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Research Article

Assessment of soil quality for different land uses in the Chure region of Central Nepal

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ABSTRACT

Soil quality is the capacity of soil to sustain biological productivity and environmental quality. Assessment of soil quality in different land use systems is essential as inappropriate land use management can degrade and deteriorate its function and stability. In this regard this study was carried out to evaluate soil quality of different land use types in Chure region of central Nepal. Soil quality index (SQI) was determined on the basis of the soil physiochemical parameters. Soil properties like soil pH, organic matter (OM), total nitrogen (TN), available potassium (AK), and available phosphorous (AP) were significantly affected by land uses types. Forest soil had the highest soil quality index (0.82) followed by bari (0.66), khet (0.64), and degraded land (0.40). Of the soil properties studied, total nitrogen and soil organic matter had the determining role in making significant impacts in the SQI among the different land uses. Hence, the results of this study can be important tool for planner, policy makers, and scientific community to frame appropriate land use management strategy.

Keywords: Soil quality index, land uses, Chure

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INTRODUCTION

Soil quality has been defined as "the capacity of specific kind of soil to function, within natural and managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen, 2004). Thus, it would appear to be an ideal indicator of sustainable land management as it helps to assess the overall soil condition and response to management, or resilience towards natural and anthropogenic forces (Doran *et al.*, 1994). Depletion of soil quality is an important process in land degradation and a major constraint to improve plant growth and food security in developing countries (Drechsel *et al.*, 2004).

Soil quality is a dynamic interaction between various physical, chemical and biological soil properties, which are influenced by many external factors such as land use, land management, the environment and socio-economic priorities (Tiwari *et al.*, 2006). The conception of soil quality can be interpreted as two parts: the intrinsic part covering the inherent capacity of the soil for plant growth, and the dynamic part influenced by the soil user or manager (Carter, 2002). Dynamic soil quality is the result of human use and management on soil function (Seybold *et al.*, 1998). A decline in soil quality as a result of soil degradation is a serious problem affecting plant growth and food production in the hilly region in Nepal. In the developing country like Nepal where the majority of the population is still dependent on forest and agriculture, maintenance and improvement of soil quality is a prime concern. The gradual decline in soil fertility, the increase in soil erosion, a reduction of the productive forest area and misuse of agrochemicals are the major environmental problems in Nepal. Thus, assessment of soil quality has been recommended as a valuable tool for evaluating the sustainability of soil and land management practices (Sitaula *et al.*, 2000).

Soil quality is an account of the soil's ability to provide ecosystem services by performing a range of functions under changing conditions (Toth *et al.*, 2007). The functions of soil are not only in the production of food and fibers, but also in the maintenance of environmental quality which improves the importance of value of soil quality (Glanz, 1995). Therefore, maintenance and improvement of soil quality is very important as it provides both economic and environmental benefits. As the improper land management can lead the harmful changes in soil function, there is need for appropriate tools and methods to assess and monitor the soil quality (Doran & Jones, 1996). Hence, the knowledge of soil quality is important for appropriate decision making regarding sustainable soil management and land use practices. In Nepal there are many studies have been conducted on agricultural and forestry crops for their benefits and other tangible importance, however there are very few studies regarding the soil quality assessment in relation to different land use. In this context, finding of the study expected to help planner and policy maker for appropriate land use management decisions.

MATERIALS AND METHODS

Study Area

The study was carried out in the Chhatiwan area of Bakaiya Rural Municipality which lies in the South-East part of Makawanpur district in the Province 3 of Nepal. The site is situated in the South east part of Hetauda City, between 27º 32' N latitude to 85º 21' E longitudes. It is about 26 kilometers from district head quarter Hetauda (DDC, 2016). The study area experiences tropical climate with altitudinal range from 420 to 750m from mean sea level (Figure 1). Agriculture and animal husbandry are the main occupation of this area. Broadly, the study site can be divided in to forest, cultivated land (khet and bari) and degraded land (land with stocking class i.e. crown cover is less than 10%, or area with prominent soil erosion and soil degradation as defined by DFRS, 1999). Two major types of agricultural lands were khet (irrigated low land) and bari (unirrigated/rain fed upland). Maize and potato was the principal crop in bari and paddy was the principal crop in khet. Sand stones, claystones, phyllites, and conglomerates etc. are the major rock types found in the study sites and with sandy boulder type soil. Forest is mainly dominated by *Shorea robusta* (Sal) with other associate such as *Terminalia tomentosa (*Saj), *Dalbergia sissoo* (Sissoo) *etc*. The samples were collected during August, 2016.

