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Sustainable Soil Management Practices - a key to combat soil desertification in the hills of Nepal

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Abstract

Purpose Temporary and permanent decline in the productive capacity of the land due to natural and human-induced activities such as soil erosion, changing cropping practices and less use of organic matter has been the greatest challenge faced by mankind in recent years, particularly in the hills and mountains of Nepal. Hence, this research examines the effectiveness of Sustainable Soil Management Practices to mitigate desertification process in the hills of Nepal.

Methodology Promotion of Sustainable Soil Management (SSM) practices through a decentralised agriculture extension approach by involving all the stakeholders in a participatory way.

Findings SSM practices mainly: Organic Matter (OM) management, fodder and forage promotion, increased biomass production systems, Integrated Plant Nutrition Systems (IPNS), and bioengineering for soil and water conservation are identified as the most appropriate and relevant technologies in mitigating the desertification process without deteriorating land quality, particularly conserving the top-soils effectively and efficiently in the hills and mountains of the country.

Keywords Soil erosion, Top-soils, Desertification, Sustainable Soil Management Practices

Paper type Review

Background

Desertification is a dynamic process of 'land degradation in arid, semi-arid and sub-humid areas resulting from various factors including climatic variations and human activities' (see Figure 1) (UNCCD, 2007). This affects terrestrial areas – top-soil, earth, groundwater reserves, surface run-off, animal and plant populations – as well as human settlements and their amenities. Around the globe, about, 24 billion tonnes of fertile soil disappears annually. Over the past 20 years, roughly one third of the world's land surface is threatened by natural and human-induced land desertification. In totality, 1035 million ha land area is affected by human induced degradation, of which 370.5 million ha is in Asia (GEF-IFAD, 2002). Nepal is one of the Asian countries which has a good share of this pie.

Desertification in the context of Nepal

Temporary and permanent decline in the productive capacity of the land has been the greatest challenge faced by mankind in recent years, particularly in the hill and mountain area of Nepal. Out of the total land area of 14.7 million ha in Nepal, about 3.1 million ha is under cultivation, which supports the food security and livelihoods of more than 76.3% of the population (CBS, 2010/11). Hence, agriculture has been the primary source of food and income for most of the people living in Nepal. These cultivable lands are spread over three agro-ecological regions, namely terrain, hills and mountains. All these regions are prone to land degradation in general, particularly the hills and mountains.

The steep slopes and rain-fed agriculture makes Nepal one of the most vulnerable countries to climate change effects and soil desertification (Nepal Abroad, 2009). Soil erosion is a major contributor to the desertification process in the hills and mountains of Nepal (Subedi and Gurung, 1991). The annual loss of fertile top-soil is estimated to be 240 million cubic meters, which is about 5 to 40 tonne/ha; even more from the agricultural soils in some cases with outward sloping areas (Upadhaya, 1995). This loss of soils leads to the washing out of top-soil layer, 0.6 mm to 1.46 mm depth per year, which clearly depicts that the desertification process in the hilly region is critical. Nepal's rivers carry around 336 million tonnes of soil per year to the main river systems entering into India (Brown, 1981) and damage more than 400,000 hectares of productive agricultural lands (LRMP, 1986). The topsoil being washed down the river systems into India and Bangladesh is now Nepal's most precious export, but one for which it receives no compensation (Eckholm, 1976). The extent and severity of the damage has been increasing every year due to changes in cropping practices and the frequently changing nature of mountain rivers. If appropriate measures are not taken in time, the threat of more land being converted into barren land will be great, resulting in severe food deficits (Carson, 1992).

Major causes and effects of land degradation in Nepal

The agricultural environment in the hills and mountains of Nepal is degrading at a high rate. Physical, biological and chemical are the most common types of degradation caused by both natural and human-induced activities. Wind and water erosion, avalanches and dry landslides are some of the major natural causes (Shrestha et al., 2004), whereas deforestation, overgrazing, over-cultivation, farming on the steep slope without proper terracing, shifting cultivation and inefficient irrigation are common human-induced causes (Aryal and Kerkhoff, 2008). In addition, low soil organic matter (SOM) reserves due to fertility mining practices, residue removal, imbalanced use of chemical fertilizers and pesticides hasten the soil degradation process (ISCO, 2004). Among many effects, removal of top-soil by wind and water soil erosion, decrease of land productivity due to the gradual decline in soil fertility, and washing away of agricultural land after flooding are the common ones, which have given rise to the poor socio-economic status of rural people in Nepal. As a result, Nepal has the lowest per capita income (US$ 220 per year per person) in south Asia. Apart from the loss of productive top-soil, it has further damaged the land and water resources due to siltation of dams and deposition of thick and sandy plains near the rivers.

