CHAPTER 4

Land degradation and SLM typologies

4.1 Land degradation definitions and processes

When land is degraded, its productivity is reduced and many other ecosystem services are deleteriously affected. Land degradation may be primarily caused by natural processes, related to the characteristics of the given land resources and ecosystems. However, human activities often accelerate these degradation processes, leading to a rapid decline in the quality and quantity of the land resources and the ecosystem services flowing from these. Drylands are fragile and particularly susceptible to land degradation.

There are many definitions of land degradation:[3]

- LADA defines land degradation as*: "The reduction in the capacity of the land to provide ecosystem goods and services and assure its functions over a period of time for its beneficiaries."*
- UNCCD defines land degradation in the context of drylands as: *"a reduction or loss, in arid and semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns."*

These definitions provide a broad view on the nature of land resources (they include soil, vegetation and water) and the range of products, goods and services people obtain from the land.

3 There is sometimes confusion between the terms degradation and desertification, whereby UNCCD, UNEP and GEF define desertification as *"land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities"*.

Land degradation is caused by a variety of complex interrelated degradation processes. These can be grouped into three major land degradation types, each of which can be subdivided according to a specific sub-set of degradation processes, namely:

- Soil degradation;
- Vegetation degradation;
- Water resources degradation.

A number of these degradation types and processes are likely to occur in a specific site or area and are caused by the same land uses and management practices but they may be more easily assessed and the causes understood, by assessing them one by one – soil- vegetation- water - and then pulling the information together for the land use and livelihood system.

The assessment team needs to identify the main LD / SLM processes occurring across the study areas and to assess the extent and degree of their impacts in each of the main land use systems and land use types.

In addition to direct effects of land use and management practices, three specific drivers need to be given due attention as they often lead to a lower productive potential, notably: i) land use change ii) contamination / pollution of water and soil from other sources and iii) climate change and variability.

Observations of the effects of land use type and management practices (e.g. burning, overgrazing etc.) on soil, water and vegetation indicators need to be triangulated and supplemented with feedback from land users and local key informants explaining reasons for changes in land use or management, also any constraints to the adoption of SLM practices. The process of identifying the main drivers and pressures of land degradation with the land users helps to highlight the SLM "bottlenecks", broadening the scope and relevance of the assessment for land use planning.

TABLE 3 **Soil degradation types and processes**

Soil degradation types	Key processes
Degradation of soil biological properties	Reduction in numbers and activity of beneficial soil organisms *(bacteria, rhizobia, mycorrhiza, earthworms, termites etc. and associated loss of function)*
	Increase in numbers and activity of harmful soil organisms *(nematodes, parasitic weeds etc. and associated pest / disease damage)*
Degradation of soil chemical properties	Decline in number and availability of soil nutrients *(N,P,K, secondary and trace elements through leaching, gaseous losses, removal in harvested products etc.)*
	Changes in soil pH *(acidification or alkalinisation)*
	Chemical imbalances and toxicities (e.g. *through application of inappropriate types and quantities of fertiliser, pesticides etc.)*
	Salinization *(build up of salts through poor irrigation practices in crop lands and poor grazing practices in grasslands)*; and sodicity.
	Chemical pollution (e.g. *from over use of agro-chemicals, plastic mulches or poor management of industrial and mining wastes)*

4.1.1 Soil degradation

Soil degradation occurs when there is a decline in the productive capacity of the soil as a result of adverse changes in its biological, chemical, physical and hydrological properties and/or attributed to the removal of soil through erosion by water or by wind or by mass movement. Sheet, rill and gully erosion by water, also the scouring and re-deposition of soil by wind and landslides are some of the most visible symptoms of soil degradation, but other less

