

# Application of DPSIR Framework for Assessment of Land Degradation: A Review

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## Abstract

The main objective of this review paper is to give an overview on the causes and impact of land degradation in Ethiopia through the DPSIR scheme for land degradation assessment. Land degradation is a process of the reduction of land resources production potential and is the deterioration in quality of the environment for humans, vegetations, animals and aquatic life. It is a complex phenomenon triggered by the interplay of environmental, social, economical factors. It happens all over the world but its severity is more in parts of Africa particularly in sub-Saharan Countries. The problem of land degradation in rural areas is highly interlinked to food security and quality of environment. Despite the nonstop ongoing degradation, land users and policy makers have responded in many instances with innovative practices and policies to protect degraded lands and degradation process at all. DPSIR approach is among the appropriate environmental assessment tools contributing in the formulation of environmental policies. It is a significant model and simplifies the monitoring system of land degradation.

**Keywords:** Land; Degradation; DPSIR; Ethiopia

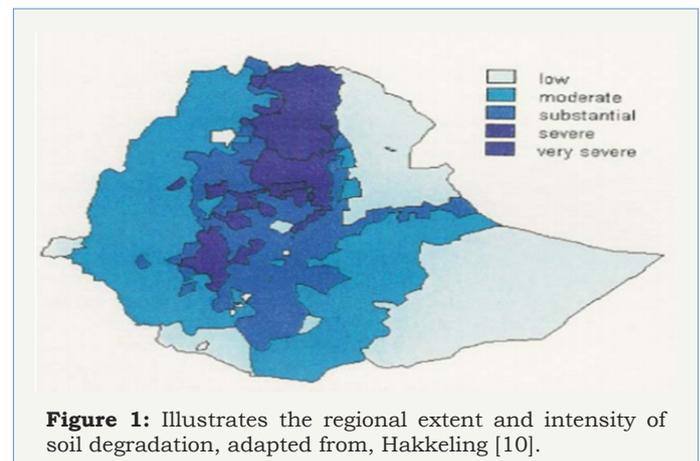
**Abbreviations:** EHRS: Ethiopian Highland Reclamation Study; UNCCD: United Nation Convention to Combat Desertification; DPSIR: Driving force, Pressure, State, Impact and Response; CCD: Combat Desertification

## Introduction

Land degradation processes, which imply a reduction of the potential of productivity of the land (soil degradation and accelerated erosion, reduction of the quantity and diversity of natural vegetation) are widely spread and are defined as the long term loss of ecosystem function and productivity caused by disturbances from which the land cannot recover unaided. It refers to deterioration in the quality of the environment for humans, vegetations, animals and aquatic life and degradation has no single readily-identifiable feature but instead describes how one or more of the land resources (soil, water, vegetation, rocks, air, climate, and relief) has changed for the worse [1,2]. Land degradation is a complex phenomenon triggered by the interplay of environmental, economic and social factors and is reaching a significant dimension especially in rural areas of developing countries where its effects are more severe [1,3-7].

Land degradation includes all process that diminishes the capacity of land resources to perform essential functions and services in ecosystems which are caused by two interlocking complex systems: the natural ecosystem and the human social system and the interactions between the two systems determine the success or failure of resource management [8]. Land degradation which is also seen as a decline inland quality caused by human activities, has been a major global issue since the 20<sup>th</sup> century and it has remained high on the international agenda in the 21<sup>st</sup> century. In the last decades, humans have more than ever been changing

the world's ecosystems to meet the growing demands for food, freshwater, timber, fiber, fuel and minerals [9].



Land degradation happens all over the world, but is a particular problem in parts of Africa and Ethiopia. The importance of land degradation in Ethiopia is enhanced because of its impact on food security and quality of the environments. Its consequences can be devastating for people and wildlife and closely linked with other environmental and social problems such as climate change and poverty and its remedy is tied up with them. An assessment of the status of land degradation in Ethiopia was done 20 years back. Although it is believed that land degradation has continued with equal or greater intensity, there has never been a systematic and

comprehensive assessment since then. Therefore according to the Ethiopian Highland Reclamation Study (areas above 1500m), sheet and rill erosion and the interrelated physical degradation process are the dominant degradation processes on land degradation (Figure 1) and the annual soil erosion rate was estimated to be 1.5 billion tons (Table 1) [10,11].

