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Soil erosion and environmental degradation in Nepal: A Review of Environmental Policies

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Abstract

Soil erosion is a natural process that occurs more frequently in mountainous regions in the Himalayas due to the complex landforms. Nepal also experiences severe forms of soil erosion due to its geographical complexity. This study examines the issues of soil erosion in relation to the environment and evaluates the effectiveness of existing environmental policies in Nepal, using secondary sources of data. The study reveals that Nepal has an average annual soil erosion rate of 25 tons per hectare per year, resulting in the total annual loss of 369 metric tons. This rate is higher compared to other areas around the world. The middle mountain region of Nepal has a higher mean annual soil erosion rate per hectare per year (which is of 38.4 tons) than other physiographic regions. Soil erosion is caused by various factors such as rainfall, water flow, land cover, geographical setting, and conservation practices – which leads to a decrease in agricultural productivity. Both on-site and off-site effects pose a significant risk to agriculture, development projects and the environment. It is suggested that the steps have to be taken to the environmental safeguard for reducing soil erosion and mitigate the problem through government agencies by emphasizing on effective implementation measures of the existing environmental policies, regulations, and development plans.

Keywords: Soil erosion, agriculture, mitigation measure, environmental policies, national adaptation plan

Introduction

Soil erosion is a serious process of land degradation that typically occurs in mountainous regions. It has a detrimental impact on natural resources; and agricultural production has become a global environmental concern (Bakker et al., 2005; Ighodaro et al., 2013; Guerra et al., 2017). Nepal is also facing significant challenges, particularly in the agriculture sector, due to soil erosion (Chalise et al.,

2019). It is threatening sustainable soil management and food production (Rickson et al., 2015). Of the 17 Sustainable Development Goals (SDGs), 8 are related to land degradation, with its control and protection practices being prioritized by the United Nations (FAO, 2019).

The estimated world mean soil erosion rate is between 12 and 15 tons per hectare per year (Biggelaar et al., 2003). In Nepal, the mean annual soil erosion rate was estimated to be 25 tons per hectare per year, with a total annual loss of 369 metric tons (Koirala et al., 2017). This rate is higher compared to other areas around the world. However, the erosion rate of China and other mountainous regions like the Andes is higher than that of the Himalayas in Nepal. The primary causal factors of soil erosion are rainfall, soil characteristics, topography, land cover, and soil conservation practices (Navas et al., 2004; Koirala et al., 2017). These factors are generally used in the assessment studies of soil erosion rates.

Soil has played an essential role in the development of human civilization, providing us with food and other materials that we use daily. However, with the increasing population, soil is being over-exploited, which leads to low productivity. This issue has been recognized by the global community as it creates challenges for the economic development of people. Nepal, for example, is known as the land of billions of terraces, thanks to the ancient practice of cutting the Himalayas and mountains into flats to produce grain crops (Shrestha, 1998). However, farmers have noticed a decrease in crop yields; and soil erosion has turned the fertile land into deserts, leading to disasters such as floods and landslides. It is crucial to address this issue urgently and find sustainable solutions to conserve our soil for future generations.

The process of moving soil from one place to another is called soil erosion. It degrades the soil. The process of soil erosion disintegrates the soil layer up to the roots of plants. Both the processes of soil formation and erosion are ongoing on the surface of the earth. If the rate of soil erosion is faster than the rate of soil formation, the effect of soil erosion is seen in many places. The joints of rocks and soil become loose due to weathering. Similarly, soil and rock particles begin to erode through the process of wetting, drying, heating, cooling, melting and freezing. Additionally, soil erosion also occurs due to chemical reactions of water and carbon. All these processes lead to soil degradation and environmental destruction in a wide area of landforms (Saxena, 1999).

During the monsoon rain, the rivers flowing from Nepal's Himalayas, middle mountain and Siwalik hills or Chure hills carry away the loosened soil through various processes and deposit it on the plain areas of the Terai region

(Gurung, 2000). Those materials are accumulated in the base level of the rivers flowing in the plains raising the height from 35 to 45 centimeters per year (Dent, 1984). A study showed that the annual estimated soil erosion was about 40-42 million tons in the Koshi basin of Nepal during 1990-2010 period (Uddin et al., 2016). Moreover, it was found that more than 400 thousand hectares of productive agricultural land is being degraded due to regular soil erosion in Nepal (LRMP, 1986).

