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REVIEW ARTICLE



Status of forest soil and necessity of sustainable soil conservation practices of Nepal

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ABSTRACT

Forests are the fundamental natural resource regarded as the crucial aspect to uplift rural livelihood in Nepal. Forest, not only acquaints us with ecosystem services but also deals with carbon sequestration and nutrient cycling in forest soil, serving the most crucial part of human welfare. However, several human forces such as construction of roads, deforestation, shifting cultivation, overgrazing, and forest fires have decreased the organic matter content and contributed to landslides, erosion and sedimentation in forest. Frequent landslides, soil erosion on the landscape of Nepal is degrading the environment and soil, where 1.7mm of fertile topsoil is lost annually. Considering the fact, present study points to recognize the status of forest soil, its relationship and necessity of sustainable soil conservation practices. Secondary sources of data were used to assemble the related information. Hence, Involvement of different institutions, policy, law, local participation and community-based approach is significantly important in adopting forest soil conservation approaches. Different strategies of carbon sequestration should be maintained by increasing plant cover, enhancing microbes, utilizing agricultural inputs and slowing down the amount of soil disturbances. Likewise, strengthening different thematic areas of Forest Policy 2015 is indispensable in effective implementation of sub sectoral programmes. Forest management strategies incorporating the concepts of carbon storage, buffer strips, terracing, windbreaks, agroforestry, conservation tillage are the major areas highlighted through this paper for further researchers on preserving forest land.

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INTRODUCTION

Soil is a fundamental basis to every life that acts as a water strainer and provides a settlement area for billions of organisms. Agricultural production considerably depends upon soil fertility and maintaining biodiversity (Basnet, 1992). Considering the current scenario, about <30% of earth's lands are products that need to feed more than six billion people where every year the population is increasing by 1.05% (LePan, 2021; Worldometers, 2021). Diversification in the forest is also indirectly related to

the soil as it provides us with fresh pure air which can be maintained through the proper vegetation. Therefore, the soil is considered as the building block structure for the microorganisms as well as different types of nutrients for plants, it is regarded as a complex ecosystem carrying fungi, bacteria, animals and protists (Bonkowski *et al.*, 2009). Fertile soil leads to proper vegetation and proper vegetation leads to mitigate the deleterious results of climate variation. The objective of this review paper is to know the interrelationship between soil and forest which ultimately concludes the necessity to adopt

conservation practices of soil in the forest areas of Nepal. Nepal is rich in forest occupying a total of 5.96 million ha of land which is equal to 40.36% of the acreage of the nation (GoN, 2015). Forests are regarded as the crucial aspect for rural livelihood where forest timber holds 1% GDP of global economy (The World Bank, 2016). Hence, it can't be denied from the fact that forests are the main natural resource that manages to profit from diverse commodities of economic value. Continuously harvesting of forest leads to the "mining" of forest resources which finally resulted in ecological degradation. According to a report made by WWF, the forest occupies second position in terms of storing greenhouse gases after the ocean which provides ecosystem services and those services are the most crucial part of human welfare. Forest soils are also important for different reasons such as nutrient cycling and carbon sequestration. To control ecosystem nutrient recycling, soil microbes perform an important role (Blanco, 2018). There are many forest management strategies targeted at preserving forest land, enhancing forest biodiversity, reducing runoff, increasing the fertility of forest soil, etc. which contributes to sustainable forest development (Shifley, 2012).

Mostly two agents erode the soil *i.e.*, water erosion and wind erosion. Globally, about 56% of the land is degraded by water erosion while about 28% of the land area is degraded by wind erosion (Oldeman, 1994). Landslides, sedimentation, soil erosion are an often-happening process on the landscape of Nepal that degrades the environment and soil where 1.7mm of fertile topsoil is lost annually. Estimation done concludes that it requires 200-400 years to form 1 cm topsoil (Hohmann, 2010). Likewise, studies have reported the loss of 20 t soil ha⁻¹ in the Mid mountains which resulted in the downfall of 300 kg OM, 15 kg N, 20 kg P, and 40 kg K, suggesting soil erosion to be a major contributor to soil deterioration (Carson, 1992). Hence, Soil conservation practices are almost needed either in agricultural, forest, or pasture land. To maintain the fertility and productivity of soil, the soil is to be secured from different elements of deterioration especially soil erosion. Overall, soil conservation includes water use and watershed management (UN, 1997). It was an almost unsolved problem during the Dust Bowl and faced doubt on the question to get a solution of continuous rain and wind. Meanwhile, Bennet noticed that "one man cannot stop erosion but one man can start it, (Helms, 2010) which finally led to the direction of soil conservation practices.