Realising the context, this paper examines the effectiveness of Sustainable Soil Management (SSM) practices to mitigate the desertification process in the hills of Nepal.

Sustainable Soil Management Practices a possible solution to combat soil degradation in the hills and mountains of Nepal

Sustainable Soil Management (SSM) practices mainly comprise: SOM management, Sloping Agriculture Land Technology (SALT), stall feeding through promotion of fodder and forage, composting and crop residue/biomass management, Integrated Plant Nutrition System (IPNS), integration of legumes in cropping system and bio-engineering for soil and water conservation are considered the most appropriate and relevant technologies that contribute to conserve fertile top-soil, increase soil fertility and mitigate the desertification process in the hills and mountains of the country.
Having internalised the fact, the promotion of SSM practices (promoted by the Sustainable Soil Management Programme [SSMP]) has been undertaken by different governmental and non-governmental organisations with the support of the Swiss Agency for Development and Cooperation (SDC) across the hills of the country since 1999. More than 378 Village Development Committees (VDCs) of the government of Nepal, and 40 Local Service Providers (LSPs) are engaged to promote these practices through a decentralised agriculture extension system i.e. the Agriculture Forestry and Environment Committee (AFEC) lead Farmer-to-Farmer extension by involving all the stakeholders in a participatory way.

The major SSM practices are:

Management of Soil Organic Matter (SOM)

After prolonged and imbalance use of chemical fertilizers and pesticides, many farmers have reported declining yields and deteriorating physical quality of their soils (Bajracharya, 2002; Bajracharya and Sherchan, 2009; RSTL, 2004), which also leads to an increase in soil acidity (Jaishy, 2000). The Soil Management Directorate of Department of Agriculture, Nepal has reported that out of the analysed soil sample in the year 2013, about 49 % of analysed soils were found to be acidic, 28.4 % were neutral and about 22.7 % of soils were alkaline in nature (Table 1) (SMD, 2013). Imbalance of pH directly affects the uptake of soil nutrients by crop plants.

Low external input of chemical fertilizers and organic amendment causes depletion of the SOC pool, because nutrients harvested in agricultural products are not replaced, and are made available through mineralisation of SOM. It has been reported that annually, 1.8 million tonnes of plant nutrients are removed due to crop harvest and soil erosion processes. Out of this, only 0.3 million tonnes of organic and mineral fertilizers replenish while the rest is permanently taken out of the soil, thereby depleting the land productivity (DFRS 2006). The losses of SOM and nutrients are threatening the sustainability of agriculture and the environment (Regmi, 2001).

Composting and crop residue management

This includes on-farm composting and green manuring of the crop residue with resultant vegetation from the terrace risers and farm land, incorporation of crop residues into the soil and use as livestock bedding. It avoids biomass burning and uprooting of the legumes. These practices have been able to supplement the soil organic matter and major plant nutrients in the soil and reverse the situation of continuous biomass removal from the agricultural soils. These practices help to combat soil degradation.

Integration of legumes in the cropping system

SSM practices promote the inclusion of legumes in the cropping system via several methods: mixed, relay, catch, cover crop, pulses and vegetables, forage for livestock and green manuring crop. These legume crops provide an additional cash income to the farmer and are often considered a compensation crop in cases where the major crop fails. Legumes improve the N cycle in cultivated soil through biological N fixation (Table 2), scavenging the soil residual N and turning it into nutrients for subsequent crops. These crops also have many other benefits, such as supplying organic matter, suppressing weeds and breaking pest cycles (Peet, 1996; Magdoff, 1998; Sarrantonio, 1998).

Stall feeding of animals through promotion of fodder and forage

Almost every household in the country rears cattle, but the rearing practice remains unscientific—free-grazing in open public land is the common practice. Overgrazing of animals in cultivated land in the hilly and mountainous area accelerates the compaction and pulverisation of fertile top-soils, which speeds up the physical degradation of soil. Hence, SSMP has promoted stall feeding through the on-farm production of fodder/forage, which supplies livestock feed, nutrient cycling and builds resilience of the local agro-ecosystem. One of the strategies of the SSM is to utilise the terrace risers, ridges (Figure 2) and wasteland around the farm (which often accounts for about 25 % of the farmlands) for fodder/forage production, integrating legumes to improve the quality of livestock feed and encourage stall feeding. This practice has been highly recognised by the farming community as it has reduced the workload of women in fetching animal feed.

