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ANALYTICAL STUDY ON FERTILITY STATUS AND SOIL QUALITY INDEX OF *SHOREAROBUSTA* FOREST, CENTRAL NEPAL

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ABSTRACT

Physiochemical parameters of soil under Shorearobusta forest was estimated to evaluate the soil fertility status and soil quality index in different altitudes of community managed forest of Khairani Municipality Chitwan district Nepal. Altogether 75 soil samples were collected from the forest area at five different depths. Sandy clay loam and sandy loam texture was found in surface and subsurface layer respectively. The mean soil pH of altitudinal strata was 5.57 which is moderately acidic and showed decreasing trend with increasing soil depths. Average bulk density ranged from 1.14 to 1.30 in all attitudes. Organic carbon varied from 0.30 to 1.30% and organic matter ranges from 0.52 to 2.23%. The amount of mean available phosphorus seem low to medium rating in these forest strata. Mean exchangeable potassium varied from 61.89 mg kg^{-1} to 96.02 mg kg^{-1} in different altitudes. Most of these soil attributes decreased with the increasing depth. Pearson correlation analysis among the different soil parameters were showed statistically significant at the 0.01 level (2 – tailed) and 0.05 levels (2 - tailed).One way ANOVA of the studied soil parameters in different altitudes observed that they were statistically significant at 0.05 level ($p \leq 0.05$). The overall soil fertility status of the Kankali Community Forest is low to medium. An average SQI was found 0.55 (fair) up to 120 cm depths,slightly decreased with increasing soil depths. Regulation of Leaf litter collection and adoption of appropriate silvicultural operation may help to increase the fertility status and site quality of Kankali community forest.

Keywords: total N - available P - SOC - soil texture - bulk density.

INTRODUCTION

Forest soil influences the composition of the forest stand and ground cover, rate of tree growth and vigor of natural reproduction. Physiochemical characteristics of soils vary in space and time due to variations in topography, climate, physical and chemical weathering processes, vegetation cover, microbial activities, and several other biotic and abiotic variables. Vegetation plays an important role in soil formation (Chapman & Reiss 1992) through decomposition of plant tissues for the main source of soil organic matter, which controls the physiochemical characteristics of soil such as pH, water holding capacity, texture and nutrient availability (Johnston 1986). Nutrient supply varies widely among ecosystems (Binkley & Vitousek 1989), resulting in differences in plant community structure and production (Chapin et al. 1986). Organic matter supplies energy and cell building constituents for most microorganisms (Allison 1973) and is a critical factor in soil fertility (Brady 2000).

The soil quality is a capacity of specific kind of soil to function, within natural or managed landscapes, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Karlen et al. 1997). Inherent and dynamic soil quality has been used to analyze for productivity of forest ecosystem. The inherent soil quality shows little change over time whereas dynamic soil quality changes with respect to soil management (Larsen & Pierce 1994). Soil quality assessment is carried out by selecting a set of soil properties which are considered as indicators of soil quality. Soil quality evaluation using both surface and subsurface properties will help to identify the soil properties having maximum influence on soil functions. The present study was undertaken to understand the soil fertility and soil quality status at Kankali community forest of Nepal and tried to correlate macronutrients content of the soils with other soil properties.

MATERIALS AND METHODS

Study Area

The Kankali Community Forest (KCF) of the Siwalik zone in Khaireni municipality-4 of Chitwan district, central Nepal was selected for the study (Fig. 1). The altitude of the KCF ranges from 200m to 500m. It comprises fine to medium grained sandstone and gray to greenish gray mudstone rocks of Lower and Middle Siwaliks. The KCF contains dominantly of *Shorearobusta* with *Dalbergiasissoo* and other species. The maximum and minimum temperature was 31°C and 18°C respectively while total annual rainfall was 2278 mm and average relative humidity was 78%.

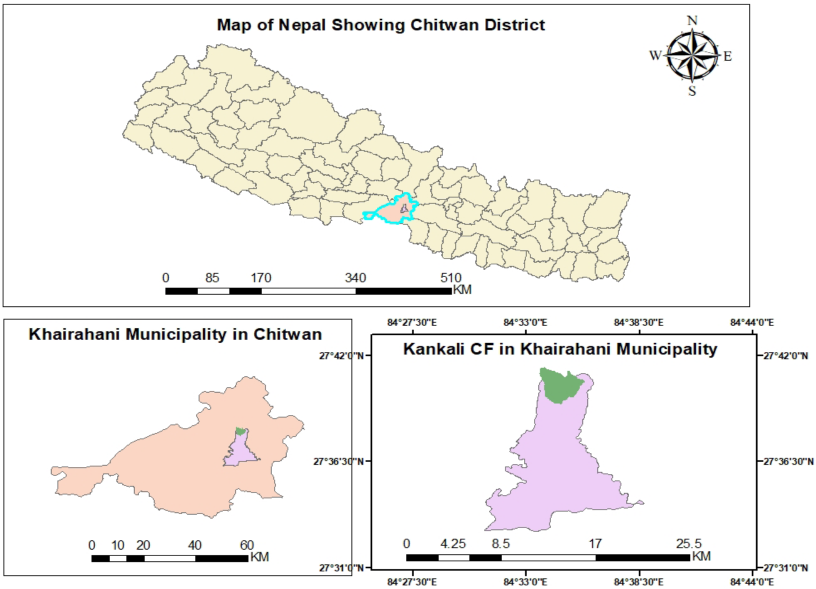

Figure 1: Study area map.