The soil is constantly being transferred from the place of origin by disintegration through various processes. Elements such as water, air and minerals play an important role in this process of soil erosion (FAO, 2019). Soil erosion disrupts the maintenance of healthy soils and dynamic ecosystem services (Adhikari and Hartemink, 2016). Apart from the natural processes, soil erosion is also associated with the construction and development of landscapes. Human activities such as deforestation covered by vegetation, excessive grazing and mining on steep land, and land use change etc. have greatly increased the process of soil erosion (Borelli et al., 2017). Besides this, climate change, land leveling, continued mechanical mining of agricultural land, and changes in land use also increase soil erosion. As a result, landslide, an increase in the emission of greenhouse gases and decrease in soil organic carbon (SOC) have started to be observed (Lal,2019); and this acute erosion negatively affects food crop production, water quality and the environment (Borselli et al., 2006). In addition to this, it also reduces the nutrients of the soil. Therefore, this study has analyzed the problems that have arisen in Nepal due to soil erosion and environmental degradation; and this has also presented the situation in the effective implementation of environmental policies to solve them.

Methods and materials

The impact of soil erosion is more on steep topography and less on flat land. As about 83 percent of Nepal's land is located in the mountain range, soil erosion is happening naturally at a fast pace. Deforestation, population growth and expansion of rural road networks are also causing soil erosion. This study is based on the data from secondary sources like land resource mapping projects and other studies. In addition to this, digital data and textual information are also included. It is difficult to get comprehensive data on soil erosion because this discipline does not exactly match a single subject matter. Interested individuals or groups like soil scientists, geomorphologists, hydrologists, agricultural engineers etc. study soil science which is very important for policy makers, environmentalists and farmers, etc.

Conceptualization of environmental protection

During the 1970s, the environmental condition worsened in Nepal due to rapid population growth and deforestation. This resulted in increased pressure on forests and soil. Many experts studied the issue and presented their findings. Among these studies, the most important was conducted by Ives and Messerli (1989), who conducted an in-depth study on the theory of environmental degradation of the Himalayas. They indicated three main concerned matters: (i) The highest population growth in the history of Nepal occurred between 1971 and 1981, leading to an increased demand for forest fodder, fuel wood and timber, (ii) The 30 years from 1950 to 1980 witnessed excessive deforestation, and (iii) Severe soil erosion occurred from the ground surface and productive rice cultivation. These findings subsequently pointed out damage to the ecosystem services; and the increased occurrence of terrible flood and landslide would lead to destruction in the socio-economic and environmental sectors of Nepal. Moreover, it was estimated that the sediment materials eroded from the Hind-Kush Himalayan range and transported by the Ganga and Brahmaputra river systems deposited in the Bay of Bengal which contributed to the rapid development of new islands.

In the 2010s, among the various environmental problems in the world, climate change has become a serious concern for everyone. Even though Nepal and the people therein have negligible contribution to the problems created by climate change, it has to suffer from the negative consequences. In the Himalayan region of Nepal, glacier lake outburst floods (GLOFs) are an integral part of environmental destruction from global warming. Study has shown that the snow line is moving above and the vegetation is moving closer to the Himalayas. A study conducted from 2000 to 2010 showed that the tree line in the world's mountainous regions was rising at an average rate of 1.2 meters per year (He et al., 2023).

Throughout history, humans have maintained a close relationship with soil. This connection started when our ancestors began farming, and soil quickly became an essential element in our lives. Soil erosion has been a problem for a long time, caused by water and wind. In the 1930s, there was a discussion in the United States about studying soil erosion more closely. After the issue of dust bowls was raised, soil research began.