Management of Farm Yard Manure (FYM)

The rearing of cattle and FYM management is very poor across the country. The construction of cattle sheds is highly unscientific for animals, as in the management of their excretion. Mostly, farmers' directly expose cattle dung and urine to sunlight and rain, causing, heavy losses of nutrients from FYM. To minimise such losses, SSMP has promoted the scientific management of FYM. This involves the whole chain management, comprising: careful collection, layering and moistening; shading heaps from sunlight to minimise N-volatilisation; protecting heaps from rainfall to reduce leaching and erosion; immediate mixing with soil after taking FYM to the field (Figure 3a, 3b) and the systematic collection and use of cattle urine as liquid fertilizer. More than 100,000 farmers have adopted this package. Out of these, 350 farms were monitored to identify the level of N-content in FYM before and after the adoption of SSM techniques over periods of 1–3 years. Results show that N-content has significantly increased in FYM after the adoption of proper management practices (Figure 4) thereby, increasing soil fertility and also the contents of soil organic matter (SOM) in the top-soil. About two thirds of farmers reported that adoption of SSM practices resulted in easier tillage, increased moisture availability, better soil aggregation, and decreased crusting and clodding. Some particularly mentioned improved crop yields in dry years. The systematic collection of cattle urine has added a significant amount of additional N (Table 3) (SSMP, 2010).

Homemade botanical pesticides - the SSM Options for managing crop insects/pests

Excessive use of chemical pesticides has been posing several threats to the local environment, including both human and animal health. At the same time, pesticides affect the microbial activities of soil, thereby increasing its biological degradation. SSMP has promoted cattle urine-based bio-pesticides by using different parts of locally available plants, such as: Justicia adhatoda (Ashuro), Artemisia vulgaris (Titepati), Eupatoriuma adenophorum (Banmara), Azadirachta indica (Neem), Melia azedarach (Bakaino), Zingiber officinale, Tagetes erecta, Tagetes patula (Sayapatri), Acorus calamus (sweet flag), Mentha, Curcuma domestica (Turmeric), Allium sativum (Garlic), Urtica dicioa (Sisnu). Various parts are either mixed with water or fermented with cattle urine for 30–60 days. These pesticides are then mixed with water at various proportions (depending upon the crop growth stage) and sprayed at an interval of 7 to 15 days to control insect pest management.

Results from several on-farm studies and farmer-led experiments (Figure 5) have shown that such homemade urine-based botanical pesticides are effective in managing several insect/pests with no or minimal damage to the local agro-ecosystem. These botanical pesticides often have an ameliorating effect on the plant–soil environment and beneficial organisms, supply several essential nutrients, add organic matter into the soil and work as a tonic for the plant in stressed environments, thus enhancing better crop growth and production.

Integrated Plant Nutrient System (IPNS)

The integrated plant nutrient management system (IPNS) is a holistic approach which integrates all components of soil, plant and nutrient management so as to achieve higher crop yields and better soil fertility (FAO, 1995). The Farmers' Field School (FFS) approach was adopted to disseminate the concept of plant nutrition management. Evaluation from 54 FFS implemented throughout the programme districts recorded an increase in crop yields by 26 %. Soil analysis showed the increase of soil fertility status, particularly OM, N, P, K, pH and biological activities as compared to the base year, and after the third year of the project intervention (Table 4).

Water management strategies

The mid-hill farmers are operating in very difficult conditions, often with small, fragmented landholdings, and no irrigation supplies. These farmers are entirely reliant upon rainfall and precipitation; they have been facing great challenges to manage water for their crops. Therefore water management strategies for the smallholder farmers in winter and summer is crucial for sustainability of agricultural production. SSMP has therefore provided material and technical support at individual farmers' level; collecting waste water/ rain water is crucial for the production of winter/summer crops. Small plastic ponds/earthen ponds and plastic drums are effective means to collect waste/ rain water. Daily used water, such as water used for cleansing, washing and the monsoon, surface run-off and roof water is directed to such small ponds and collected for crop production during the scarce periods (Figure 6). In addition, bioengineering for soil and water conservation is also promoted in the hill and mountain regions.

Irrigation methods to improve Water Use Efficiency

Proper application methods and time often increases the water use efficiency and avoids the loss of irrigated water. Various irrigation methods, such as drip irrigation and ring irrigation, require much less water than flooding.