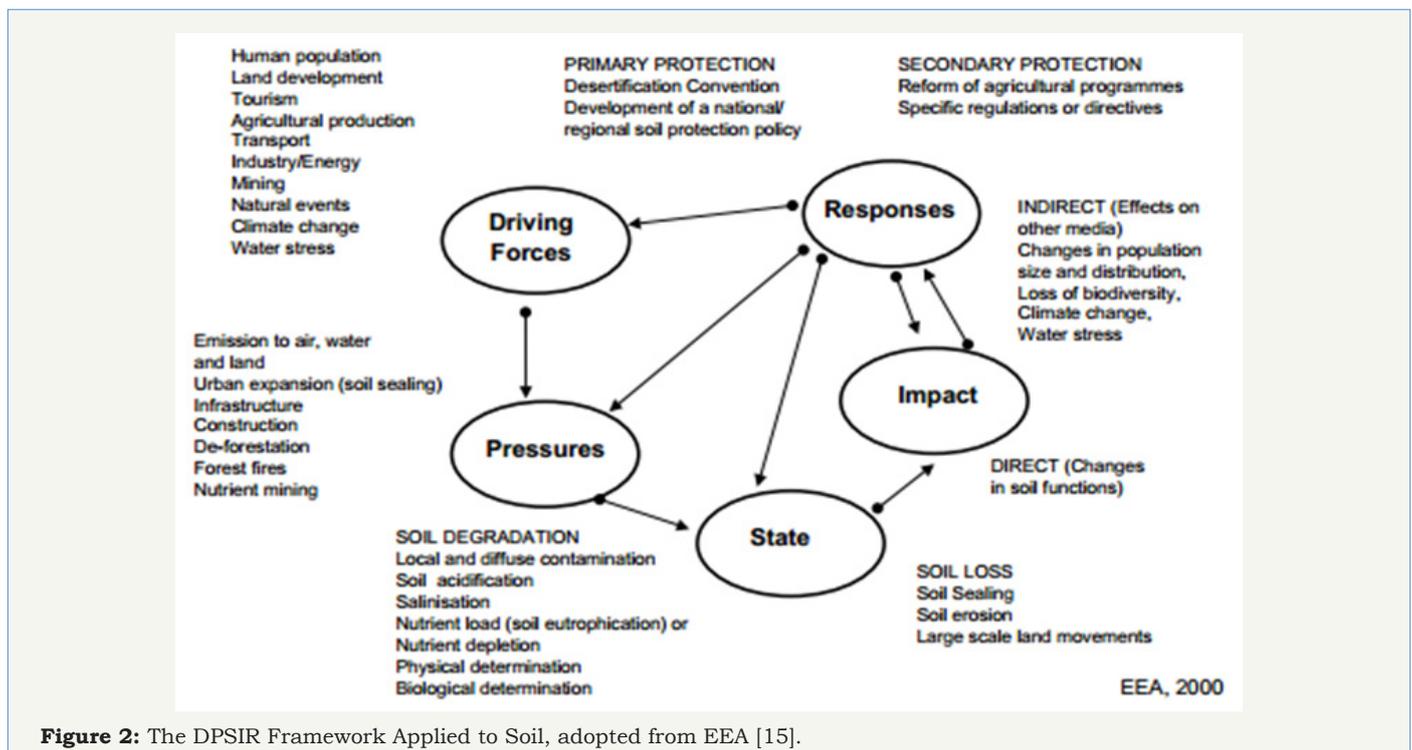
From all land use and cover types, the severity is worst on cropland, where the annual soil loss rate is in a range of 42 tons

ha-1 yr-1. The Ethiopian Highland Reclamation Study (EHRS) estimated that the annual soil erosion rate on the highlands is 1.9 billion tons, of which 10% of it is carried away irretrievably by the highland rivers [12]. Though it cannot be unequivocally proven with research data, chemical degradation due to leaching and development of aluminum toxicity are found at local level and with limited extent, while chemical degradation due to “mining” of soil nutrients as a result of poor farming practices is likely to be widespread being serious to phosphorous [12].