TABLE 3 **Soil degradation types and processes** *(continued)*

Soil degradation types	Key processes
Degradation of soil physical properties	Surface crusting and compaction (e.g. *through the impact of raindrops, animal hooves and farm machinery)* and burning
	Loss of topsoil structure (e.g. *through excessive tillage and loss of soil organic matter)*
	Sub-soil compaction (e.g. *due to the passage of heavy farm machinery and / or ploughing to a constant depth)*
	Reduced soil rooting depth (erosion)
	Loss of soil fines (erosion of silts and clay) leaving sandier and stonier soils
Degradation of soil hydrological properties	Waterlogging *(rise in the water table close to the soil surface due to poor irrigation practices, or loss of deep rooted vegetation whose water needs would have kept the water table low or reduced soil permeability)*
	Aridification *(decrease in soil moisture availability, typically due to reduced rain water capture and infiltration following loss of vegetation, deep rooting and deterioration in the soil physical structure including wind blown deposition)*
	Reduced plant water uptake due to soil salinization
Soil erosion	Soil erosion by water (splash, sheet, rill and gully erosion)
	Soil erosion by wind (removal and re-deposition of soil particles, abrasion by transported materials and formation of mobile sand dunes)
	Gravitational erosion (mass movement through landslides, slumps, earth flows and debris avalanches)
	Freeze/thaw erosion
Soil pollution	Soil chemical imbalances and nutrient toxicities (e.g. *due to the application of inappropriate types and quantities of fertiliser)*
	Build up of inorganic pollutants in the soil (e.g. *as a result of over use of agro-chemicals and deterioration, in the topsoil, of residues from use of plastic mulches)*
	Accumulation of pollutants / toxicities of organic origin following the planting of certain crops (tobacco, eucalyptus, Jatropha spp. etc)
	Emissions of toxic chemicals (e.g. *from industrial smoke from heavy industry settling on the soil surface (downwind)*

visible forms of degradation of soil properties are even more widespread and sometimes more serious, notably depletion of nutrients and soil organic matter decline.

The key processes that are responsible for soil degradation are listed in Table 3. It should be recalled that soil conservation and improvements and their impacts should also be assessed; thus the indicators can show negative or positive changes or trends or stability.

Several of these degradation types and processes may occur simultaneously and they all result in a decline in soil productivity (i.e. the reduced capacity of the soil to support plant growth and to sustain yields of food and fodder crops, to sustain livestock productivity on pasture and rangelands and to sustain forest productivity). They also result in reduced soil resilience of the soil (i.e. capacity to support intensive management practices year after year and to withstand extreme events such as rainfall or drought).

Soil salinization is a particular type of dryland degradation that deserves specific attention. Soil salinization often restricts options for cropping and forestry, also affecting the quality of grazing in a given land area, as a limited number of plant species grow well on saline soils. It also negatively affects the quality of shallow ground water and surface water resources, such as ponds, sloughs and dugouts.

- **Saline soils** occur where the supply of salts, for example from rock weathering, capillary rise, rainfall or flooding, exceed their removal by plant uptake, leaching and flooding. Thus salinization on the soil surface occurs where the following conditions occur together:
  - the presence of soluble salts in the soil (e.g. sulphates of sodium, calcium and magnesium;
  - a high water table;
  - a high rate of evaporation; and
  - low annual rainfall.
- **Sodic soils** contain a higher amount of sodium attached to clay particles. When in contact with water, a sodic soil swells and disperses into tiny fragments. On drying these tiny fragments block the soil pores, causing problems of crusting, hard-setting, poor infiltration and water-logging.

Excess salts hinder crop growth, not only by their toxic effects, but by reducing water availability, regardless of the total amount of water actually in the root zone. Salts in the soil increase the effort plant roots must make to take up water. High levels of salt in the soil have a similar effect as drought, reducing availability of water for uptake by plant roots, reducing plant growth and yields.

Soil erosion is a major form of land degradation. It comprises various processes that are described separately below; however, any one of these processes may occur in the same locality, either in combination or at different times of year:

- **Soil erosion by water** is often quite widespread and can occur in all parts of drylands where rainfall is sufficiently intense for surface runoff to occur[4]. This category includes processes such as splash, sheet, rill and gully erosion.
  - Splash erosion is commonly the first stage of water erosion and occurs when rain drops fall onto the bare soil surface. Their impact can break

4 Although the total annual rainfall in dryland areas may be low, the amount and intensity of rainfall received during an isolated storm event can result in high rates of surface runoff and hence severe water erosion.

up surface soil aggregates and splash particles into the air.
- As water runs over the soil surface it has the power to pick up particles released by splash erosion and the capacity to detach particles from the soil surface. This may result in sheet erosion, where soil particles are removed from the whole soil surface on a fairly uniform basis.
- Where runoff becomes concentrated into channels, rill and gully erosion may result. Rills are small rivulets of such a size that they can be worked over with farm machinery. Gullies are much deeper (often being several metres deep and wide) and form a physical impediment to the movement across the slope of farm machinery, even people and livestock.