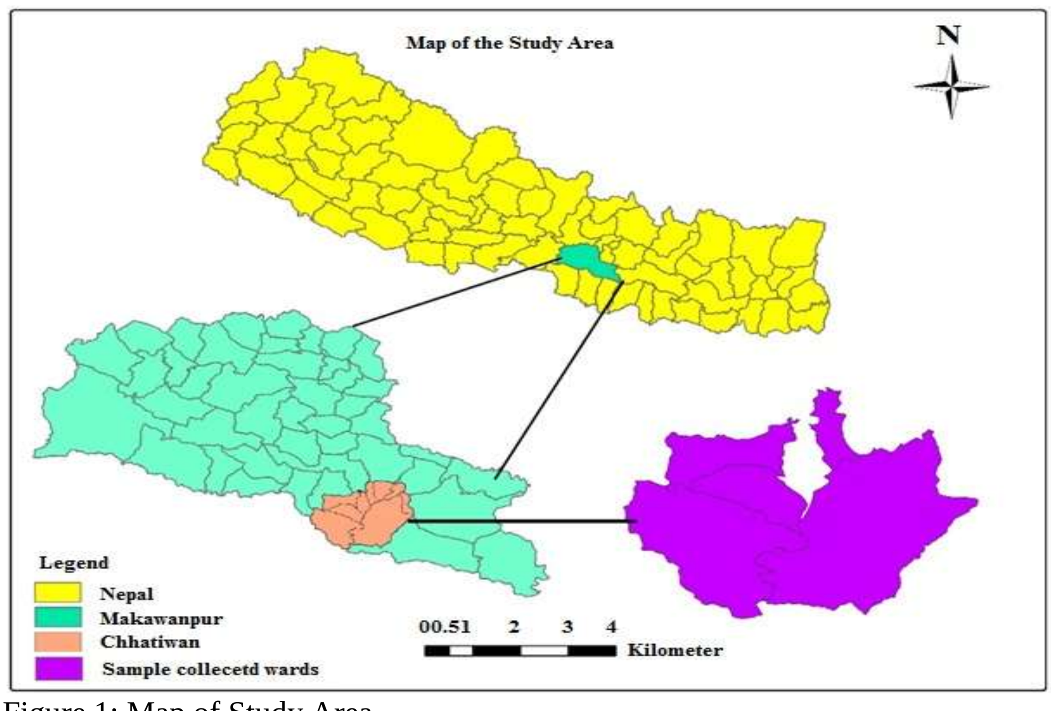

Figure 1: Map of Study Area

Soil Sampling

Stratified random sampling was used for collecting soil samples. Four major land uses as forest, degraded land, khet and bari lands were used as strata. A total of 40 soil sample consisting of 10 from each land use types were collected from 0-15 cm and 15-30 cm plough layer surface to quantify soil nutrient reserves and soil quality in view of maintaining a feasible total sample size for handling and the typical tillage depth used by the farmers. About 500 g of mixture of two sample layer of fresh soil excavated were bagged in polythene bag, sealed, labeled and transported to laboratory for further analysis. The soil samples were analyzed for specific physical and chemical indicators. Soil physical and chemical properties were determined as follows: soil texture by the Bouyoucos hydrometer method (Bouyoucos, 1962); soil organic matter by Colorimetric method (Anderson & Ingram, 1993); total nitrogen (TN) by Kjeldahl method (Bremner & Mulvaney, 1982); available phosphorus (AP) by Olsen's and Somers method (Olsen & Sommers, 1982); available potassium (AK) by flame photometer method (Thomas, 1982) and soil pH by using digital pH meter (McLean, 1982).

Computation of Soil Quality Index

Soil Quality Index value was calculated by the formula as recommended by Bajracharya et al., (2006);

$SQI = [(a\times R_{STC}) + (b\times R_{pH}) + (c\times R_{OC}) + (d\times R_{NPK})]$

Where,

SQI = Soil Quality Index

$R_{STC,}$ = assigned ranking values for soil textural class

R_{pH} = assigned ranking values for soil pH

R_{OC} =assigned ranking values for soil organic carbon

R_{N}=assigned ranking values for nitrogen,

R_{P}=assigned ranking values phosphorus

R_{K} =assigned ranking values for potassium

And a=0.2 b=0.1 c=0.4 and d=0.3 are weighted values corresponding to each of the parameters.