Several factors are related to soil conservation practices. Among all other factors, tillage is considered the primary one. Soil conservation practices perform a key role in solving climate change which will sustain the soil quality (Al-Kaisi, 2012). According to NRCS (National Resource Conservation Service), 12 conservation practices will organize the health of the soil in a better way such as conservation cover, contour buffer strips, cover crops, crop rotation, forage, and biomass planting, Manure management, no-till, nutrient management, pest management, prescribed burning, prescribed grazing and tree/shrub establishment (Moines, 2017). On that account, maintenance of soil fertility and productivity are almost needed in

order to protect soil from any form of deterioration. Likewise, incorporating sustainable management practices for soil conservation is a need of today.

MATERIALS AND METHODS

This review completely uses secondary sources of information. Sections of literature were collected from different Journal articles, National resource conservation service (NRCS), other sources like MoFSC, and relevant reports were analysed and the conclusions were summarized.

RESULTS AND DISCUSSION

Status and prospects of forest soil in Nepal

Nepal is tracked down between 26 22 N and 30 27 N latitude and 80 04 E and 88 12 E longitude which comprises five physiographic regions based on geology and geomorphology (LRMP 1986). While approaching the area of forest in the world, the forest area has decreased from 4.28 billion ha to 3.99 billion ha from 1990 to 2015 but increased forest plantation area from 167.5 to 277.9 million ha (Payn et al., 2015a). This data concludes that management strategy has to be done to create sustainability and reduce climate change in the world.

Soil plays an important role in forest regions by balancing the ecological functions. Any group of management work when executed in a forest will have some effects on forest soil. Nepal had a total of 136 ecosystems in 1970 (Bhujju et al., 2007) and later on decreased to 118 ecosystems in 2009 (Durbar, 2009). According to TISC (2002), there are 59 kinds of vegetation which later on decreased to 36 kinds of vegetation (Lillesø et al., 2005). Soil and forest are hence interrelated to each other (Payn et al., 2015b). FAO has researched Global Forest resources, which have been reported in Nepal in the years 2000 and 2005 (Figure 1).

Deforestation is the main cause which is a continuous process and till now it's been the habit of people to cut down trees for their settlement. ICIMOD (2010), reported Nepal's deforestation rate to about 1.6 percent per annum where the dependence of rural livelihoods mostly on forest resources has adverse impacts on flora and fauna. As a result, exchanging land cover and progressing causing land degradation (ICIMOD, 2010).

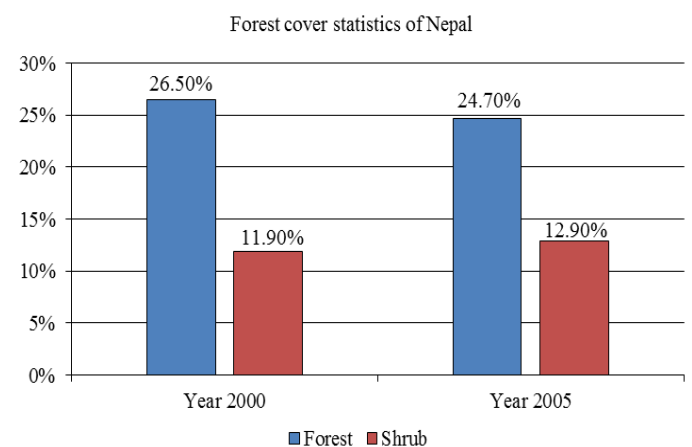


Figure 1. Forest cover statistics of Nepal (Source: MoFSC, 2009).

Due to deforestation, negative impacts hit more than the positive side which will eventually destroy the habitat of wildlife and the amount of fresh air, therefore bringing imbalance in the ecosystem. Between 1990 and 2005, 24.5% of forest cover was reduced, and lost 7.9% of forest and woodland habitat (Guégan et al., 2020).

