different quantities and in different states of dormancy or procession to germination.

Seeds in the soil seed bank may occur in or on the soil, but in many situations, there is continuity between seeds at the surface, partly buried and completely buried seeds.

Plants differ in the duration their seeds remain in the soil and even within a species and among seeds of the same cohort there is variability in the time they spend in the soil seed bank.

Soil seed bank types

- Viable seeds present for less than 1 year
- Persistent seed banks for species with viable seeds that remain for more than 1 year. Persistent soil seed banks can be subdivided further into short-term persistent for seeds that are detectable for more than 1 but less than 5 years, and long-term persistent seed banks that are present for more than 5 years.

Evolution of Soil Seed Banks

Soil seed banks are both the outcome of environmental or plant developmental contingencies and the result of evolutionary history. Climate, herbivory and disturbances vary and lead directly to year-to-year changes in soil seed bank density and spatial heterogeneity.

- Some environments particularly favor the evolution of persistent soil seed banks, such as

river mud flats or ephemeral ponds, forest gaps, pastures and arable fields since they are often or intensely disturbed or have very variable habitat conditions. Plants with persistent soil seed banks are some of the most characteristic species of these habitats.

- Ecosystems also contain at least a few plant species with persistent soil seed banks, either with some kind of dormancy with increased germination in presence of smoke derived substances

5.4.3 Bio-physical Indicators

Biophysical indicators are tools that can be used to define resource status. They cannot directly
measure sustainability, but are useful for comparing present resource status with defined limits set within a socio-economic framework.

The ability to predict long-term resource trends from one-off indicator measurements is limited. Predictability will be increased where measurements are taken over time, or where well-defined land-use patterns have occurred in the past and present-day indicator measurements give an idea of impact on resource status over time.

Farmers routinely use a range of biophysical indicators, e.g., soil nutrient status, animal live weight, and pasture cover, primarily to assist in optimizing economic performance. Farmers could extend the range of measurements they make to include indicators which estimate the environmental consequences of farming systems.

Good biophysical indicators should be simple, cheap, obvious and responsive to environmental stresses. It would also be advantageous if indicators of sustainability of pastoral farming reflected productivity level as well as resource status, given that productivity is an important element of economic performance. Herbage production (quantity and quality) is a useful indicator of both economic performance and resource status. On one hand it drives the economic farm output (animal production), and on the other it reflects aspects of resource status, e.g., vegetation change due to weed ingress or environmental stress, and ―health‖ of the soil resource because it integrates effects of soil fertility, biological activity, physical condition, moisture holding capacity and erosion. For this reason considerable emphasis is given here to identifying variables which reflect herbage production, as well as resource status in an ecological sense.

Chapter Six

6. Sustainable Land Management (SLM)

6.1 SLM Concept and progress

Setting the frame

Land degradation, resulting from unsustainable land management practices, is a threat to the environment, as well as to livelihoods, where the majority of people directly depend on agricultural production. There is a potentially devastating downward spiral of overexploitation and degradation, enhanced by the negative impacts of climate change - leading in turn to reduced availability of natural resources and declining productivity: this jeopardizes food security and increases poverty.

Sustainable land management (SLM) is the antidote, helping to increase average productivity, reducing seasonal fluctuations in yields, and underpinning diversified production and improved incomes. Sustainable land management is simply about people looking after the land for the present and for the future.

The main objective of SLM is thus to integrate people's coexistence with nature over the long-term, so that the provisioning, regulating, cultural and supporting services of ecosystems are ensured. This means SLM has to focus on increasing productivity of agro-ecosystems while adapting to the socio-economic context, improving resilience to environmental variability, including climate change and at the same time preventing degradation of natural resources.

These guidelines provide important guidance to assist countries to design and implement SLM technologies and approaches to scale up sustainable land and water management, at either the national program level or at the level of projects on the ground.

Aims and audience

The overall aim of these guidelines is to identify, describe, analyse, discuss, and present for dissemination SLM practices, both technologies and approaches that are appropriate and based in solid science.

Materials are drawn from experience and representative case studies; these focus in particular on those practices with rapid paybacks and profitability and / or other factors likely to drive adoption. The direct objectives thus are:

1. Knowledge synthesis and dissemination of 'best' SLM practices;
2. Alignment of stakeholders for improved decision support

3. Promotion of standardized documentation, evaluation, sharing and use of SLM knowledge for decision-making.

6.2 Focus on Sustainable Land Management

Land degradation is simply defined, within the 'FAO-LADA Approach' as a decline in ecosystem goods and services from the land. Land degradation negatively affects the state and the management of the natural resources – water, soil, plants and animals - and hence reduces agricultural production.