**Table 1:** Estimated soil loss from different land use land cover types.

Land Use Land Cover Types	Estimated Area (%)	Estimated Soil Loss	
		Tons/ha/yr	Tons/yr
Crop land	13.1	42	672,000,000
Perennial crops	1.7	8	17,000,000
Grazing land	51	5	312,000,000
Currently unproductive land	3.8	70	325,000,000
Currently uncultivated land	18	5	114,000,000
Forest	3.6	1	4,000,000
Wood land and shrub land	8.1	5	49,000,000
Total	100	12	1,493,000

Source: Hurni [11].



**Figure 2:** The DPSIR Framework Applied to Soil, adopted from EEA [15].

The general pressure and driving forces that attribute to land degradation share communalities across the country. Typical pressure factors include over cultivation, overgrazing and deforestation. The underlying factors include rainfall erosivity, soil erodibility, land slope and land use factors [12-14]. The ongoing degradation of land over many years has been studied as one of the main factors responsible for the decline of agricultural

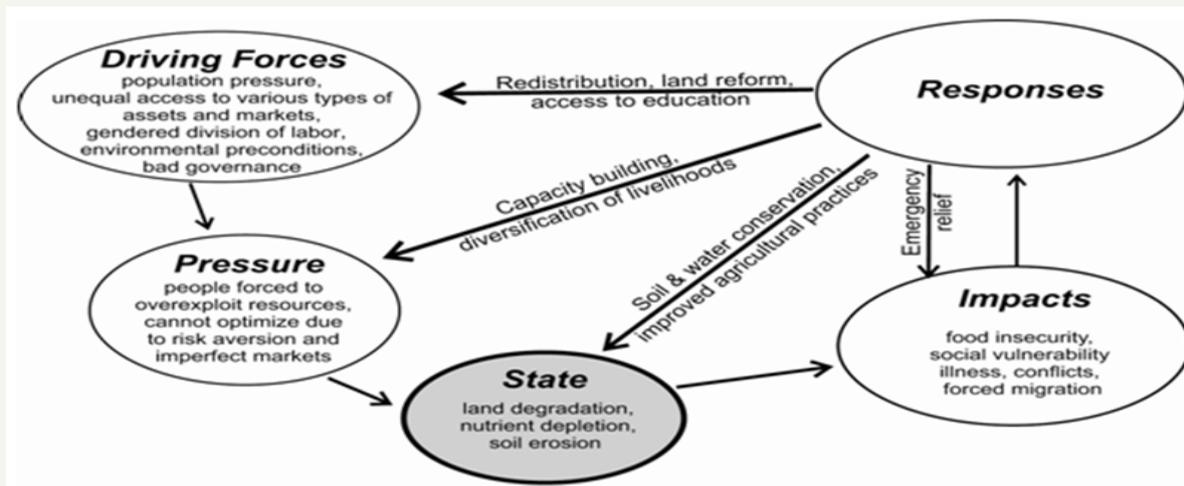
production whenever unsustainable environmental practices have been pursued. Thus, the purpose of this paper is to give an overview on the causes and impacts of land degradation in Ethiopia through the driving forces (D), pressures (P), state (S), impact (I), responses (R) scheme and the causal chain, from the driving forces to the state, impacts and system responses, for several present and past human activities related to land use and land degradation is

assessed because DPSIR framework approach is used for analyzing and assessing land degradation problems within a comprehensive view of interactions between human society and the environment (Figure 2) [15].

### DPSIR Analysis of Land Degradation

DPSIR is short for Driving forces, Pressures, State, Impacts and Responses. Within a short time, the DPSIR framework has become popular among researchers and policy makers alike as a conceptual framework for structuring and communicating policy

relevant research about the environment. According to the DPSIR framework there is a chain of causal links starting with ‘driving forces’ (economic sectors, human activities) through ‘pressures’ (emissions, waste) to ‘states’ (physical, chemical and biological) and ‘impacts’ on ecosystems, human health and functions, eventually leading to political ‘responses’ (prioritization, target setting, indicators). Describing the causal chain from driving forces to pressure, state, impacts and responses is a complex task (Figure 3) [16,17].



