Land Degradation in Bhutan – An Overview

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Abstract

Bhutan lies in the foothills of the Eastern Himalayas (latitudes 26°47'N to 28°26'N and longitudes 88°52' to 92°03'E) at altitudes of 100-7500m. Because of its rugged topography and altitude, Bhutan has limited resources of productive land (<8% of the total area). These land resources are at risk from the various types of land degradation that occur in Bhutan, threatening the livelihoods of the 80% of population who depend on agriculture. Land degradation surveys and other studies show that different types of land degradation occur in Bhutan to differing extents and intensities. Water induced degradation, specifically gullies, landslides, ravine formation and local flooding are more prominent and devastating. *In-situ* chemical degradation, such as depletion of soil organic matter and nutrient mining, and *in-situ* physical degradation, such as topsoil capping and subsoil compaction, are also prominent. Surface erosion is extensive but less severe than would be predicted from the topography, due to the high proportion of gneissic soils. Even though land degradation is common in Bhutan, it is not well documented. This paper gives an overview of the land degradation types in Bhutan, their extensiveness and degree of degradation, as a step towards facilitating future land degradation studies in support of sustainable development planning and appropriate mitigation interventions.

Introduction

Land degradation is becoming an important global issue because of its adverse impact on agronomic productivity and the environment, and consequently on food security and the quality of life (Eswaran *et al.,* 2001). Although the main causes of land degradation are natural, anthropogenic factors also contribute substantially, directly or indirectly. Natural causes may be beyond the scope of economic mitigation but anthropogenic causes need to be addressed to combat land degradation.

Bhutan lies in the foothills of the Eastern Himalayas (latitudes 26°47'N to 28°26'N and longitudes 88°52' to 92°03'E), with most of its mountain ranges running from north to south. Because of its topography and altitude, Bhutan has inherently limited resources of productive land. Moreover, the predominantly steep slopes make land degradation an even more serious threat in Bhutan than in most places (Norbu *et al*., 2000). National policy, vision, and review documents recognise this (Biodiversity Action Plan (Ministry of Agriculture, 1998), National Environment Strategy (National Environment Commission, 1998)).

The Food and Agriculture Organisation (FAO) and the International Soils Reference and Information Centre initiated the Global Assessment of Soil Degradation (GLASOD) in the early 1990's (Oldeman, 1994). Young (1994) applied the GLASOD classification and criteria in a survey of land degradation in South Asia that included Bhutan, but without any land degradation data from Bhutan. He tried to extrapolate to Bhutan from the situation in neighbouring parts of the Himalayas, but felt that this gave an exaggerated picture of degradation in the country.

To aid such studies (e.g. GLASOD), land degradation information for Bhutan needs to be generated and made available internationally. This paper makes a contribution by providing an overview of the land degradation types in Bhutan, their extensiveness and degree of degradation, as a step towards facilitating future land degradation studies that will enable realistic development planning and appropriate interventions in the degraded sites in Bhutan.

Definition of Land Degradation and its Interactions with Natural Hazards

Numerous terms and definitions surround land degradation and are a source of confusion, misunderstanding, and misinterpretation (Eswaran *et al.,* 2001). It is important to standardize the terminology, and develop a precise, objective, and unambiguous definition accepted by all disciplines.

Oldeman (1994) defines land degradation as 'the decline of land's capacity to sustain agroforestal and other biotic production due to human activity'. This definition has significant implications: it excludes decline in productivity that is due wholly to natural causes, and restricts land degradation to anthropogenic effects. Stocking and Murnaghan (2001) indicate that land degradation includes all productivity-reducing effects that are due to 'inappropriate use', implying that degradation is a result of human activities. The definition excludes changes, no matter how visible, that do not detract from the land's productivity. Other definitions, e.g. Stocking (2001), Young (1994), do not restrict degradation in this way.