Assessments in different countries show the severity of land degradation and the urgency of improving natural resource use through sustainable land management (SLM). Land degradation occurs in different forms on various land use types:

- ✓ **On crop land**: soil erosion by water and wind; chemical degradation - mainly fertility decline - due to nutrient mining and salinisation; physical soil degradation due to compaction, sealing and crusting; biological degradation due to insufficient vegetation cover, decline of local crop varieties and mixed cropping systems; and water degradation mainly caused by increased surface runoff (polluting surface water) and changing water availability as well as high evaporation leading to aridification.
- ✓ **On grazing land**: biological degradation with loss of vegetation cover and valuable species; the increase of alien and 'undesirable' species. The consequences in terms of soil physical degradation, water runoff, erosion are widespread and severe. Low productivity and ecosystem services from degraded grazing lands are widespread and a major challenge to SLM.
- ✓ **On forest land:** biological degradation with deforestation; removal of valuable species through logging; replacement of natural forests with mono crop plantations or other land uses (which do not protect the land) and consequences for biodiversity, and soil and water degradation. Concerted efforts to deal with land degradation through SLM must address water scarcity, soil fertility, organic matter and biodiversity. Improving the water productivity and water cycle, soil fertility and plant management are important in raising land productivity.

SLM thus seeks to increase production including traditional and innovative systems and to improve resilience to food insecurity, land degradation, loss of biodiversity, drought and climate change.

Sustainable Land Management has been 'the adoption of land use systems that, through appropriate management practices, enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources.

SLM includes management of soil, water, vegetation and animal resources. It also includes ecological, economic and socio-cultural dimensions. These three are not separate: in reality they are interconnected. They are also referred to as the **'3 Es'** of sustainable development - Equality, Economy, and Ecology.

Ecologically, SLM technologies – in all their diversity –effectively combat land degradation. But a majority of agricultural land is still not sufficiently protected, and SLM needs to spread further.

Socially, SLM helps secure sustainable livelihoods by maintaining or increasing soil productivity, thus improving food security and reducing poverty, both at household and national levels.

Economically, SLM pays back investments made by land users, communities or governments. Agricultural production is safeguarded and enhanced for small-scale subsistence and large-scale commercial farmers alike, as well as for livestock keepers. Furthermore, the considerable offsite benefits from SLM can often be an economic justification in themselves.

6.3 Sustainable land use and food security

1. Increased land productivity

The primary target of SLM is thus to increase land productivity, improve food security and also provide for other goods and services. There are three ways to achieve this:

(a) expansion, (b) intensification and (c) diversification of land use.

a. Expansion: agricultural production has been increased mainly by expanding the area of land under farming. Limited access and affordability of fertilizers and other inputs (e.g. improved planting material) has forced farmers to cultivate less fertile soils on more marginal lands; these in turn are generally more susceptible to degradation and have poor potential for production.

b. Intensification: The last 50 years have witnessed major successes in global agriculture, largely as a result of the 'Green Revolution' which was based on improved crop varieties, synthetic fertilizers, pesticides, irrigation, and mechanization.

c. Diversification: This implies an enrichment of the production system related to species and varieties, land use types, and management practices. It includes an adjustment in farm enterprises in order to increase farm income or reduce income variability.

This is achieved by exploiting new market opportunities and existing market niches, diversifying not only production, but also on-farm processing and other farm-based, income-generating activities.

Expansion, intensification and diversification to increase agricultural productivity imply:

– increasing water productivity (water use efficiency),

– enhancing soil organic matter and soil fertility (carbon and nutrient cycling),

– improving plant material (species and varieties), and
– producing more favorable micro-climates.

2. Water use efficiency

Water use efficiency is defined as the yield produced per unit of water. Optimal water use efficiency is attained through minimizing losses due to evaporation, runoff or drainage. In irrigation schemes, conveyance and distribution efficiency addresses water losses from source to point of application in the field.