**Figure 3:** Land degradation and potential responses by society expressed in the form of a DPSIR (Drivers, Pressure, State, Impacts, and Responses) scheme, adapted from Andersson [17].

### Driving forces (D) of land degradation

Driving forces are the factors that cause changes in the system. Sometimes referred to as indirect or underlying drivers or driving forces and refer to fundamental processes in society, which drive activities having a direct impact on the environment. They can be social, economical or ecological and can have positive or negative influences on pressures. The encountered causative factors of land degradation are both proximate causes and underlying forces [4,18,19] in which the proximate causes of land degradation are

those that have a direct impact on terrestrial ecosystems, while the underlying causes are those that stimulate the proximate causes [20]. Land degradation operates in a synergistic manner with other phenomena such as climate change, biodiversity loss and water scarcity, among others [4,21-24]. One of the most recurrent synergies is, for example, population increase, leading to a pressure on the use of land, leading to deforestation and forest degradation, in turn leading to climatic variability and poverty. This is one vicious circle difficult to cope with and to reverse [17,25].

**Table 2:** Simplified analytical framework of driving forces and processes involved in LD.

Type of Cause	Causative Factor (Driving force)
Processes	Prominent: Vegetative cover degradation; Water and wind erosion Others: Acidification; Aridization; Biodiversity loss; Bush encroachment; Dry lands expansion; Fresh water reduction; Physical soil degradation; Pollution; Salinization; sand drift; Sandification; Soil crusting; Soil fertility decline.
Proximate causes	Prominent: Agricultural mismanagement; Deforestation; Land use change Others: Slope steepness and poor soils; Demand for food; Fires; Forest resources overexploitation; Inadequate waste disposal; Land cover change; Over fertilization; Overgrazing; Over plowing; Illegal logging; Urban encroachment.
Underlying causes	Prominent: Inadequate environmental policy; Land mismanagement; Unsuitable land use; Insecure land tenure; Tenure fragmentation. Others: Floods; Droughts; Lack of available environmental knowledge; Lack of information about appropriate alternative technologies; Unplanned land use change; Unplanned urban growth; Land use pressure; Limited access to farm inputs and credit; Livestock pressure; population pressure; Poverty; breakdown of the indigenous (local) institutions; Lack of local non-farm employments; Demand of forest products.

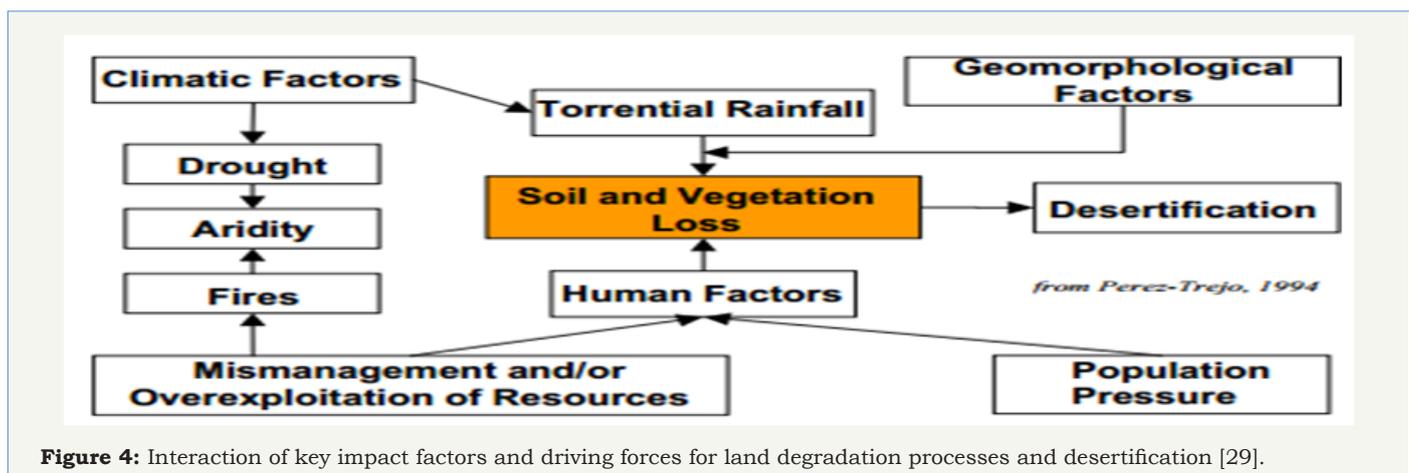
The cause of land degradation involves the natural ecosystem and the human social system. Moreover, biophysical factors such as unsuitable land use (land use for the purpose for which environmentally unsuited for sustainable use), socioeconomic factors such as poor land management practices, land tenure, marketing, institutional support, income and human health, and political factors such as lack of incentives and political instability and in parallel, a biophysical process driven by socioeconomic and political causes in which subsistence agriculture, poverty and illiteracy are important causes of land and environmental degradation in Ethiopia [8,26] (Table 2).