The exclusion of natural degradation processes is particularly problematic in Bhutan. Because of its high relief, steep slopes, and location in a zone of orogenic (mountain building) activity, the landscape of Bhutan is naturally dynamic. There are many powerful natural processes such as river down-cutting, underground piping, water saturation, etc. that are working vigorously. Much of the landscape of Bhutan is only quasi–stable, and needs only a small trigger to destabilize it and for its surface materials to slip down slope and eventually be washed downstream. In such events, it is difficult to attribute the cause between the small anthropogenic trigger, i.e. land degradation as defined by Oldeman, Stocking and Murnaghan above, and the large natural event that was poised and waiting to happen. We therefore do not attempt to distinguish rigorously between anthropogenic degradation and natural processes. Instead we indicate how processes that detract from the productive capacity of land can be initiated and/or intensified by human activities.

In our view, land degradation processes are interactive, sequential and cumulative. For instance, quite small depletions of some nutrients may lead to a decrease in soil organic matter. This in turn may weaken the physical structure of the topsoil, making it easier for rainfall and surface runoff to remove it. In this way a relatively minor change in soil chemistry can lead to erosion. Similarly, minor forms of erosion can intensify rapidly, and small rills can grow to large gullies. These processes are common in Bhutan and slowly lead to the formation of huge gullies, landslides and ravines.

Common Land Degradation Types

Norbu *et al*., (2000) give a general account of the land degradation types in Bhutan but do not pinpoint the most common types or their severity (degree of degradation). By applying the GLASOD definitions of degrees of degradation (Table 1 below) to our survey data, we estimate the degree to which the land is presently degraded and present this in Tables 2-6.

Table 1 GLASOD definitions of degrees of degradation.

Degree	Definition
1. Light	The terrain has somewhat reduced agricultural suitability, but is suitable for use in local farming systems. Restoration to full productivity is possible by modifications of the management system. Original biotic functions are still largely intact.
2. Moderate	The terrain has greatly reduced agricultural suitability, but is still suitable for use in local farming systems. Major improvements are required to restore productivity. Original biotic functions are still partially intact.
3. Strong	The terrain is non reclaimable at farm level. Major engineering works are required for terrain restoration. Original biotic functions are largely destroyed.
4. Extreme	The terrain is non-reclaimable and beyond restoration. Original biotic functions are fully destroyed.

Table 2 Types of Degradation – In-situ degradation

Land degradation type	Possible causes	Impacts	Degree of degradation	Occurrence
In situ– Chemical[†]				
Soil organic matter (OM) depletion	• No or inadequate application of organic fertilizers • Forest and grassland converted into arable land	• Weakens soil structures • Reduces soil reserves of moisture and nutrients • Reduces crop yields and soil biodiversity	Moderate	• Extensive • In irrigated *chhuzhing* (wetland fields) • Some occurrence in *kamzhing* (dryland fields)
Soil nutrient depletion	• No or inadequate application of fertilizers • Leaching of nutrients • Erosion of fertile topsoil	• Reduces crop yield • Acidification	Moderate	• Extensive • In both *chhuzhing* and *kamzhing*

[†] After Oldeman, 1994

Land degradation type	Possible causes	Impacts	Degree of degradation	Occurrence
In situ– Physical[†]				
Topsoil capping	• Insufficient organic fertilizers • Bare soils exposed to heavy rain	• Reduces water infiltration • Increases runoff and surface erosion • Delays seedling emergence	Light	• Occurs mostly in *chhuzhing*
Subsoil compaction	• Cattle grazing on irrigated fields • Repeated ploughing to the same depth	• Increases surface runoff • Reduces infiltration • Increases risk of water logging	Moderate	• Extensive • In *chhuzhing* and orchards

Table 3 Types of Degradation – Glacial, wind and cultivation erosion

Land degradation type	Possible causes	Impacts	Degree of degradation	Occurrence
Glacial erosion	• Freeze-thaw cracking and rockfall • Glacier scouring	• Debris becomes prone to wind and water erosion • Glacial lakes burst and cause flood downstream	Light	• Limited to altitudes above 5000m a.s.l.
Wind erosion	• Silty soil texture • Cultivation on steep slopes	• Removes fertile topsoil • Reduces crop yield	Light	• Not very extensive • In *kamzhing* on steep slopes
Cultivation erosion	• Repeated cultivation on steep slopes	• Exposes sub-soil at the top of the fields as fertile topsoil moves down slope • Makes soil vulnerable to surface erosion	Moderate	• Extensive • Mostly in *kamzhing* on steep slopes