There is a lack of comprehensive research on soil erosion in the major river systems of Nepal. Currently, there are only a limited number of case studies available that include field-level exercises in small watersheds. Most of the studies on soil loss rely on secondary information without proper field-based exposure. However, it is necessary to conduct a detailed field-level study to accurately

determine the extent of soil loss in Nepal, especially after the Land Resource Mapping Project (LRMP) report, 1986. There has also been a detailed study in the Koshi river basin, but a complete study on soil loss in other parts of Nepal is still lacking. Moreover, the theoretical concept of the development and destruction of various landforms on the earth's surface involves water and wind cutting mountains and creating new islands by accumulating material on the bed level of the river or ocean, which are regular natural processes. Recently, there has been increased emphasis on studying soil erosion or land degradation to address the issue of environmental deterioration, with a realization of the sensitivity of this issue.

Soil erosion scenario

Soil erosion is a natural phenomenon that occurs at different rates depending on the land use and topography of the area. Forest, bushes and grasslands tend to experience less soil erosion compared to open and bare areas. Similarly, steep lands are highly prone to soil erosion, while valleys and flat lands experience lower rates. The amount of rainfall also affects soil erosion, with humid climate experiencing more erosion than dry climate. Furthermore, large development projects can also contribute to soil erosion. The rate of soil erosion is measured by the amount of soil per unit of land that has been eroded within a specified period. The results of three studies conducted accordingly are discussed here.

Table 1: Estimated annual average soil erosion rate by land use

Type of land use	Erosion rate (tons/ha/year)
Managed Forests	5-15
Unmanaged steep land	20-100
Degraded Rangeland	10-100

Source: MPFS, 1988.

Unmanaged hilly land lost soil at an estimated rate of 20 to 100 tons per hectare per year, while well-managed forest areas lost a maximum of 5 to 10 tons per hectare per year (Table 1).

Table 2: Soil erosion rate by Physiographic region, Nepal

Physiographic region	Mean erosion rate (ton/ha/ yr.)	Soil Loss (metric ton/ yr.)
Terai	0.1	0.1
Chure	6.9	13.0
Middle Mountain	38.4	165.3
High Mountain	32.5	96.8
High Himal	28.1	94.4

Source: Koirala, et al., 2019.

According to the physiography of Nepal, the middle mountain region has the highest average rate of soil erosion, which is approximately 38.39 tons per hectare per year. This is followed by the High Mountain and high Himalayan regions, while the terai region has the lowest erosion rate. (Table 2)

The middle mountain region is particularly sensitive to soil erosion when compared to other mountainous areas. On one hand, due to the growing needs of the population, agricultural activities are expanding rapidly in these ranges. On the other hand, the unscientific construction of roads in the rural areas of hilly regions is causing an increase in soil erosion.

Table 3: Area of land affected by soil erosion tools

Types of degradation	Affected area (in million ha)	Percent of affected area out of the total area of Nepal
Water erosion	6.7	45.4
Wind erosion	0.6	4
Chemical degradation	0.3	1.7
Physical deterioration	0.2	1.3

Source: Ministry of Environment, Science and Technology, 2008 (adapted from Nepal Environment Statistics, 2019).

Based on soil erosion agents, 45 percent of the total area of Nepal was found to be affected by water. It was also observed that wind had a minimal effect on soil erosion.

Table 4: Soil erosion rate by major river basin, Nepal

River Basin	Mean erosion rate (ton/ha/year)	Soil loss (metric ton/year)
Koshi	31	79.7
Gandaki	30.7	96.1
Karnali	32.2	135.8

Source: Koirala, et al., 2019.

The major three river systems - Koshi, Gandaki, and Karnali - originate from the Himalayan range and flow south, ultimately merging with the Ganga river system. The Karnali river basin areas have the highest average rate of soil erosion, followed by Gandaki, while the Koshi river basin experiences the lowest erosion.

Problems of soil erosion

Soil erosion problems vary depending on the local geographical situation. Water, air and heat are the natural forces that are constantly in motion and can influence the landscape differently. In humid regions, water plays a significant role in erosion, whereas in dry regions, wind plays a bigger role. Soil erosion can also be caused by the mechanical and chemical processes of one or more erosion agents on the ground, as well as human activities such as unscientific agricultural system,

deforestation, grazing, expansion of physical infrastructure, and urbanization. These forces play a direct or indirect role in soil erosion, resulting in decreased crop production, land degradation, decreased soil fertility, variability in rainfall, frequent and intense droughts, floods and landslides (ADB, 2014). As a result, about 62 percent of Nepal's agriculture-dependent farmers are affected (National Statistics Office, 2023). Besides this, due to illiteracy and ignorance of people, the environment has been indirectly degraded. Soil erosion problems occur in the places where the soil is eroded and where these materials are deposited. The accumulation of sediments in reservoirs is called sedimentation or soil reclamation. The effects of soil erosion generally occur in two areas (Lal, 2019; Raya, 2013): i) On-site effect, ii) Off-site effect