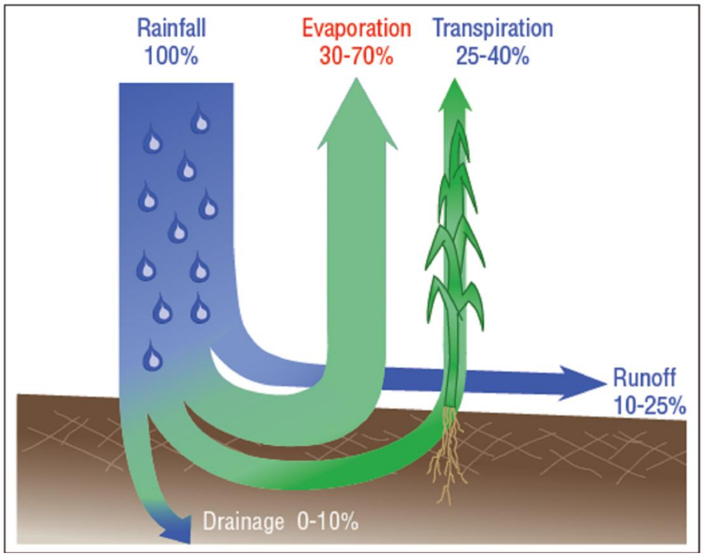
Often the term water productivity is used: this means growing more food or gaining more benefits with less water. Commonly it is reduced to the economic value produced per amount of water consumed.

Water scarcity and insecure access to water for consumption and productive uses is a major constraint to enhancing livelihoods in rural areas. Hence, improving water use efficiency to minimize water losses is of top-most importance. In relation to agriculture, water is often referred to as being **'blue' or 'green'**.

Blue water is the proportion of rainfall that enters into streams and recharges groundwater and is the conventional focus of water resource management.
Green water is the proportion of rainfall that evaporates from the soil surface or is used productively for plant growth and transpiration.

Three major sources of water loss in agricultural production, namely **surface runoff, deep percolation and evaporation** from the soil surface.

Surface runoff can, however, sometimes qualify as a gain when it feeds rain water harvesting systems. Similarly,
Deep percolation of water can be a gain for the recharge of groundwater or surface water. **Evaporation/Transpiration** the main useful part ('productive green water') is the soil water taken up by plants and transpired and evaporated back to the atmosphere.



Figure, Productive water (transpiration) and water losses (evaporation and runoff) without water conserving measures in dry lands.

Different strategies for improved rainwater management

1.Divert / drain runoff & run-on

Where there is excess water in humid environments, or at the height of the wet seasons in sub humid conditions, the soil and ground water can become saturated, or the soil's infiltration capacity can be exceeded. Thus safe discharge of surplus water is necessary. This helps avoid leaching of nutrients, soil erosion, or landslides. It can be achieved through the use of graded terraces, cut-off drains and diversion ditches etc.

2.Impede runoff (slow down runoff)

Uncontrolled runoff causes erosion and represents a net loss of moisture to plants where rainfall limits. The strategy here is to slow runoff, allowing more time for the water to infiltrate into the soil and reducing the damaging impact of runoff through soil erosion. It is applicable to all climates. This can be accomplished through the use of vegetative strips, earth and stone bunds, terraces etc.

3.Retain runoff (avoid runoff)

In situations where rainfall limits plant growth, the strategy is to avoid any movement of water on the land in order to encourage rainfall infiltration. Thus water storage is improved within the rooting depth of plants, and groundwater tables are recharged. This is crucial in sub humid to semi-arid areas. The technologies involved are cross slope barriers, mulching, vegetative cover, minimum / no tillage etc.

4. Trap runoff (harvest runoff)

Harvesting runoff water is appropriate where rainfall is insufficient and runoff needs to be concentrated to improve plant performance. Planting pits, half moons etc. can be used. This can also be applied in environments with excess water during wet seasons, followed by water shortage: dams and ponds can further be used for irrigation, flood control or even hydropower generation.

5.Reduce soil evaporation loss

Water loss from the soil surface can be reduced through soil cover by mulch and vegetation, windbreaks, shade etc. This is mainly appropriate in drier conditions where evaporation losses can be more than half of the rainfall.

3. Improved livelihoods

Increased and sustained agricultural production, the provision and securing of clean water and maintaining a healthy environment are essential for improved livelihoods.

Costs and benefits

For improved livelihoods and for adoption and spreading of SLM, costs and benefits play a central role. Because it is:-

1. Long-term but not short-term: many land users might be constrained to make these long-term investments, thus might need a kick-start, where the establishment costs are partly funded by aid and external sources. The maintenance costs however would need to be covered by local sources and direct paybacks.

2 .Long-term and breaking even in the short-term: thus increased benefits but also higher inputs. Depending on the wealth of the land users, the initial investments are not possible without external assistance.