Table 4 Types of Degradation – Water (+gravity) erosion

Land degradation type	Possible causes	Impacts	Degree of degradation	Occurrence
Splash erosion	• Heavy rainfall on bare soil exposed by clearing	• Depletes organic matter (and nutrients) by preferential removal of light organic particles • Increases runoff, sheet and rill erosion	Light	• Extensive • Mostly in *kamzhing*
Sheet erosion	• Steep slope • Heavy rain on bare soil • Deforestation • Overgrazing	• Removes fertile topsoil • Exposes subsoil • Develops into rills • Reduces crop yield	Moderate	• Extensive • In *kamzhing* on clay-rich soils in Eastern Bhutan
Rill erosion	• Heavy rain on loose, bare topsoil • Leaking irrigation channels • Livestock trails • Unchecked sheet and splash erosion • Poor ground cover • Overgrazing • Deforestation	• Develops into gully erosion • Depletes organic matter and nutrients • Reduces crop yield	Moderate	• Extensive • In *kamzhing* when pre-monsoon rains are heavy
Piping erosion	• Water logging and subsoil compaction • Leaking irrigation channels • Over-irrigation	• Collapsed depressions can merge to form gullies • Concentrated seepage facilitates landslips • Subsoil removal depletes some nutrients	Moderate	• Localised in all types of land

Land degradation type	Possible causes	Impacts	Degree of degradation	Occurrence
Gully erosion	• Unchecked rills • Logging and stock trails • Steep slopes • Deforestation • Overgrazing • High rainfall • Poor drainage system	• Completely removes productive land • Gully head and side walls are vulnerable to landslips • Sediments reduce the capacity of reservoirs	Moderate	• Extensive • In unstable geology e.g. phyllite and on unstable soils e.g. deep red clays at Lobeysa-Punakha
Landslides	• Free faces, e.g. road cuttings, gully sides, etc. • Over-irrigation and other water-logging activities • Deforestation • Unstable soil and unstable underlying geology	• Completely removes productive land • Destroys infrastructure • Sediments reduce the capacity of downstream reservoirs • Damages hydro-plants	Strong	• Extensive • In unstable geology in the south and eastern parts of the country
Ravine formation	• Unchecked gullies and landslides • Unstable soil and underlying geology • Inappropriate land management practices • Deforestation • Overgrazing	• Completely removes productive land • Secondary landslips may occur that enlarge ravine • Poses risk to lives of people and animals • Forces people to resettle elsewhere	Extreme	• Localised e.g. Radhi and Tshogompa under Trashigang District
Flooding	• High and intensive rainfall • Accentuated by upstream land clearance and erosion	• Raw debris buries productive topsoil • Deposits easily re-eroded, by the river or wind	Strong	• Concentrated in wide valleys e.g. Punakha, Bomdeling, Paro, (where much cultivation occurs)

Table 5 Types of Degradation – Industrial and urban erosion

Land degradation type	Possible causes	Impacts	Degree of degradation	Occurrence
Encroachment on agro-forestal land	• Population growth and urbanisation • Industrialisation	• Productive land is lost • Soil is polluted by spoils toxic to flora and fauna	Light	• Localised, mainly in Thimphu, Paro, Jakar, Gelephu, Phuentsholing
River bed mining	• Mining of sand, gravel and stones for roads and building construction	• May intensify bed erosion downstream	Light	• Extensive • In the west e.g. Punakha-Wangdi stretch of Puna Tsang Chhu

In situ Degradation

In-situ degradation processes and their effects (Table 2) are less spectacular than erosion, and are not always easy to identify. However, they are the most extensive kinds of land degradation in Bhutan. Their effects in reducing agricultural production have not been quantified, but are almost certainly substantial. Although serious, these forms of degradation are mostly reversible, if timely mitigation activities are undertaken.

The most widespread *in-situ* chemical degradation in Bhutan is the depletion of soil organic matter. A decade ago, the Bhutanese farmers had an enviable and vigorous tradition of using organic fertilizers (Norbu, 1997) but now they are slowly replacing the organic fertilizers by inorganic fertilizers (SFU, 2005; Norbu *et al*., 2000). The shift from organic to inorganic fertilizers is mainly attributed to the vigorous crop response to inorganic fertilizers and to the shortage of labour in the rural areas to collect bedding materials for making farmyard manure (FYM) (SFU, 2005). Organic matter (OM) levels are naturally moderate to high in forest and grassland soils in Bhutan but they are usually considerably reduced when the vegetation is cleared for cropping or by repeated cultivation without adding adequate organic fertilizer such as FYM. The OM decline is more marked in the intensive soil cultivation associated with basin irrigated rice (*chhuzhing*), than in soils under rainfed cropping (*kamzhing*), orchard or shifting cultivation (*tseri*).