Soil samples collection and analysis

A total of 75 soil samples (25 soil samples/stratum)were collected from predetermined depths *viz.* 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm and 90-120cm from each altitudinal stratum(201-300 m, 301-400 m and 401-500 m). The soil pH was estimated in distilled water (1:2.5) suspension using a digital pH Meter (Jackson 1967). Organic carbon was estimated using the Walkley and Black, and total nitrogen was determined using Kjedhal method as described by Jackson (1967). Exchangeable K was determined by the ammonium acetate extracting solution using flame photometer (Jackson 1967). Texture was determined by Bouyoucos hydrometer method (Bouyoucos 1962).

Interpretation of Soil Quality Index

Soil parameters such as soil texture, soil pH, soil organic matter (SOM), total nitrogen, available phosphorus and exchangeable potassium are used to determine SQI using soil quality rating guide developed by

Bajracharyaet al. 2006 (Table 1). The individual index values for all the soil properties measured on study area are summed to give a total SQI (Bajracharya et al. 2006):

SQI = [(a*RSTC) + (b*RpH) + (c*ROM) + (d*RNPK)]

Where,

RSTC = Ranking for soil textural class,

RpH = Ranking for soil pH,

ROM = Ranking for organic matter

RNPK = Ranking for nitrogen, phosphorus and potassium, and

a, b, c, and d = weighting values corresponding to each of the above mentioned four parameters.

Table 1: Soil quality rating guide

Parameters	Ranking values				
	0.2	0.4	0.6	0.8	1
Soil textural class*	C, S	CL, SC, SiC	Si, LS	L, SiL, SL	SiCL, SCL
Soil pH	< 4, > 8.5	4 to 5	5 to 6	6 to 6.5; 7.5-8.5	6.5 to 7.5
Soil OC %	<0.5	0.5 to 1	1 to 2	2 to 4	> 4
Fertility (N+P+K)	Low	Mod. Low	Moderate	Mod. High	High
SQR†	V. poor	Poor	Fair	Good	Best

Source: Bajracharya et al. 2006

*C=clay, S=sand, CL=clay loam, SC=sandy clay, SiC=silty clay, Si=silt, LS=loamy sand, L=loam, SiL=silt loam, SL=sandy loam, SiCL=silty clay loam, SCL=sandy clay loam. † = soil quality rating

Bajracharya et al. (2006) has given weighting value of NPK in their equation on the basis of soil quality rating by NARC (1999) from the reference of hill soils of Nepal (Table 2).

Table 2: N, P and K interpretation of hill soil of Nepal

Total N (%)		Available P (kg/ha)		Exchangeable K (kg/ha)	
Range	**level**	**Range**	**level**	**Range**	**level**
<0.1	Low	<31	Low	<110	Low
0.1-0.2	Medium	31-55	Medium	110-280	Medium
>0.2	High	>55	High	>280	High

Source: NARC 1999

RESULTS AND DISCUSSIONS

Soil fertility status based on physical properties

Altitudinal strata of KCF indicate that soils in general are sandy clay loam (SCL) and sandy loam (SL) texture. At 201-300 m altitude, all the layers of soil have SCL texture with increasing sand percentage and decreasing clay percentage in surface layer. Sandy loam texture in surface layers and SCL texture in deeper subsurface layers are found at 301- 400 m altitude with slight increasing percentage of sand and clay in subsurface layers. The distribution of texture at 401-500 m altitude in KCF is SL in top layer and SCL in deeper layers. The sand percentage decreased with increasing soil depths. The textures found in all altitudes fall in good and best rating. It means that the textures of this forest can support suitable growth of plants due to nutrients available from finer soil, root respiration and mechanical strength from coarser soil. Bajracharya et al. (2006) reported the similar textures for forest regeneration and high quality trees (Paudel & Sah 2003). These textures are also very common in the Terai, Siwalik and Doon valley, which support dense *S. robusta* forests and other valuable timber trees (Shah 1999). This may be due to the similar type of forest vegetation, *i.e*., *S. robusta* dominated forest, climate and parent materials.