Although natural processes such as adverse climatic conditions, earthquakes, drought, tsunamis and hurricanes have been identified as major causes of environmental and resource depletion, human activities such as indiscriminate grazing, large and small-scale mining, sand and stone quarrying, periodic bush burning and firewood harvesting, have played an increasingly important role in driving environments far beyond their carrying capacity, causing unprecedented degradation and depletion of natural resources [27,28]. The UN Convention to Combat Desertification (CCD), of which Ethiopia is a signatory, recognizes land degradation as a global development and environment issue. Accelerated land degradation and/or desertification commonly are caused as a result of human

intervention in the environment, and by the natural landscape, which Ethiopia is most vulnerable. In some places of the country processes of land degradation is exceeding the rate of natural rehabilitation. Unsustainable cultivation of Crop lands, Overgrazing of rangelands, deforestation, Soil erosion, conversion of unsuitable and low potential land to agriculture, failure to undertake soil conservation measures in areas at risk of degradation, and removal of all crop residues resulting in soil mining.

### Pressures (P) of land degradation

Pressures are the human activities that directly affect the system and are generated by the driving forces. Unsustainable human activities that take place in already fragile areas and that are aggravated by natural disturbance such as drought or flooding lead to land degradation and desertification. Conditions which exacerbated are recurrent drought and over exploitation of natural resources. Overgrazing and poor land management further worsened the occurrence. In general the direct pressures towards land degradation includes; Land use area trend, Land use intensity trend, Crop management level, Deforestation, Over-exploitation of vegetation, Overgrazing, Industrial activities, Urbanization, Natural causes, Discharge of effluents, Washing out of pollutants and Airborne pollutants, rapidly increasing population, high per capita consumption of resources, imbalance of trade etc (Figure 4) [29].



**Figure 4:** Interaction of key impact factors and driving forces for land degradation processes and desertification [29].

### States (S) of Land Degradation

State is the condition of the system at a specific time and is represented by a set of descriptors of system attributes that are affected by pressures and the type, degree and rate of land degradation. As a result of pressures, the 'state' of the environment is affected; that is, the quality of the various environmental compartments (air, water, soil, etc.) in relation to the functions that these compartments fulfill. The 'state of the environment' is thus the combination of the physical, chemical and biological conditions. Examples of state descriptors could be the features or quality of water, sediment, species composition, habitat structure.

Intensive management practices in agriculture escalating rates of land degradation threatens most crop and pasture land throughout the world. Worldwide, more than 12 million hectares

of productive arable land are severely degraded and abandoned annually. Increased pressure is connected with deterioration of the state of environment, mainly soil and water. Soil is the most fundamental asset on farms. Its quality that directly affects provisioning ecosystem services is strongly affected by management practices. The state of soils can be assessed by the help of indicators on soil contamination, erosion, and compaction. Soil contamination implies that the concentration of a substance in soil is higher than would naturally occur. Agricultural activities contribute to soil contamination by introducing pollutants or toxic substances.

### Impacts (I) of land degradation

Impacts are commonly the result of multiple stressors and effects on human health and/or ecosystems produced by a pressure. Impacts related to land degradation are reduction in abundance or

biodiversity, decline in productivity, carbon storage loss, decline in water availability and quality, impact on ecosystem services and tourism. All these exert pressure on the environment be it may beneficial or harmful and can result in either of environmental impacts. All these consequences, with wide variation in different systems, characteristics and practices throughout the world, may arise at site specific level but can have impacts at local to global level to mean when land is degraded, wildlife, plants and people suffer and can worsen the effects of poverty and bring about hunger.