3 .Short as well as long-term: This is the ideal case, where land users receive rewards right from the beginning. The question remains whether they need some initial support for investments (micro-credit, loans, access to inputs and markets etc). However, due to the rapid and continuous returns, land users have the possibility of paying back loans and credits quickly.

4. High initial returns but poor or no returns in the long term: These options are tempting for land users but will lose attractiveness in the long-run as the returns are not sustained. This has occurred where high yielding varieties and inorganic fertilizers were applied but yield responses fell away after a few years.

While establishment costs can be partly funded by aid and external sources, maintenance costs must be covered locally by land users to avoid the 'dependency syndrome' of continuous aid and to ensure self-initiative and ownership.

4.1. Inputs challenges for land users

Land users may require additional inputs to take up SLM practices. These are related to materials (machinery, seeds, fertilizers, equipment, etc.), labor, markets, and knowledge. Some of the SLM practices require few extra or different inputs and little change compared to current practices; others mean a complete change in machinery, inputs and management.

Some considerations are:

l .Small-scale land users in subsistence agriculture have fewer options and resources to invest than commercial or large-scale farmers with a high level of mechanization.

2. A clear distinction between initial investment for the establishment and the maintenance of SLM practices is essential. Special attention needs to be given to poor and marginalized land users.

3. Access to inputs and equipment such as machinery, seeds / seedlings, fertilizers, etc. is essential.

4. Access to knowledge related to SLM practices and their introduction is a prerequisite for all land users.

6.4 Challenges to SLM

Institutional, policy and market bottlenecks in the context of SLM adoption

Institutional:

– Inappropriate national and local political agendas

– Lack of operational capacity

– Overlapping and unclear demarcation of responsibilities

– Ineffective decentralization

– Lack of good governance

Policy / Legal framework:

– Often there are laws in favor of SLM, but they are not followed

– Enforcement is difficult, costly and can create adverse relationships between government and land users

Land tenure and user rights:

– Inappropriate land tenure policies and inequitable access to land and water

– Insecurity about private and communal rights

– Modern laws and regulations not considering traditional user rights, by-laws and social and cultural norms which may enhance conflicts and insecurity

Market and infrastructure:

– Insecure prices of agricultural products (crop, animal, timber, fuel / firewood etc.)

– Increasing input prices and costs for the inputs (materials, equipment, labor etc.)

– Access to markets for inputs and output

6.5 Strategic options

Institutional and policy framework

Policies in support of SLM are needed to promote and address the complexity of sustainable land use, in particular policies providing incentives for SLM investments at household, community, regional and national level.

Policies must address the root causes of land degradation, low productivity and food insecurity and simultaneously establish socially acceptable mechanisms for encouragement or enforcement.

Improvement of national policy frameworks: There are clear opportunities to improve national policy frameworks in support of SLM and to overcome bottlenecks that hinder the spread of SLM:

1. Creating an enabling institutional environment: 2. strengthening institutional capacity

3. clarifying roles and responsibilities 4. enhancing collaboration with land users

5. furthering collaboration and networking between institutions

6. strengthening and integrating farmer-extension-research linkages

7. securing finances (budgetary provision for extension)

Setting-up a conducive legal framework:

l. creating acceptance of rules and regulations or setting up mechanisms of control and enforcement

2. defining meaningful laws for local land users to support compensation mechanisms

3. recognizing customary rights in the local setting

Improving land tenure and users' rights is a key entry point:

1. providing basic individual and collective security of resource use

2. clarifying tenure and user rights to private and communal land, including locally negotiated tenure systems, regulations and land use.

3. looking for pragmatic and equitable solutions in cases where land tenure reforms are ongoing

4. increasing land title registration and linking this to land use planning through a cadastral system

5. promotion of women's land rights in land registration and customary land tenure systems

Improving access to markets for buying inputs and selling agricultural products and other outputs:

1. developing and strengthening local informal markets

2. securing accessibility by improving infrastructure (especially access roads)

3. better understanding of the impact of macroeconomic, liberalization and trade policies

3. facilitating markets for raw and processed products derived from SLM exploring and promoting access to regional, national as well as international markets.

4. develop favorable and fair international trade regulations

Trends and new opportunities: To make SLM and its products, emerging trends and opportunities need to be further explored. These may include:

1.Processing of agricultural products: This can reduce post-harvest losses and produce higher value products where the market exists.