Results & discussion

• SSM interventions clearly indicated that there is significant impact in increasing soil fertility, conserving fertile top-soils and mitigating physical, chemical and biologic desertification processes. These are possible through maintaining and improving the soil organic matter, which is the most important indicator for soil health.

• The implementing organisations, both governmental and non-governmental, and the farming community have reported that the SSM practices are crucial for the improvement of soil health, particularly soil pH and soil structure, as the interventions have improved soil organic carbon.

• Organic Pest Management (OPM) utilises the locally available botanicals used as alternatives to chemical pesticides, and in some cases they are found to be very effective. These kinds of activities are suitable for reducing chemicals, and this increases the organic systems, thus leading to better soil and environmental health. In the long run, OPM helps in improving soil and crop productivity as well as human health. However, there is scope for doing research on the different aspects of SSM practices and the extent of their effect on different soil parameters (chemical, biological and physical).

• Comparison of major soil indicators (Biological Activities, OM, N, P, K, and pH) from the baseline year and after the third year of project interventions has indicated that SSM practices can maintain soil health in a balanced condition without deterioration of the land quality, particularly conserving the top-soil effectively and efficiently. Table 5 indicates that the SSM practices have positive impacts on soil health.

• This has created awareness among farmers. Hence, farmers are mitigating pH through increased use of organic manures, where there is less availability of agriculture lime and they are far from road access.

• Further, the SOC survey in the four districts: Baglung, Dhading, Kavre and Okhaldhunga during 2009–2010, revealed that SOC was significantly higher in the SSM than in the non-SSM arable top-soil. Management of organic matter through improved FYM, composting and use of biomass had increased the SOC. N is the main nutrient associated with organic matter and its pattern was similar to that of SOC, with significantly higher contents in the SSM soils, particularly in the top-soil (Dahal and Bajracharya, 2012).

• SSM practices have resulted in an increase of up to 30% in crop yield compared to yields without SSM practices. This might be due to the improvement in SOC which improves soil texture, increases nutrient supply from organic source and conserves water quality, thus, improving soil quality.

• The scaling up of these technologies was found to be in wide demand in the non-project area, and the government of Nepal has aimed to mainstream and upscale SSM practices by the year 2013/14, especially cattle shed management and the collection and utilisation of urine in more than 40 mid-hill districts, which indicates the important aspect of success of the technology and acceptance by the government and farming communities in the hills and mountains.

Conclusion and recommendations

SSM practices were found to be the most appropriate and relevant technologies in increasing soil fertility, conserving the top-soil and maintaining soil health without deteriorating the quality of the land, which ultimately contributes in minimising the desertification process in the hills and mountains of the country. Adoption of SSM practices also helps in reducing input cost, easy tillage operation and often doubles the yield of cereals, vegetables and cash crops production, thus increasing income and food security for the middle-hills smallholder farmers (SSMP, 2010b). Realising these facts, the Ministry of Agriculture Development decided to upscale and mainstream SSM practices in 40 mid-hill districts from the year 2013/14. However, the government of Nepal should develop strategies for minimising losses, restoring soil quality and including SSM practices in the regular planning and programme for all districts. In addition, it should develop focused programmes to provide necessary subsidies and technical guidance to farming households for the promotion of SSM practices, especially for FYM and cattle shed improvement.

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Mr Shiva Kumar Shrestha holds a BSc degree in Agriculture Science from Tribhuvan University, Nepal and an MA Degree in Social Inclusion, Gender and Rural Livelihoods from Wageningen University, the Netherlands. His main areas of expertise are sustainable agriculture development and agriculture-based rural livelihoods. He has contributed to the above-mentioned fields for more than 18 years as a front line extension worker and a senior policy adviser in different international organisations: GIZ, DFID, UN-FAO, USAID and HELVETAS, Nepal. Currently, he is supporting the Nepal Government in decentralising the FtF extension approach to the local level and formulating enabling policies.