Scoring Method

The scoring method developed by NARC (1993) was used to interpret SQI (Table 1).

Table 1: Common soil parameters and ranking values for SQI in Nepal

	Ranking Values				
Parameters	**0.2**	**0.4**	**0.6**	**0.8**	**1.0**
Soil Textural class	C,S	CL,SC, SiC	Si, LS	L, SiL, SL	SiCL, SC
Soil pH	<4	4-4.9	5-5.9	6-6.4	6.5-7.5
SOC %	<0.5	0.6-1	1.1-2	2.1-4	>4
Fertility(NPK)	Low	Mod Low	Moderate	Mod. High	High
SQI	Very poor	Poor	Fair	Good	Best

Where,
C- Clay S-Sand CL-Clay loam SC- Sandy Clay
SiC- Silty Clay Si-Silt, LS-Loamy sand, SiL- Silty loam,
SL-Sandy loam LS-Loamy Sand SiL-Silty loam, SL-Sandy loam
SiCL-Silty clay loam SCL- Sandy Clay loam
SQI-Soil Quality Index
Soil organic matter = organic carbon × 100/58

Accordingly soil pH and soil fertility interpretation chart developed by NARC (1993) was used to determine the soil pH and soil fertility (Tables 2 and 3 respectively).

Table 2: Interpretation for Soil pH in Hill soil

pH	**Range**
<4.5	Strongly Acidic
4.5-5.5	Moderately Acidic
5.5-6.5	Weakly Acidic
6.5-7.5	Nearly Neutral
>7.5	Alkaline

Table 3: Interpretation table for Soil Fertility in Hill soil

OM (%)		**TN (%)**		**AP(kg/ha)**		**AK(kg/ha)**	
Range	Level	Range	Level	Range	Level	Range	Level
<2.5	Low	<0.1	Low	<31	Low	110	Low
2.5-5	Medium	0.1-0.2	Medium	31-55	Medium	110-280	Medium
>5.0	High	>0.2	High	>55	High	>280	High

Where, OM= Organic matter; TN= Total nitrogen; AP= Available Phosphorous; AK=Available Potassium

Statistical Analysis

Data were analyzed by using IBM statistical software SPSS version 16.0 (and Microsoft Excel 2016 (Arkkelin, 2014; Mady and Shein, 2018).One-way ANOVA was used for testing significant differences of different soil physiochemical properties in different land use system at 95% of confidence interval.

RESULTS AND DISCUSSION

Effect of land uses on soil properties under study

The study revealed that mean value of the soil quality parameters varied among the different land use types (Table 4). Forest soil had higher mean pH (7.25) while khet has lower soil pH (5.47). Slightly higher pH in forest soil might be due to the higher OM of the site and soil derived from the calcareous rocks such as limestones, sandstones, and parent materials of the area. The result of the study was different from the Kalu *et al.* (2015) who reported that higher level of pH in bari and pasture than in the forest in Panchase area of western Nepal. This may be due to the forest was dominated by *Shorea robusta* forest which characterized the presence of high pH (> 6.5) base rich soil (Amatya *et al.*, 2016). Higher rate of application of chemical fertilizer in khet is one of the reasons for acidic pH in the khet land as it is reported that farmers used higher dose of chemical fertilizer in khet to meet the demand of crops. The finding is similar to that of Puget and Lal (2005) who reported that soil pH and nutrient levels were higher in forest land than in cultivated land.

Table 4: Chemical properties of soil averaged for each land use under study

Land Use	**Nutrients**									
	pH		**OM %**		**TN (%)**		**AP (kg/ha)**		**AK (kg/ha**	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Forest	7.25	0.19	2.56	0.34	0.27	0.07	9.77	0.64	155.44	33.17
Degraded land	5.81	0.37	0.86	0.12	0.07	0.01	1.22	0.03	98.24	12.58
Khet	5.47	0.31	1.40	0.08	0.12	0.04	15.91	2.03	184.73	35.51
Bari	5.95	0.55	1.56	0.15	0.15	0.03	24.16	3.33	245.57	23.66