As forests are the principal source of income for the rural households, it plays an important aspect to uplift the role of farmers. Out of a total of 7,000 vascular plant species, 1,600 are identified as having medicinal value, of which 238 are chemically tested and 160 species are in collection and trade have been reported (Ghimire et al., 2021). The NTFPs create high economic value and large-scale employment. In the mid-hills of Nepal, NTFPs have regarded as the important source of livelihood for farmers and continue to be in the future, as there is a lack of off-farm employment opportunities (Shrestha et al., 2020). While analysing GIS-based geographical and time related changes in land use between 1978 and 1992 in VDCs with and without community forest in mid-hills of Nepal, large differences in the rate of total forested area loss were observed over the 14 years. Moreover, the big forest area expanded by 77% for VDCs with community forests, while it was 13% for VDCs without community forests (Gautam et al., 2009). Hence, positive impacts of Nepal's community forestry activities were observed on the extent of forest cover.

Degradation of forests results in erosion and decreased productivity of the land. So, forest management strategies have to be implemented from all government, individual, and private sectors (Figure 2).

Interrelatedness between soil and forest

Soil and Forest are interrelated to each other because forest and soil go together. One can protect others so they carry a symbiotic relationship in environmental conservation. Forest soil has originated from geological parent materials in various climatic areas mentioning their climates and vegetation. Forest soil provides supporting all four ecosystem services such as water, food, fresh air for vegetation as well as acts as functions of hydrology and watershed for rivers and streams (Boyle and Powers, 2013). Forest soils are very acidic and have limitations

in their chemical fertility (Kauppi et al., 1986). Acidity mainly depends upon the type of the forest. The litter gathered from coniferous forests have a more acidic nature and more carbon concentration than deciduous forest (Burgess-Conforti et al., 2019).

Due to proper vegetation in forest areas, the chance of erosion and runoff will be very low at a rate of less than 0.1Mg/ha (Elliot et al., 2019). But continuous degradation of the forest land has an undesirable effect resulting in more soil erosion at the different parts of Nepal: 64t ha⁻¹ soil loss is encountered in Khajura catchment in siwalik (Ghimire et al., 2013); 22t ha⁻¹ in Koshi basin (Uddin et al., 2016); 11.7t ha⁻¹ in Araingale Khola watershed of Nepal (Chalise et al., 2018). Reports from eastern Nepal suggest forest clearance leads to decreased soil aggregate stability. This is the cause of soil erosion in Nepal. In forest areas, erosion is mainly due to two types of forces: Natural forces and human forces. Forest roads are an important factor of disturbance leading to sedimentation in forest areas with a loss of 0.5% forest areas due to the construction of a kilometer (0.6 mi) of the road in 1km² of forest that results in reducing forest productivity (Elliot et al., 2019). Natural forces such as fires which decrease the primal matter content in forest areas and increase erosion are emphasized fire effects on ecosystem management, considering fire as the natural structure of forest health (Agge, 1994). The forest environment has broadly divided into two aspects i.e., biotic and abiotic environment. Forests are indirectly linked to the soil which helps to reduce the runoff and the consequence of the forest is of great importance in increasing the quantity of water that percolates in it during spring months. According to a study done in Ohio and the central state region, forests have the greatest infiltration rate than those of adjacent neglected old fields by 50 to 700 times (Auten, 1933). Apart from maintaining physical health by providing fresh air, clean environment, the forest also reduces stress and strongly contributes to physiological health (Shin et al., 2010). Research done on the influence of forest has been overviewed by two theories; one increasing stress reduction (Ulrich, 1983) and the other emphasizing the treatment of the power to focus attention (Kaplan and Kaplan, 1989). Hence, Soil and forest are interrelated to each other.

Fundamental needs of forest soil conservation practices

In their study by Burton et al. (1989) in the Chitwan district of Nepal found, conversion of natural productive forest into agricultural land led to decreased fertility of soil as indicated by total nitrogen, organic carbon and cation exchange capacity. Likewise, exchangeable bases, aluminium, pH, and compaction were also found significantly affected. To improve the conservation of forest soil, the condition is to be applied as required by the NRCS state office. Some of the practices such as avoiding soil compaction, roads and landings, maintaining a suitable environment for forest growth, soil productivity, and carbon storage on-site should be retained and managed properly (USDA, 2016)

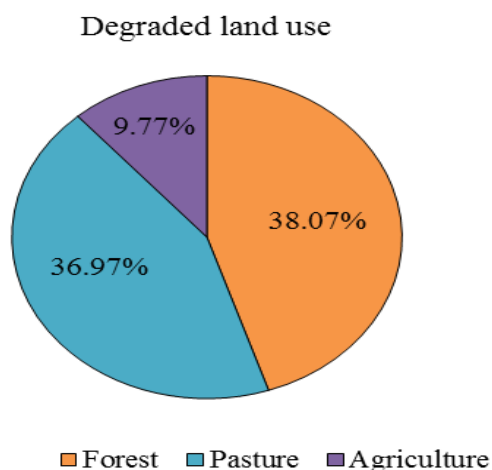


Figure 2. Degraded land by land use.