Degradation of land has serious consequences for food security. Many small scale farmers in areas of degraded land can only watch in dismay as their soil grows less each year to feed their families. This situation is made worse by droughts and unpredictable weather patterns caused by climate change. Land managers and policy makers need information about soil change in order to be able to predict the effects of management on soil functions compare alternatives and take appropriate decisions since it manifests itself in many different ways such as reduction in vegetation cover, drying up water courses, pastures predominated in thorny weeds, footpaths grow into gullies, and soils become thin and stony. Thus, all of these manifestations have potentially severe impacts on the environment, for land users and for people who rely for their living

on the products from a healthy landscape [8,30].

### Responses (R) of land degradation

Responses are the efforts made by society as result of the changes manifested in the impacts. As directed actions, responses typically take the form of programme activities, such as the number of inspections done. In recent decades, increasing concern for the environment and sustainability has compelled many governments to continuously adjust their land use policies to balance multiple uses of land resources. These policies have caused changes in crop land and its spatial distribution. There are different environmental objectives incorporated into agri-environment measures; macroeconomic policies, training programs, and support for investments in agricultural and water holdings, protection of the environment in connection with agriculture and landscape conservation, support to improving the processing and marketing of agricultural products, conservation and rehabilitation, land policy and policy instruments, commitment to international conventions and monitoring and early warning systems. An integrated land resource planning as an approach, among others, is an opportunity to bring about sustainable use of land resources. Attempts were underway to prepare and implement integrated land use plans at various levels (Figure 5 & 6).



**Figure 5:** Reclaimed land in Adwa Mariam Sheweto and area under conservation farming, in Ambalaje, Adi Sebhat, Tigray National state.



**Figure 6:** Traditional stone-faced bench terraces in “Basso” village of Konso and Contour trash line on gentle slope farm (Konso).



In the history of mankind never greater attention has been given to the environment. But, The Future We Want, the outcome document of the international Rio+20 meeting [31] and currently as political discussions in states, land degradation identified as the need to advance towards within the context of sustainable development. This is particularly important for those people living with and affected by land degradation in their everyday lives. This arises because of the realization that the environment holds fundamental but finite resources for economic and social development and should therefore be used sustainably and the United Nations has worked assiduously to impress upon member states the need to protect the environment and manage its natural resources. Environmental degradation has been identified as a high impact problem in physical and financial terms that could result in human and environmental disasters globally [27,32-35].

## Conclusion

Land degradation includes all process that diminishes the capacity of land resources to perform essential functions and services in ecosystems and happens all over the world, but is a particular problem in parts of Africa and Ethiopia. The importance of land degradation in Ethiopia is enhanced because of its impact on food security and quality of the environments. Despite the ongoing degradation, land users and policy makers have in many instances responded with innovative practices and policies that have transformed degraded landscapes and prevented further degradation. Such success stories are isolated and the global challenges are vast, so it is critical to better understand the drivers of ongoing degradation processes, in order to learn from past errors and local successes in achieving sustainable land management. Moving towards being able to upscale successful sustainable land management becomes all the more important as enter post-2015 era, in which the Millennium Development Goals look set to be succeeded by Sustainable Development Goals.

Assessment of environmental degradation and natural resource depletion has therefore become an essential tool for the long-term management of natural resources and the sustenance of livelihoods that are dependent on them. A key step in the assessment of human driven environmental problems is to research the spatial and social determinants of such problems through the adoption of an appropriate environmental assessment tools such as through the application of the DPSIR framework in the assessment of environmental problems (land degradation) to contribute to the formulation of environmental policies. Even though, its adoption is still at the infant stage in many developing countries, like Ethiopia, it is a significant model and simplifies the Monitoring system of land degradation in DPSIR-Based in stepwise as: define the area and scale, select indicators, select methods (procedures) and tools, collect existing data and identify data gaps, stratify or partition variability, design a data collection strategy for missing data, analyze data and integrate results, identify "hot spots" and "bright spots", validate results and assess accuracy, map out and report results and monitor changes over time.

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