On-site effects of soil erosion

Water droplets can carry away the nutrient-rich upper layer of soil, causing reduction in the thickness of the soil layer around the roots of plants. This results in the roots appearing on the surface, leading to the loss of organic properties and nutrients necessary for plant growth (Figure 1). Ultimately, soil erosion can lead to decrease in crop production. This is a serious issue that can lead to the wastage of precious soil resources. Furthermore, if soil erosion occurs around development infrastructures such as roads, canals, dams, etc., it can cause significant damage to these structures in the long run. In sensitive areas, soil erosion can escalate into landslides, resulting in the loss of valuable assets.

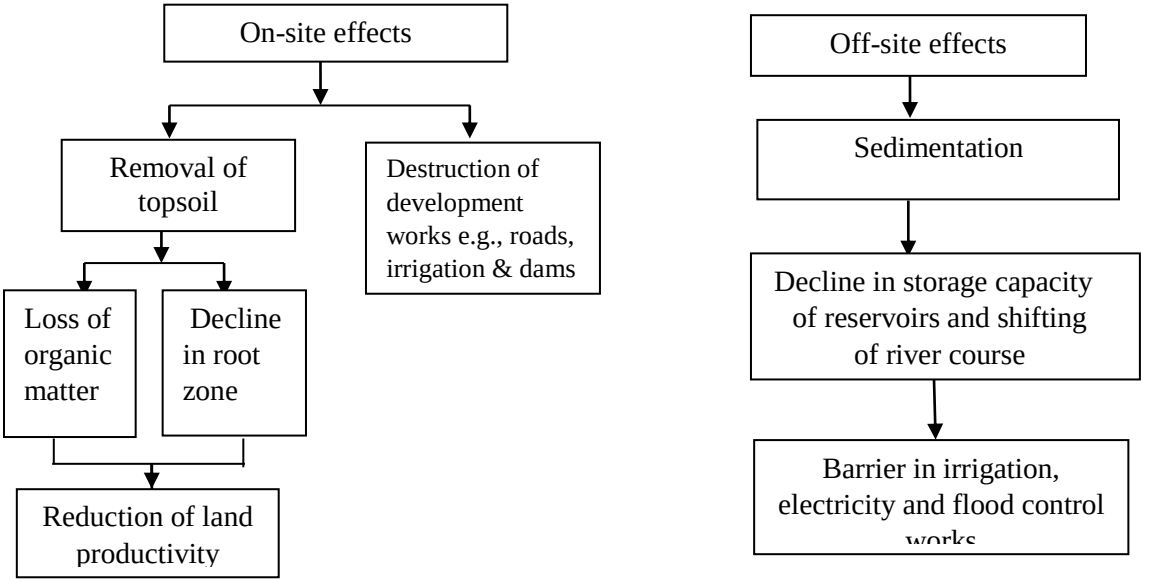

Figure 1: Consequences of erosion

Source: Adapted from Raya, 2013

Off-site effects of soil erosion

When soil erosion occurs, the material that is washed away ends up accumulating in a specific location. This can cause problems for large development projects such as irrigation, hydropower generation, embankments, and flood control projects (Figure 1). Accumulated runoff materials can reduce the capacity of reservoirs and lead to significant economic losses for the country. In the watershed area of the Kulekhani hydropower project, heavy rains caused several incidents of flood and landslide in 1993. This resulted in a large mass of sediments being carried away by the flood and deposited in the *Indrasarovar* reservoir. Consequently, this caused the lifespan of the reservoir to decrease by ten years (Dhital et al., 1993), reduced water storage capacity, and decreased power generation during the dry season. Similarly, the Bagmati, Sunsari and Morang irrigation projects have to spend a lot of money every year to clean out the deposited sediments from their canals.