Carbon storage

Humans are the major threats to forest degradation. Deforestation is the major criteria to increase the atmospheric CO₂ which resulted in the global rise from 285±5ppmv to 366 ppmv between 1850 and 1998 i.e., about 28 % (IPCC, 2000). All over 67,000 ha of forest land was destroyed during 1979-1996 encountered a mean of 0.3% deforestation in central Nepal. The total lost biomass accounts for 4.6*10⁶ Mg for fuelwood which in turn added up to 5.6* 10⁶ Mg CO into the atmosphere (Upadhyay et al., 2005). In a report made in the mid-hills of Nepal, soil organic carbon has been approximated to be about 14 kg cm⁻² which is the smallest value than cultivated area due to dominant gravel and stone. Hence, the carbon sequestration is maintained through reforestation or using abandoned land as grazing land. For levelling up soil organic carbon, 103 countries have a strategy regarding mitigation, and 129 countries made goals related to degraded land and forest (Richards et al., 2016). Carbon sequestration can be achieved by the following mechanisms:

- By slowing down the degree of soil disturbances
- By utilizing agricultural inputs
- By increasing microbes in the soil
- By enhancing ground cover on soil year-round

Increase forest soil productivity

Implementation of conservation practices in a forest will have a direct effect on forest soil (Kiran and Kaur, 2011). Due to changes in topography, vegetation cover, microbial activities, and so on, forest soil differs in time and space (Shrestha et al., 2018). According to research done in a community forest in Syangja, it is concluded that forest regions are fertile in which organic matter, nitrogen, and phosphorus are high in amount but potassium and P^H are small in amount. So, the application of fertilizer to increase the amount of potassium and P^H is highly suggested (KC et al., 2013). To manage the productivity of forest soil, cultivation of those species is preferred which are fit for proper drainage. The study reveals that the factor that declines sisso forest in Tilkane, Nepal is waterlogging. Hence based on the conclusion on the proper growth of sisso forest, loose textured soil with proper drainage is appropriated (Sah et al., 2002). Good drainage leads to prevent flooding in forest areas.

Buffer strips

Forest buffer is a region of forest left for protection adjacent to a water body. Creating the variable width of the forest buffer has been noticed. But fixed widths are more valuable to implement than variable-width buffers (Kuglerová et al., 2014). Buffer strips are built to reduce the runoff and these practices are also applied in a forest area with the motive to:

- Prevent the negative effects of forests on water purity
- Decrease the export of suspended solids.

Within the increase of urban areas, concentrated runoff often

results in channelized flow in these areas. It finally leads to pollution and pollution amounts increase with the increase in urban areas as runoff volume, sediment deposition will become maximized. Hence, buffer strips will be the factor to minimize the erosion practices in forests. Another positive impact of buffers on wildlife habitat is that it provides a food source for fauna and enhances the biodiversity species in forest areas as well (Lamichhane et al., 2019). These buffer strips are the right location where riling is not an issue and the area has a gentler slope and increases the infiltration rate removing the sediment overflow (Gilley, 2004).

Conservation tillage

Conservation tillage includes minimum tillage which has the effects on deforestation into addressing the environmental degradation and increasing the crop yield by establishing the soil organic matter (Haggblade and Tembo, 2003). As of research done in Zambia, it concluded that minimum tillage, being labour-intensive and yield supplementing, its expansion of forest is quite hard in that area (Ngoma and Angelsen, 2018). Wildfires in forest areas also create an erosion issue because fire destroys plant materials and little layers. This results in disturbance in soil protection. Hence, Wildfire is to be controlled by replanting the grass seeds, spreading the crop cover in the burned area. By this, the importance of conservation tillage including crop cover to reduce erosion in forest soil is noted (Moench and Fusaro, 2012).