Soils that have lost organic matter and had their structural stability degraded through excessive tillage are more vulnerable to water erosion. Likewise surface and subsoil compaction reduces the amount of rainfall that can infiltrate into the soil, leading to increased surface runoff and increased risk of water erosion.

- **Soil erosion by wind** is also widespread throughout drylands that are exposed to strong winds. It includes both the removal and re-deposition of soil particles by wind action and the abrasive effects of moving particles as they are transported. In areas with extensive loose, sandy material, wind erosion can lead to the formation of mobile sand dunes that cause considerable economic losses through engulfing adjacent farm land, pastures, settlements, roads and other infrastructure. Wind erosion occurs:
  - In farmland areas when soil is left bare of vegetation and the topsoil has been reduced to a fine tilth as a result of cultivation;
  - In overgrazed grassland areas that have lost their protective vegetative cover;
  - In forest / woodland areas following the cutting of trees and shrubs, in particular following the removal of the leaf litter and herbaceous ground cover.

In temperate climatic zones, the risk of wind erosion is highest in spring, prior to the onset of the summer rains, due to the combination of strong winds, dry topsoil, poor vegetative ground cover, also a lack of leaves on the trees in windbreaks planted to protect croplands.

In those parts of the tropics and sub-tropics with distinct wet seasons and dry seasons, the risk of wind erosion is highest in the latter part of the dry season when the topsoil is at its driest and the vegetative ground cover has died back.

- **Gravitational erosion** tends to be more localised in regions with steep, rocky slopes and in mountain ranges. On sloping land when soil is saturated, its weight increases and the downward forces of gravity will induce a relatively large down-slope movement of soil and / or rocks (e.g. landslides, slumps, earth flows and debris avalanches). This mass movement of material may be very rapid and involve large volumes of soil, but is usually limited to isolated and localised events. Landslides may be natural events, however, their frequency and severity is likely to greatly increase following deterioration or loss of the natural vegetative cover by logging, overgrazing and / or clearing for cultivation. This manual does not cover the assessment of landslides and mudflows.

- **Freeze - thaw erosion** is restricted to high altitude areas and areas with cold climates. It occurs when water in the topsoil initially freezes and expands, then melts, damaging topsoil structure and enabling loosened surface soil particles to be carried away in melt water runoff. It is primarily a natural process rather than one which is accelerated by particular human activities. Its assessment is not covered in this manual although it was identified as an important form of erosion in colder parts of China.

Soil pollution also deserves consideration, as agricultural and industrial pollutants may contaminate the soil and affect plant growth and productivity, which may in turn contaminate water resources through leaching and runoff. No specific tools are included in this manual for assessing soil pollution; however, the team should look out for and if necessary identify suitable tools if there is substantial evidence or information for the problem. Examples of soil pollution include:

- Certain crop inputs can build up chemical imbalances or toxicities in the soil, notably mineral fertilisers, pesticides and inadequately treated organic waste / sewage sludge.
- Certain plants result in the accumulation of pollutants / toxicities of organic origin due to the production of organic chemicals in their roots or leaf litter that inhibit the growth of other plants, or result in other negative changes in soil properties (e.g. increasing soil acidity as can occur under pine plantations).
- Uncontrolled discharge of pollutants can contaminate water sources and also the land (e.g. when the water is used for irrigation purposes, or flooding takes place, or through erosion (by wind and/or water) and subsequent deposition of the material from spoil heaps and other wastes associated with mining and quarry operations).