Tables & Figures

Table 1. *Status of soil pH in Nepal*

	Acidic	Neutral	Alkaline
Soil pH (5553)	48.9	28.4	22.7

Source: *SMD, 2013 Figure in parentheses indicates number of soil samples analysed*

Table 2. *Comparing estimates of N2*

Group	Crop	N fixed (Kg/ ha/year or crop duration)	Contact details
		Minimum	***Maximum***
Pulses/ Beans	Gahat	45	552
	Rahar	168	280
	Cowpea	73	342
	Mung	63	342
	Soybean	60	168
	Lentil	88	114
	Groundnut	72	124
Forage/ Green Manure	Lucern	45	552
	Dhaincha	73	354
	clover	52	77
	Stylo	40	70
	Vetch	370	450

Table 3. *Comparison of total N-gain from FYM and urine with and without SSM management techniques*

From FYM (dung) N-gain/year		From cattle urine, N-gain/ year		Additional N-gain
Traditional FYM management	Improved FYM manage-ment	Without systematic collection	With sys-tematic collection	Additional N-gain with systematic collection/year
15 kg	21 kg	4.2 kg	16.8 kg	12.6

Source: *: SSMP 2010*

Table 4. *Status change in soil fertility in the IPNS monitoring plot*

Soil parameters	Site I (Sanga)		Site II (Chalal)	
	Year 1	Year 3	Year 1	Year 3
OM in %	1.17	2.35	2.25	2.5
N in %	0.05	0.15	0.09	0.12
P kg/ha	90.67	94.12	312.07	350.08
K kg/ha	350.5	511	142.42	220.56
pH	4.3	6.5	5	6.7

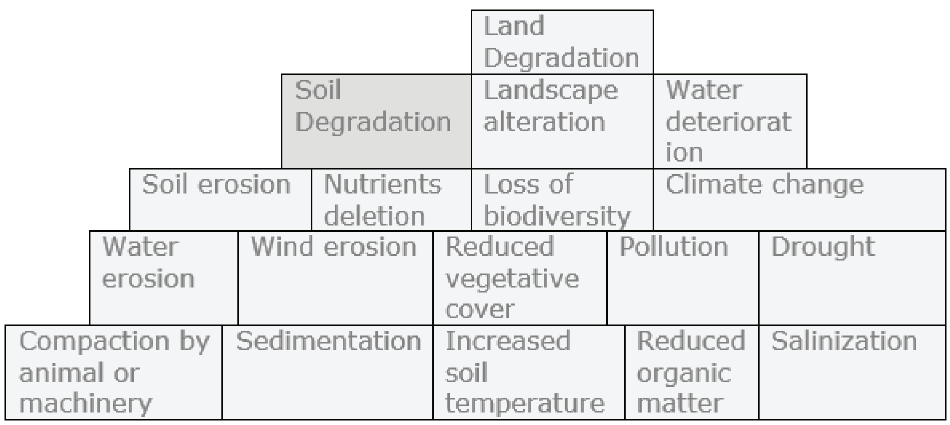
Source: *: DADO, 2004 and RSTL, 2004*

Table 5. *Results of benchmark sites after intervention of SSM (n = 236)*

	pH	N (%)	P kg/ha	K kg/ha	OM (%)
Year 1	5.9 (.08)	0.17 (.08)	31 32	477 (201)	3.2 (1.4)
Year 3	6.0 (.90)	0.19 (.08)	36 34	142.42 (345)	3.6 (1.6)
Difference	(34)	462 (345)	3.6	-15	+0.4

Figures in parentheses indicates STDEV

Figure 1. *The Land Degradation Wall*



Source: Stocking and Murnaghan, 2001

Figure 2. *Forage/fodder production on terrace risers*

Figure 3a. *Farmer mixing FYM in the field through ploughing*

Figure 3b. *Improved management practices: FYM heap protected from sun exposure, rainfall and leaching*

Figure 4. *N-content in FYM before and after adapting improved management*

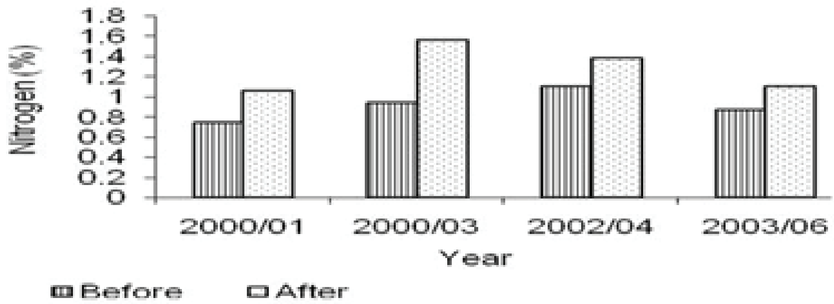


Figure 5. *On-farm research trials on effectiveness of botanical pesticides for managing crop insect/pests*

Figure 6. *Water collection in simple pond for irrigating winter/summer crops*