Terracing

Terracing should be practiced all over the country to prevent soil erosion on hilly areas and these terrace practices help in the development of forest growth on higher slope areas (Kathmandu, 2013). Several types of terraces have shown the relation of root density to stop soil erosion, watershed management, forest management (Achat et al., 2008). Higher fine root density, higher chance to reduce the erosion. The research was done on *Pinus tabulaeformis* Carr. Roots under different terraces show that level trenches have favourable effects on soil amelioration and fixation (Qi et al., 2020). Due to associated quick flow, high infiltration rate, and absence of terraces in forest soil results in runoff displacing soil and groundwater (Collins and Neal, 1998).

Agroforestry

Agroforestry and its practices play an important role in planted forests that have the potential to give forest-related services to society such as soil and water resources, healthy ecosystems, maintaining carbon cycle, and wood and non-timber products (Facility, 2002). Agroforests are less spread than native forest as it consists of fewer plants than forest plantation and is considered as working forest helping to reduce pressure to withdraw native forest. Singh (1987) reported that the recent land-use system accounted for shifting cultivation, cultivation of trees in agricultural fields, and Agri-silviculture in different locations.

The selection of agroforestry species relies on the agroecological behaviour of given locations. Agroforestry consists of different species such as *Bauhinia purpurea*, *Artocarpus lakoocha*, *Bauhinia variegata*, and various species of bamboo for the agro-climatic region of Nepal (Withington et al., 1987).

Windbreak

Inhibition of growth and electrolyte balance can be reduced by forming the windbreak forest (Grace, 1988). These windbreaks have been constructed worldwide to achieve various projects (Bitog et al., 2011) and to reduce fluctuation of salinity or damage from drifting sand (Lee et al., 2010). The effect of the windbreak depends on the width, density, height (Bitog et al., 2011). A study done on windbreak construction 3 rows of *Pinus thunbergii* showed the perfect windbreaks among four types of structures a simple structure of coniferous trees (1, 2, and 3 rows of *P. thunbergii*), a simple structure of broadleaf trees (1, 2, and 3 rows of *Quercus acutissima*), mixed structure 1 (3 rows: *P. thunbergii*, *Q. acutissima* and *P. thunbergii*) mixedstructure2 (3rows: *Q. acutissima*, *P. thunbergii* and *Q. acutissima*).

Strategies and policies in forest areas of Nepal

Giving information on time about forests will be easier to address the issues surrounding forest conservation in the future. Hence, through the knowledge and involvement of policy, different institutions, law, local participants, and Community based approach is of great importance (Cubbage et al., 1993). The policy of forest management was categorized in different years (before 1957, 1957-1990, and after 1990) with the motive to protect forest areas of Nepal. By the 1950s, there was a system of birta tenure where one-third of total forests were under birta tenure. Out of this, 75% belong to the Rana family. After 1950, the democratic government drafted a policy and focused on two issues: Soil conservation in Siwalik Hills and the problem of reforestation (Graner, 1997). The Private Forest Nationalization Act was endorsed in 1957. The reason behind this act was to reduce the destruction of forests and protection of privately governed forests (Katary, 2015) with lots of controversies (Hobley, 1985). During 1986-88, a 25-year plan for the forest sector was endorsed, and later on, it was approved by the Government of Nepal (GoN).

This plan focuses on the necessity to establish a Forest User Group (FUG) for the sustainable development of local forests (Bartlett, 1992). Therefore, Nepal's Community Forest User Groups (CFUGs) have been involved in restoring and Protecting 1.3 million hectares of forests and grasslands since they were formalized in 1993 (UNDP, 2015). A new vision on forestry was made on 23rd September by the Ministry of Forest and soil conservation of 10th National conservation Day called "Forest for Prosperity". The vision mainly focused on four supports (Poudel, 2018):

- Creating favourable Environment
- Sustainable and scientific forest Management
- Sustainable use of forest products and services
- Marketing and commercialization of forests.

Based on this vision, a new forest policy was made by the Government of Nepal (GoN) in 2015. Nepal has several policies in the forestry sector. Some key policies and legal framework are Nationalisation of Private Forest Act, 1957; National Parks and Wildlife Conservation Act, 1972; National Forest Plan, 1976; Master Plan for Forestry Sector, 1989; Forest Act, 1993; Revised Forestry Sector Policy, 2000; Leasehold Forestry Policy, 2002; Herbs and NTFP Development Policy, 2004; Terai Arc Landscape Strategy, 2004-2014; Gender and Social Inclusion Strategy in the Forestry Sector, 2004-19; Sacred Himalayan Landscape Strategy, 6 State Of Nepal's Forests 2006-16; National Wetland Policy, 2012; National Biodiversity Strategy and Action Plan, 2014 and Forest Policy, 2015 (GoN, 2015).