Actions to prevent soil erosion

Soil erosion can greatly decrease the productivity of farmland. To combat this, it is important to adopt soil conservation measures. Although soil erosion is a natural process that is difficult to control completely, there is a need to find suitable methods to reduce it. According to the International Union for Conservation of Nature (IUCN), three methods can be used to mitigate soil erosion: (i) Preventive method, (ii) Mechanical method, and (iii) Supportive method (GoN & IUCN, 1993).

Preventive methods are used to protect the soil before the problem of soil erosion occurs. This includes actions like planting fruit, trees, grass, and protecting forests. This kind of preventive action is also known as biological technology. The steps taken to prevent soil erosion are called mechanical measures. These methods include pollution control, improvement, embankment, and landslide control. In addition to spreading awareness about the importance of soil and the need for conservation programs, the participation of local people is included in the supporting activities. Soil protection can be achieved by conducting income-generating programs in the community, practicing agroforestry systems, and implementing effective programs to protect soil and water bodies.

International efforts on environmental dialogue

Environmental problems are not confined to the borders of a single country. Their impacts are trans boundary and can affect the whole planet. At present, several environmental issues cannot be addressed by any single nation. These issues include the loss of biodiversity, climate change, depletion of the ozone layer, and pollution of water sources. Therefore, international cooperation is crucial for resolving these problems. Modern international environmental laws are being developed to stress the need for every country to contribute to safeguarding the environment. Every nation is responsible for causing damage to the global environment in one way or another; so all nations must work together to protect our planet.

In 1972, the United Nations held the Stockholm conference on the Human Environment. The conference recommended that each country should create an action plan for the environment. It highlighted environmental protection as an agenda of national and international importance, giving priority to financial and institutional arrangements at the international level for protection of environment. It is also known as the 'Magna Carta' of environmental law. Nepal has become a signatory to over 20 international environmental treaties, including the Ramsar Convention 1971, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) 1973, World Charter for Nature 1982, and the Convention on Biological Diversity (CBD) 1992. These treaties are crucial to Nepal. After the United Nations conference on Environment and Development in Rio de Janeiro, Brazil in 1992, environmental activities in Nepal have progressed.

Environmental policy and conservation efforts at national level

Although there is a strong foundation for the social and economic development of Nepal such as its unique geographical setting, abundant natural resources, sufficient water, fertile land and cultural diversity etc., major challenges were seen in the context of sustainable use and management of the resources just mentioned. The National Planning Commission (NPC) of the Government of Nepal (GoN) does not seem to have given much priority to environment-related topics from the beginning of the first periodic national development plan to the fifth plan between 1954 and 1980.

At the same time, some aspects of the concept related to environmental protection were started to be included in the periodic plan of Nepal. In the sixth periodic plan from 1981 to 1985, emphasis was placed on environment-related

topics such as forest protection, watershed management, wildlife protection, water and sanitation, and urban management. In this way, environmental issues began to get a place in the periodic plans of the government of Nepal; and environmental programs started to be mainstreamed. Integrated environmental management strategies were also added to the environment-friendly policies and thematic plans.

Likewise, by the early 1980s, the environmental problems of water, air and noise pollution in urban and industrial areas became widespread; and new types of problems began to appear. On the other hand, the rural areas were suffering from problems such as flood, landslide and drying up of drinking water wells and springs. Along with this, there was a decrease in biological diversity and erosion of productive soil. To tackle these problems, the need for cooperation was realized between various governmental and non-governmental agencies and local users. Meanwhile, emphasis was placed on institutional and structural development for sustainable use of natural resources. It was decided to make local people partners in new development projects. Finally, the management of natural resources was started through public participation. For example, the concept of community forest in the management of forest resources was started at this time. Currently, about 40 percent of Nepal's forest management has been entrusted to 22,415 community forest user groups (FECOFUN, 2022). The initiation of such positive efforts has become an exemplary work in the field of natural resource conservation. Also, researchers from all over the world are observing how the middle hills of Nepal have been transformed into attractive green hills as a result of the successful implementation of community forest development program for the last 40 years.