The two most common types of *in-situ* physical land degradation in Bhutan are topsoil capping and subsoil compaction. Like chemical degradation, they are not highly visible and tend to be overlooked. However, they are quite apparent in the feel of the soils, and are noticed by farmers when ploughing and digging. They are widespread and may reduce the productivity of Bhutan's soils more than is realised. Both tend to make soils more liable to erosion.

Capping is more likely in silty and fine sandy topsoils, which are widespread in the cultivated lands of Bhutan. It is usually a temporary feature, and is less serious than subsoil compaction, to which soils with high contents of silt and fine sand are also vulnerable. In Bhutan, the compaction risk to these soils is increased by the farming practices which mean that cattle are allowed to graze in the harvested rice fields, trampling the still wet soil, that soil may be cultivated when too wet and by the inadequate OM applications already discussed. Farmers widely report hardening (compaction) of the soil as a consequence of chemical fertilizer use, especially urea. If the urea is used as a substitute for, rather than as a complement to, organic fertilisers, its association with compaction may be indirect, mainly due to reduced organic matter.

Degradation Involving Removal of Soil

The degradation processes that involve the erosion of soil (Table 3) are extensive, except for glacial erosion. This is mainly restricted to altitudes above 5000m asl, forming moraines and glacial tills. However, its effects can be devastating when glacial lake outburst (GLOB) occurs (e.g. the 1994 GLOB flood in Mochu, Punakha).

Wind erosion is also extensive in Bhutan especially when the fields are kept bare. Although it is difficult to quantify, the erosion is assessed as being quite substantial and contributing to lowering the soil fertility by removing the fertile topsoil (SFU, 2005). Deep (up to 2m) aeolian deposits are seen at many places in Bhutan between 2500 to 3500m asl (SSU, 2000) but they would have been deposited during the ice age when dry climatic conditions prevailed.

Because of the rugged terrain, most of the arable lands in Bhutan are located on steep slopes (up to 70% slope). During cultivation, the topsoil of the upper part of the field is moved down slope during every tillage operation. As a result, the whole topsoil of the field may move down slope exposing the subsoil on the upper part of the field. The topsoil accumulates at the lower part of the field and if proper soil conservation measures are not taken, the lower parts are susceptible to slumping. This type of erosion is very extensive in Bhutan.

Degradation Involving Removal of Soil and Weathered Rock by Water

The degradation processes that involve the erosion of soil and underlying weathered rock (Table 4) are very visible and familiar in Bhutan. They have impacted the public consciousness much more than the more subtle effects of *in-situ* degradation. While these erosion processes are less extensive than *in-situ* degradation, their on-site effects are more damaging. Because of the sediment and runoff that they generate, their off-site effects are also more serious (Carson, 1985). Furthermore, many of their effects are irreversible within human time scales and without great expense.

Soils vary in their vulnerability to surface erosion, with soils derived from gneiss being relatively stable and eroding less easily than those from other rocks. Bhutan is fortunate in having a high proportion of gneissic soils and over much of the country, surface erosion is less than expected from the prevailing steep topography. However, the very intense rainfall in the South erodes even gneissic soils. Erosion tends to be more severe on susceptible soils derived from other rock types, such as the deep red clays and loams derived from phyllite rocks in the Lobeysa-Punakha area. These soils are scarred by many deep gullies (SSU, 1999).

The best indicators in Bhutan of rain splash erosion are pillars of soil, which can be up to 20cm high in places, under stones, logs and any other objects that are protecting the surface against raindrop impact. Capping exacerbates this type of erosion. Splash erosion is quite extensive in Bhutan especially in the pre-monsoon season, in the period between field preparation and emergence of crop seedlings, when the soil is bare and heavy rain showers are common.