At present, Forest policy 2015 is the important policy that mentors on sub-sectoral programs. It usually works on seven different themes. Adaptation and mitigation of the effects of climate change are regarded as one of the seven ideas of this policy (Paudel et al., 2019). Along with this policy and strategy in the forest sector, involvement of Local participation also plays a vital role in conservation programs include forestry and wildlife protection. (Grace, 1988) One of the most important forestry programs in Nepal is the Nepal Australian Forestry program which signifies local participation. (Bajracharya et al., 2007) This project mainly has three purposes which are to regulate the National forestry plan in the chautara Forestry Division of Nepal. With this, it also has the objective of providing education and training in forestry in Nepal, and as well the third aim is to build a seed storage and testing facility in Nepal which was completed in February 1981 and finally opened (Shepherd, 1981).

Soil ecosystem services in Nepal

Ecosystem services are those processes of the natural system which can advantage people in different ways in food production, reducing soil erosion, and providing fresh air and water. These broad concepts came into existence during the 1970s which value soil conservation (Johnston, 2020). Biodiversity maintenance, carbon storage, watershed protection are common ecosystem services in the whole world (Wunder, 2007) but Nepal ecosystem services are somehow different in cultural services (Mishra, 2017). These services will result in the formation of soil and enhance the soil activities like mineralization, nutrient recycling, and structural development (Blouin et al., 2013). Soil provisioning ecosystem services play a crucial role in forest areas in which forest provides food products, wood, biomass, and clean water and as well increase carbon sequestration (Ninan and Inoue, 2013). Soil ecosystem services led to biodiversity which improves forest growth by the action of bacteria (Baer and Birgé, 2018) as one gram of soil contains 10 bacterial cells (Gans et al., 2006). Execution of payment for ecosystem services has been a key challenge because of the identification of tenure security (Duchelle et al., 2014). To provide ecosystem services to the community-based forest, there are several barriers such as lack of proper ecosystem information, low financial status, lack of skilled manpower as

well as the weak capacity of government institutions (Balvanera et al., 2012). By the approach of providing additional incentives for sustainable forest management, the utilization potential of ecosystem services has been addressed (Paudyal et al., 2017).

Conclusion

Soil erosion is the critical problem in hilly areas of forest region as it undergoes steeper slopes and various geographical consequences. Since, 1% of world GDP is contributed by forest timber products, millions of lives are impacted as a result of forest depletion where most of marginalized people still rely on. Nepal is a diversified country and has different types of vegetation and ecosystem which serves the positive impact to mitigate climate change. Hence, in order to protect soil from any form of deterioration and maintain its fertility and productivity, soil conservation practices are almost needed either in agricultural, forest or pasture land. Different strategies of carbon sequestration should be maintained by increasing plant cover, enhancing microbes, utilizing agricultural inputs etc. Likewise, soil productivity can be maintained through good drainage, fertilization i.e., soil organic matter, pH, Nitrogen, Potassium, Phosphorus, as well as adopting sustainable conservation practices are equally important. Buffer strips is an important factor to protect forest soil as it enhances the biodiversity species and increases the infiltration rate in forest areas removing the sediment overflow. Also, practices like: windbreaks, terracing, helps to eliminate the damage caused by drifting sand and higher slopes respectively. Sustainable practices including conservation tillage and agroforestry should also be incorporated.

Ecosystem services also play a critical aspect in forest areas by providing wood, food products as well as upgrading air and water quality, but with lots of benefits provided by ecosystem services, some challenges in implementation of payment for ecosystem services are too faced by community-based forests due to several barriers such as lack of proper ecosystem information, low financial status, lack of skilled manpower as well as weak capacity of government institutions. In Nepalese perspective there are several policies and legal frameworks which come under the forest sector and a recent important policy which includes sub sectoral programmes is National Forest policy 2015. Therefore, among the seven themes of the policy, adaptation and mitigation of effects of climate change is regarded as a major one. Hence, there are different ways to conserve the forest through different soil conservation practices where involvement of local participation through policy and legal framework done by the Government of Nepal is of utmost importance to protect forest soil.

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