2. Certified agricultural products: Look for opportunities under 'Fair Trade' with its focus on social criteria, equitable and just remuneration of producers; and 'Organic' with a focus on environmental health (production without chemical inputs, namely pesticides, herbicides, inorganic fertilizers).

3. Market for bio-energy / fuel: Although heavily debated by the public and scientific communities due to the trade-off with food security and ecosystems, bio fuels are gaining increased commercial attention. Driven by factors such as oil price spikes and the need for greater energy security, there are rapidly developing markets for bio-energy products.

4. Payments for Ecosystem Services (PES): PES is the mechanism of offering incentives to farmers or land users in exchange for managing their land to provide ecological services. Through PES, those who benefit pay for the services and those who provide, get paid. This is a relatively new source of funding with considerable potential for expansion.

The most promising PES opportunities are:

l .Carbon sequestration and GHG reductions: These offer payment possibilities for mitigating climate change. Forests-based transactions for the cost of emissions reductions can range between 1 to 15 US per tone of carbon sequestered.

2. Payment for biodiversity and protection of natural resources: By environmental interest groups through international support for protection (e.g. establishment of parks, reserves) or through enhancing ecotourism, where local communities are the main beneficiaries.

3. Payment by downstream users, watershed management payments for protection and sustainable management of upper catchments resulting in clean water, reduced sedimentation of reservoirs, increased hydro-power generation, and reduced floods.

Participation and land use planning

In the top-down approaches there was little or no involvement of land users in planning and decision-making. In the 'farmer first', bottom-up approaches local land users were empowered, though this sometimes led to inequalities. Empowerment must be for all, not just favored groups.

Furthermore gender-related aspects need to be taken into account while developing an approach to stimulate SLM.

Current promising approaches underlie the following principles:

1. People centered approaches: People and their actions are a central cause of land degradation, and thus need to be at the centre of SLM. There must be genuine involvement of land users throughout all phases.

2. Multi-stakeholder involvement: This includes all actors, with their various interests and needs, with respect to the same resources. It includes local, technical and scientific knowledge and mechanisms to create a negotiation platform.

3. Gender consideration: Gender roles and responsibilities need to be considered seriously, since in smallholder agriculture women are taking over more of the agricultural tasks once done only by men such as land preparation, and they are investing more work in cash crop production.

4. Multi-sectorial approaches: Successful SLM implementation brings together all the available knowledge in different disciplines, institutions and agencies including government, non-governmental and private sectors.

5. Multi-scale integration: This unifies local, community but also the landscape, watershed or trans boundary level, and up to the national and international level also. It implies that not only are local on-site interests considered, but off-site concerns and benefits also.

6. Integrated land use planning: This assesses and assigns the use of resources, taking into account demands from different users and uses, including all agricultural sectors - pastoral, crop and forests - as well as industry and other interested parties also.

Promotion and extension

In order to facilitate the adoption, adaptation and spread of SLM best practices, enhancing incentives are needed: these include **awareness raising, promotion, training and financial or material support.**

Capacity building and training: Many actors and stakeholders must be involved and work together towards successful planning, decision making and implementation of SLM.

Extension of SLM practices has much to do with empowering land users and they must be supported better through capacity building, knowledge management and training.

Two forms of extension and training especially need to be strengthened:

l. **Institutional capacity building**: projects, extension services, research initiatives and community based grassroots organizations (e.g. user groups) to access better means for knowledge management, awareness raising and training, but also for advice and decision support towards land users and planners; increased investments in extension services for small-scale land users, with a clear focus on sustainable techniques.

2. **Land user capacity building and empowerment**: people centered learning and capacity building through training the trainers initiatives, Farmer Field Schools, farmer based extension using local promoters and innovators, from farmer-to-farmer.

Financial and material support (incentives & subsidies): Incentives for SLM should not exclusively be seen as financial or material support, but as the intangible stimulus (or 'internal incentive') that a land user experiences through higher production, or through saving time and money.

Judicious use of financial and material support implies various considerations:

l. **The possibilities of removing some of the root causes of land degradation** such as an inappropriate land policy framework, land tenure security and market access, should be assessed.

2. **Before considering the use of direct financial and material support** for input-intensive measures, alternative approaches should be explored, such as adapting existing technologies, or choosing 'simple and cheap' technologies.

3. **If fertilizers, agro chemicals, seed or seedlings are subsidized,** the support should aim to be one element that helps build up a more integrated approach towards soil fertility, and pest and disease management