4.1.2 Vegetation and biodiversity degradation

Vegetative growth in drylands tends to be limited by a range of natural factors, notably extreme temperatures, low and erratic rainfall, low soil water availability and shallow soils with low inherent fertility. In response, a number of highly specialised vegetation types have evolved and adapted to the local climate, topography and soils. Vegetation degradation involves a combination of processes that may be natural, notably climate change which may lead to a loss of certain species and habitats, reduced biomass due to reduced moisture availability, or encroachment by invasive species. However, vegetation degradation is generally induced by human activity, through the over use or mis-management of forests, grazing and croplands, uncontrolled burning or introduction of pests and diseases.

In assessing vegetation degradation, study should focus on the adverse changes in the quantity, quality and diversity of the plants that are found in grassland, forest and woodland areas. The degradation processes are summarised in Table 4. However, for better understanding of causes / drivers and impacts of LD / SLM, degraded areas should be compared with areas that appear to be less degraded / under better management practices, therefore these indicators could show negative or positive changes or trends.

TABLE 4 **Vegetation and biodiversity degradation types and processes**

Vegetation and biodiversity degradation	Key processes
Degradation of vegetation quantity and quality	Reduction in vegetative ground cover – *with expanding areas of bare ground in formerly vegetated areas*
	Reduction in vegetation biomass – *with fewer plants, at lower density, with reduced vigour and growth producing fewer leaves, stems, flowers, fruits, seeds, etc. (resulting in reduced yield of grassland, forest and woodland products)*
	Reduction in the quality of the vegetative biomass – *where plant species of high value (for fodder, timber, fuelwood, food, medicines etc.) have been replaced, to a lesser or greater extent, by species of lower, or no value; or* • *parts of the plants have been damaged or their health affected through excessive removal of specific parts (for timber, fuelwood, fodder, fruits, food, medicine etc.)*
Degradation of plant diversity	Reduction in species diversity and / or abundance • *reduced numbers / populations of specific species in natural plant communities; or,* • *reduced diversity of local crop varieties and land-races*
	Reduction in habitat for associated species *(pollinators, beneficial predators etc.) with consequent decline in related functions and resilience*
Degradation of animal productivity	Reduction in livestock (or wildlife) stocking capacity and productivity (due to reduction in biomass and feed quality)

The timing of the assessment is important, as the vegetation may appear very degraded in the dry season but will recover astonishingly fast during the rains. It is for this reason that the assessment team is encouraged to return and take photos at various times of the year, as illustrated by photos 11 and 12 which are taken during the rains and in the dry season.

Vegetation types are often closely related to the geology, soil types and terrain (topography) as shown by Photo 12 with distinctive vegetation of the basaltic plateau in Argentina.

4.1.3 Water resource degradation

There are various processes of water resources degradation, including changes in water quantity, quality and alterations in the hydrological regime. These are described in Table 5. As in the vegetation assessment, conservation or improvements in water resources should also be assessed; therefore these indicators can show negative or positive changes.

Degradation of water resources in terms of quantity, quality and flow regime will lead to reduced productivity of the aquatic system in terms of fish and other useful aquatic species and products. It also affects the availability of clean drinking water for consumption by humans, livestock and wildlife.

D.S. NDIAYE

a

A. WELE

b

PHOTO 11 **Wet and dry season differences Senegal: a) Dried pond (Diabal) and b) large shallow pond, Niakha**

PHOTO 12 **Vegetation type on basalt plateau (Bariloche, Argentina)**

TABLE 5 **Water resources degradation types and processes**

Water resource degradation	Key processes
Degradation of surface and ground water resources and change in hydrological regime	Increased fluctuation in quantity of surface water flow *(leading to increased storm peak flows and reduced dry season flow as a higher proportion of the rain falling during storm events is lost rapidly as surface runoff rather than infiltrating into the soil)*
	Increased incidence of downstream flooding *(as upstream areas become degraded and can no longer absorb the volume of rainfall received during storm events)*
	Drying up of water sources *(rivers, springs, lakes, ponds, boreholes etc.)*, (e.g. *more frequently and for longer periods as water is lost in surface runoff rather than infiltrating to replenish groundwater levels)*
	Reduced groundwater recharge (e.g. *due to increased surface rainwater runoff or reduced rainfall)*
	Lowering of the ground water table (e.g. *due to reduced recharge and increased extraction)*
Degradation of water resources quality and storage capacity	Increased sediment load in streams and rivers (e.g. *due to increased soil erosion in their catchment areas)*
	Reduced water storage capacity (e.g. *due to sedimentation of reservoirs)*
	Increased salinity of surface and groundwater resources (e.g. *due to excess salt flushing from irrigated areas)*