Where, OM= Organic matter; TN= Total nitrogen; AP= Available Phosphorous; AK=Available Potassium

OM was found higher in forest soil (2.56%) and lower in degraded land soil (0.86%). Higher amount of OM in forest soil is attributed to high inputs of leaf litter and decomposition of fine roots in the forestland. Fu et al. (2004) reported that organic matter in the cultivated soils is less protected than that in the uncultivated soils because of the removal of large quantities of the biomass during land preparation, clearing, a reduction in the quantity and quality of organic inputs to the soil and increasing soil organic matter decompositions rates due to enhanced biological activity caused by soil mixing from tillage and higher temperatures form increased soil exposure. Agricultural management practices can also influence the amount of OM in the soil as increased tillage of the soil decreases organic matter. Similar type of result was as reported by Kalu *et al.* (2015) that higher level of OM in forest and bari in than khet and pasture in Panchase area of western Nepal.

Total nitrogen was found higher in the forest soil (0.27%) while it is found lower in degraded land (0.07%) as shown in table 1. Higher amount of organic matter in the forest is the prime reason for higher value of nitrogen as organic matter in the soil is also a source of plant nutrients, especially nitrogen and phosphorous. The finding is similar to that of Kalu *et al.* (2015) who reported that total nitrogen was levels were higher in forest and bari land than in khet and pasture land in Panchase area of western Nepal. Fu *et al.* (2004) also reported that soil nutrient in the cultivated soils is less protected than that in the uncultivated soils because of the removal of large quantities of the biomass during land clearing, ploughing, a reduction in the quantity and quality of organic inputs to the soil and increasing soil organic matter decompositions rates.

Available phosphorous for all the land use fell in low level among them highest amount was found in bari soil 24.16kg/ha followed by khet 15.91kg/ha, Forest 9.77kg/ha and degraded land 1.22kg/ha (Table 4). Available potassium was in medium level for all the land use except for degraded land soil. bari has found to be highest amount of AK with 245.57kg/ha, followed by khet 184.73kg/ha, forest 155.44kg/ha and degraded land 98.24kg/ha (table1). AP and AK content in bari and khet soil was comparatively higher as compared to other land uses. Phosphorus movement is heavily influenced by soil properties such as organic matter, age of soil and land management practices such as cropping and tillage. The use of Urea fertilizer is the major reason for higher phosphorous and potassium content in the khet and bari soil. Tiwari *et al.* (2006) reported that higher available phosphorous and available potassium in cultivated land than in forest. Similarly, Kalu *et al.* (2015) also reported that both available phosphorous and available potassium were higher in bari and khet land than in forest and pasture land in Panchase area of western Nepal. The results seem to be justified in light of the results made by Vaidhya *et al.* (1995) who concluded that cultivated soil have higher level of AP and AK.

Table 5: Physical properties of soil averaged for each land use under study

Land Use	Texture						Texture Class
	Sand %		**Silt %**		**Clay %**		
	Mean	Sd	Mean	Sd	Mean	Sd	
Forest	55.33	4.95	28.67	4.58	16	1.24	SL
Degraded land	27.33	2.46	55.34	3.92	17.33	2.26	LS
Khet	72	5.61	20	3.45	8	1.35	SL
Bari	60	3.95	30.33	2.91	9.67	2.45	SL

The most dominant texture in the study area was found to be sandy loam class however loamy sand textural class also found in degraded land table 2. As Nepalese soils are most often developed on micaceous parent material such as phyllites, schists, quartzite and granites the texture is normally loam and sandy loam in the hilly region (Carson, 1992). Bajracharya *et al.* (2007) also reported that textural class of agricultural soil of Makawanpur district as sandy loam to silt loam. One way ANOVA revealed that soil parameters like soil pH, soil OM, total nitrogen, available phosphorus, and available phosphorous were significantly different among the different land use types (P < 0.05) (Table 6).

Table 6: F-value and the significance of the factors for different soil properties at 3 df.

Factor	pH		OM (%)		TN (%)		AP (Kg/ha)		AK (Kg/ha)	
Land uses	F	Sig	F	Sig	F	Sig	F	Sig	F	Sig
	21.01	0.000*	60.50	0.000*	19.63	0.000*	90.45	0.000*	15.65	0.000*

* p< 0.05 is considered as statistically significant.