During this period and also after harvest of the crops when the fields are again bare, the splash erosion leads to sheet erosion and sheet erosion to rill erosion removing the fertile topsoils: both sheet & rill erosion are extensive in Bhutan. Due to lack of soil conservation measures, the rills slowly develop or enlarge into gullies. With time, the gullies enlarge and cause multiple secondary landslides and gullies on the main gully side slopes (SSU, 2005). When these side gullies and landslides advance, it slowly leads to ravine formation (e.g. at Tshogompa and Radhi). As a result, hundreds of hectares of productive lands are washed away, people’s lives and livelihoods are put at great risk and ultimately they may be forced to resettle.

It has been reported from other parts of the Central and Eastern Himalayas that weathered gneiss and gneissic soils are relatively invulnerable to mass movements (Gupta *et al*., 1993; Gerrard, 1994). This also appears to be the case in Bhutan. The incidence of landslips is lower than expected from the topography, as shown by the relative stability of steep road cuttings in gneisses along much of the East-West highway. The South is tectonically more active, has the heaviest rainfalls and a high proportion of non-gneissic rocks, and it therefore suffers the most frequent and severe landslips.

Flooding, encroachment, river bed mining and piping erosion are mostly localized. While they may be severe where they occur, to date they are not viewed as serious degradation problems in Bhutan. However, care will need to be taken to control them before they become serious.

Land Degradation Mitigation

Deliberate soil conservation measures are new in Bhutan. In some areas, farmers have built retaining stone walls or made terraces but these have been for ease of cultivation rather than for conserving the soil (SFU, 2005). Quite recently (2005), the Ministry of Agriculture (MoA) has initiated land management campaigns to implement soil conservation measures and to create general awareness and sensitize the public and other stakeholders about combating land degradation in Bhutan. The campaign coverage is still limited and the majority of vulnerable land is not protected by appropriate soil conservation measures. However, farmers and other stakeholders are now slowly understanding and appreciating the need to conserve the limited land resource with the available technologies and addressing land degradation remains a MoA priority for the next Five Year Plan period (2008-13).

In Bhutan, there is currently one GEF project which is implemented by the World Bank (SLMP) to promote innovative mechanisms to enhance sustainable land management practices in Bhutan by focusing on securing livelihoods for rural people, while at the same time preventing the fragile ecosystems by removing barriers to sustainable land management e.g. institutional and governance barriers, economic and financial barriers, etc. However, there is another GEF project in pipeline which will be implemented by the UNDP (MSP) to develop the National Action Programme (NAP), mainstream the sustainable land management and develop the capacity to combat land degradation. The project formalities are already completed and waiting for the final clearance from the GEF/UNDP for implementing the project. Furthermore, Bhutan is a member to UNCCD to combat desertification.

Conclusion

Various types of land degradation occur in Bhutan at various scales and degree. Amongst the land degradation types, water induced degradation, e.g. gully, landslides & ravine formation, is more prominent and devastating. Wind and cultivation erosion are also extensive as is *in-situ* degradation such as depletion of soil organic matter, nutrient mining, topsoil capping and subsoil compaction. All these contribute to reducing agricultural productivity and impairing the livelihoods of the people of Bhutan. Older farmers commonly report crop yield declines of 30% or more due to the soil "being tired" (SFU, 2001).

Even though land degradation is common in Bhutan, it is not well documented. This paper gives an overview of the land degradation happening in Bhutan. It intentionally concentrates on the physical processes of land degradation and their negative impacts. It does not attempt to be exhaustive on the causes: for example it does not analyse the social processes that contribute to land degradation. It does not cover the perception that some erosion and sedimentation sites are opportunities rather than threats (Stocking & Murnaghan, 2001): for example, Himalayan farmers, including those in Bhutan, are adept at creating agricultural land out of gullies and landslips (Carson, 1992; Gerrard & Gardner, 2000; SSU, 2000). It gives no quantitative estimates of the extent of the areas affected by land degradation or of the economic impact. All these aspects would merit investigation and papers in their own right.

What it is hoped this paper does do, by presenting this overview of land degradation in Bhutan, is to provide the basis and stimulus for further studies on land degradation in the country, studies that will contribute to international knowledge and that will facilitate sound planning and practical interventions to combat land degradation in Bhutan.

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