TABLE 5 **Water resources degradation types and processes** *(continued)*

Water resource degradation	Key processes
Water pollution	Pollution of surface and ground water resources (e.g. *from leaching or discharge of human and animal wastes, agro-chemicals, industrial and mining wastes)* affecting the water quality for human and animal consumption, for agro-industry and irrigation
	Decline in aquatic life and diversity due to water pollutants, with associated loss of key species in food web and reduced ecological resilience

4.2 SLM technologies and approaches

4.2.1 SLM technologies

The following SLM technologies or management practices are widely known in all regions of the world. The findings of more detailed assessments of these practices in the local assessment area and their impacts on livelihoods and ecosystem services can validate the national assessment findings and provide further information for decision makers on the effectiveness of practices that are being promoted with government, NGO and / or private sector support.

1. **Integrated soil fertility management (ISFM)**
2. **Conservation agriculture (CA)**
3. **Organic agriculture**
4. **Rotational cropping systems**
5. **Integrated crop-livestock management**
6. **Sustainable grazing land management**
7. **Pastoralism and rangeland management**
8. **Agroforestry**
9. **Sustainable planted forest management**
10. **Sustainable forest management** (drylands and rainforests)
11. **Cross-slope barriers on sloping lands**
12. **Rainwater harvesting**
13. **Surface and ground water management**
14. **Smallholder irrigation management**
15. **Water quality improvement**
16. **Gully control and other land rehabilitation measures**
17. **Sand dune stabilization**
18. **Riverine and coastal bank protection**
19. **Protection against natural hazards**
20. **Waste management**
21. **Biodiversity conservation and sustainable use**
22. **Protected areas**

Annex 2 provides brief descriptions of these various technologies and Annex 3 a case study.

4.2.2 SLM approaches

A SLM Approach defines the ways and means used to promote and implement a SLM Technology (be it project / programme initiated, an indigenous system, a local initiative / innovation) and to support it in order to achieve better and more widespread sustainable land management. It may include different levels of intervention, from the individual farm, through the community level to the extension / advisory system at provincial or national levels. It may be set within an international framework. Critical analyses of approaches should assist in answering questions about how land users learn about improvements or 'new' technologies, how they obtain skills to apply them, how they are stimulated to adapt technologies and innovate, also how they gain access to the required inputs, equipment and financial resources.

SLM approaches commonly stimulate the adoption and spread of improved SLM through addressing the problems and root causes of land resources degradation and low productivity that can be highlighted through the livelihoods assessment, for example:

- Lack of technical knowledge (human capital);
- social inequity (social capital);
- poverty / lack of cash to invest in SLM, limited access to external inputs (financial capital);
- conflicts over resource use, limited land resources (natural capital);
- lack of access to markets (remoteness, poor infrastructure) and to services (physical capital);
- lack of adequate policy and institutional support, with appropriate laws and regulations.

Common SLM Approaches include:

- Participatory research and development (PRD) which includes Participatory Learning and action (PLA):
- Participatory land use planning (PLUP)
- Integrated watershed / landscape management (IWM)
- Community-based natural resource management (CBNRM):
- Community development / investment funds:
- Extension, advisory service and training
- Innovative extension approaches that empower farmers' groups and innovators
- Payments / Rewards for ecosystem services (PES)

Annex 4 provides brief descriptions of these various SLM approaches and Annex 5 a case study.

These lists and descriptions draw from the LADA-WOCAT national assessment manual (CDE / WOCAT *et al.* 2011) and two WOCAT publications: the "SLM in Practice" handbook (FAO / TerrAfrica, 2011) and "Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide (WOCAT, 2007)