SQI of different land use types

SQI reflects the relative soil quality of different land uses. For the study soil physical and chemical properties such as pH, OM, TN, AP, AK and soil texture were assessed for SQI analysis. The SQI value under the study area was good to poor as forest soil has SQI value of 0.82 (Good) followed by 0.66 (Fair) of bari, 0.64 (Fair) of khet and 0.40 (Poor) of degraded land (Figure 2).

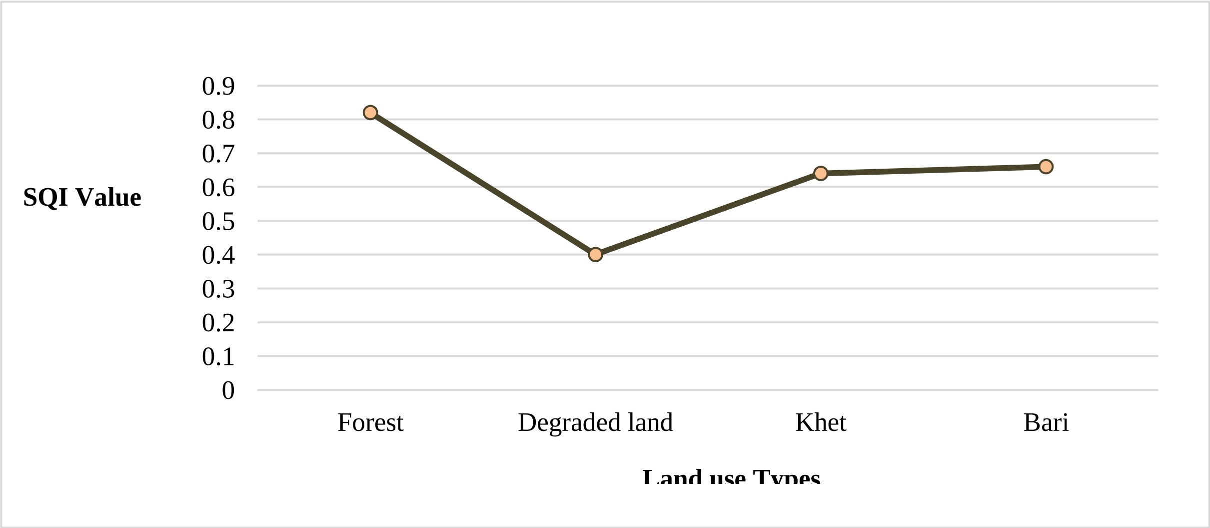

Figure 2: Soil quality index value representing different land uses

TN and soil organic matter had the determining role in making significant differences in the SQI among the different land uses. Khet and bari lands were fair in soil quality. Kalu *et al.* (2015) concluded that forest land had higher soil quality index than the cultivated land. Islam and Weil (2000) also reported that the clearing and cultivation of forested lands resulted in the deterioration of soil properties compared to soils under well-stocked natural forest ecosystems. Also excessive use of fertilizer, overgrazing in off seasons, improper use of chemical fertilizers etc. might have caused such low quality index in khet and bari than forest. Thus, maintaining and improving soil quality can provide economic benefits in the form of increased productivity and sustainable plant growth which ultimately helps to sustainable soil management.

CONCLUSION

The study concluded that forest had the highest soil quality index (SQI) than bari, khet, and degraded land (forest> bari> khet> degraded land. Significantly higher organic matter and nitrogen content had the determining role in making higher SQI in the forest land use whereas application of chemical fertilizers and tillage operations had attributed to the lower SQI on the cultivated land. Of all the land use primarily degraded land should be in priority for restoration and appropriate interventions like agroforestry systems should be introduced to combat soil quality degradation. The major soil properties that affected the SQI among the different land use types were the available nitrogen and soil organic matter content. Land use practices have made significant impact on different soil properties. Soil quality assessment should be linked to the site specific conditions to provide a practical approach to soil quality maintenance without which adoption of appropriate techniques to improve soil quality and sustainable soil management could be difficult. Hence, the study suggests a need for appropriate land use strategies and sustainable soil management practices for improving soil condition in the study area.

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Author Contributions

P.G. designed and performed experiments, analyzed data and wrote the paper; B.B, B.P and B. S. developed the methodology; and P.G. wrote the manuscript in consultation with B.B. and I.S. P.G. revise the article for the final approval of the version to be published.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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