Formulation of environmental laws

Over the last decade, the government of Nepal has been actively working for environmental protection and management through various policies, strategies and plans. These efforts have been made with both national needs and international commitments in mind. However, the implementation of physical development programs in rural areas has resulted in significant environmental destruction. To address this issue, the National Conservation Strategy 1988 and the Nepal Environmental Policy and Action Plan 1993 were introduced, which are aimed at minimizing the adverse effects of development on the natural environment. Furthermore, these policies have led to the establishment of national parks and protected areas for forest and wildlife conservation. Similarly, the National Environmental Impact Assessment (EIA) Guideline 1993 has also helped to minimize the environmental impact. Along with this, the Environmental Protection

Act 1996 and Environmental Protection Regulations 1997 were introduced realizing the need for legal bases for environmental conservation.

By doing so, the government proceeded to improve environmental management through the implementation of the environmental act. In this regard, the EIA of large projects and Initial Environmental Examination (IEE) for small and medium infrastructure projects were carried out from 1997. Up to now, efforts have been made to reduce the adverse environmental impact and increase adaptation by accepting the EIA of about 400 large infrastructure development projects and the IEE report of thousands of small and medium projects (GoN, 2019).

Environmental education and mainstreaming issue

Environmental education was first integrated into formal education in the 1990s. With the technical assistance of IUCN, environmental education courses were developed for schools and universities. It is important to modify the curriculum at both levels to equip future generations with the knowledge and skills to conserve resources and adapt to the risks of climate change. However, there are challenges in making environmental education more widespread among all citizens of the society. The government's efforts to create and enforce environmental protection laws and regulations in the 1990s were commendable. Despite evaluating the environmental impact of development programs, ineffective implementation of environmental policies has impeded progress. Moreover, there are hurdles to integrating environmental issues into development activities.

Constitutional priority

The constitution of Nepal prioritizes the protection and management of the environment. Article 30 of the constitution has been issued for the operation of a federal republican state in Nepal providing for the fundamental right of every citizen to live in a clean and healthy environment (GoN, 2015). From this perspective, it has been necessary to carry out development activities based on the geographical conditions and land use of Nepal. It seems that effective legal mechanisms, institutional structures, appropriate technology, people's participation, good governance and integrated efforts of financial means are possible for achieving sustainable resource protection and socio-economic development. As conservation issues are multifaceted, they are connected with national and international concerns. Considering these realities in mind, Nepal has expressed its commitment to various international treaties and agreements related to the

environment. Currently, Nepal government, the fifteenth periodic development plan, from 2019 to 2024 is implementing programs to ensure the right of citizens to live in a clean and healthy environment through pollution control, waste and greenery management (GoN, 2019). For this, there is a constant need for mutual coordination and cooperation between the three levels of government, civil society, community, private sector and every common citizen. Hence, there have been various policies, institutional and programmatic achievements for environmental protection and management in Nepal. The government is trying to maintain a balance between development and the environment. Nevertheless, there is a need for more progress in the interaction with stakeholders to achieve sustainable development goals by 2030.

Conclusion

It is evident from the above mentions fact and figures that soil degradation continues to be one of the major concerns in Nepal, where soil erosion rates are high in the mountainous areas, whereas well-managed forest areas and plain regions have experienced less erosion. Every year, thousands of tons of eroded materials are carried by running water from the mountains and hilly areas and deposited in the Bay of Bengal, leading to negative environmental impacts on both the eroded and deposited places. As a result, land productivity decreases; and large development projects get damaged. Modern development activities also cause soil fragmentation and loss. However, farmers have been practicing soil conservation by building embankments, planting trees, and making drains to protect soil from flood during the rainy season. These practices have prevented the Himalayas and hilly areas from turning into uninhabitable areas.

The focus of the future tasks of the three tire governments in Nepal should be on the Constitutional priority, spirit of the international conventions and national needs. For this, need is to implement national environmental policies, laws and regulations, and strategies along with National Adaptation Plan (NAP, 2019) and Local Adaptation Plan of Actions (LAPA, 2020) for mainstreaming environmental conservation issues into infrastructure and socio-economic development programs. Therefore, it is needed to create awareness at community level through the approach of citizen science.

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