Higher bulk density (1.27 to 1.33 g/cm^3) shows in the soils at middle altitude in all the depths followed by high altitude (1.15 to 1.25 g/cm^3) and the least at lower altitude (1.11 to 1.18 g/cm^3). There is substantial decrease in bulk density in all surface layers due to the addition of humus in the soils and in general, higher the humus lowers the bulk density. The slightly higher bulk density in middle altitude may be due to the presence of regeneration vegetation and steepness of slope. Gautam and Mandal (2013) reported that the bulk density was minimum (1.28 g/cm^3) in the upper layer which increased depth-wise with statistically significant different ($P < 0.001$)at three different depths (0-15, 15-30 and 30-45 cm). Ranabhat et al. (2008) reported the bulk density range of Nepalese forest soil from 1.01 g cm^{-3} in top layer to 1.47 g cm^{-3} in 80-100 cm depth with increasing Db with increasing depths.

Soil fertility status based on chemical properties

Soil reaction is slightly higher *i.e.* less acidic soils at middle altitude as compared to higher and lower altitudes. It may be due to the presence of acidic parent materials. However, all altitudes show moderately acidic to slightly acidic pH (5.23 to 5.98) in all depths. Overall, soil pH is more acidic in surface layer as compared to subsurface layer. This may be due to local environmental factors such as aspect, rainfall, and vegetation composition. These values (4.33-5.26 and 4. 74) are similar as reported by Paudel and Sah (2003) and Kharal et al.(2018)in different *S. robusta* forests. Good *S. robusta* regeneration areas favor slightly acidic soils (Bhatnagar, 1965). The acidic nature of the soil in this site may be attributed to the high rainfall, which is sufficient to leach basic cations from the surface horizons of the soils.

Organic carbon varies from 0.30 to 1.30% and organic matter 0.52 to 2.23% in the soils at different altitudes. The mean organic matter of all layers are observed higher at 301-400 m altitude (1.12 %) and followed by 401-500 m (1.09 %) and 201-300 m (1.07 %). The rating of the organic matter at KCF falls in low. Organic matter brings favorable changes in terms of the soil air, water holding capacity, structure, porosity, bulk density, color, nutrient storage and availability, cation exchange capacity and the microbial population and their activity (Kononova, 1966).

Table 3: Soil fertility status in different soil layers

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture Class	Db (g/cc)	pH	Org. Carbon (%)	Org. Matter (%)	Total N (%)	Av. P (ppm)	Ex. K (ppm)	C:N ratio
201 - 300 m Altitude												
0-15	57.25	18.75	24.00	SCL	1.11	5.45	1.28	2.19	0.20	10.75	70.10	6.51
15-30	50.50	20.50	29.00	SCL	1.12	5.47	0.75	1.28	0.19	8.25	62.70	3.91
30-60	52.25	18.75	29.00	SCL	1.15	5.54	0.49	0.77	0.13	4.25	61.65	3.77
60-90	52.25	16.25	31.50	SCL	1.14	5.5 3	0.33	0.56	0.10	5.00	58.35	3.30
90-120	52.25	16.25	31.50	SCL	1.18	5.43	0.31	0.53	0.10	5.75	56.65	3.10
Avg.	**52.90**	**18.10**	**29.00**		**1.14**	**5.48**	**0.62**	**1.07**	**0.16**	**6.80**	**61.89**	**3.69**
301 - 400 m Altitude												
0-15	54.00	27.00	19.00	SL	1.27	5.69	0.64	1.09	0.16	25.75	110.10	4.07
15-30	64.00	19.50	16.50	SL	1.28	5.64	0.74	1.28	0.13	21.00	104.35	5.80
30-60	66.50	14.50	19.00	SL	1.32	5.78	0.70	1.20	0.14	18.75	98.25	5.09
60-90	65.00	14.50	20.50	SCL	1.28	5.91	0.67	1.14	0.13	14.50	95.10	5.24
90-120	57.50	19.50	23.00	SCL	1.33	5.98	0.51	0.87	0.10	11.00	72.30	4.83
Avg.	**61.40**	**19.00**	**19.60**		**1.30**	**5.80**	**0.65**	**1.12**	**0.13**	**18.20**	**96.02**	**5.01**
401 - 500 m Altitude												
0-15	68.00	17.00	15.00	SL	1.15	5.40	1.30	2.23	0.18	20.50	115.45	7.06
15-30	60.50	17.00	22.50	SCL	1.19	5.26	0.74	1.27	0.14	10.00	73.95	5.14
30-60	60.50	19.50	20.00	SCL	1.21	5.23	0.53	0.90	0.13	9.50	52.55	4.17
60-90	55.50	22.00	22.50	SCL	1.25	5.40	0.45	0.52	0.11	6.00	58.60	4.10
90-120	55.50	24.50	20.00	SCL	1.21	5.40	0.38	0.55	0.10	5.25	66.85	3.80
Avg.	**60.00**	**20.00**	**20.00**		**1.20**	**5.34**	**0.64**	**1.09**	**0.14**	**10.25**	**73.48**	**4.32**

Source: Field survey 2016

The lower organic carbon is estimated in this forest as the reason of dominancy of young trees *i.e.* pole, saplings and very low ground cover by herbs and grasses. The main resources of organic carbon are foliage, other fragmented part of the trees and stumps.

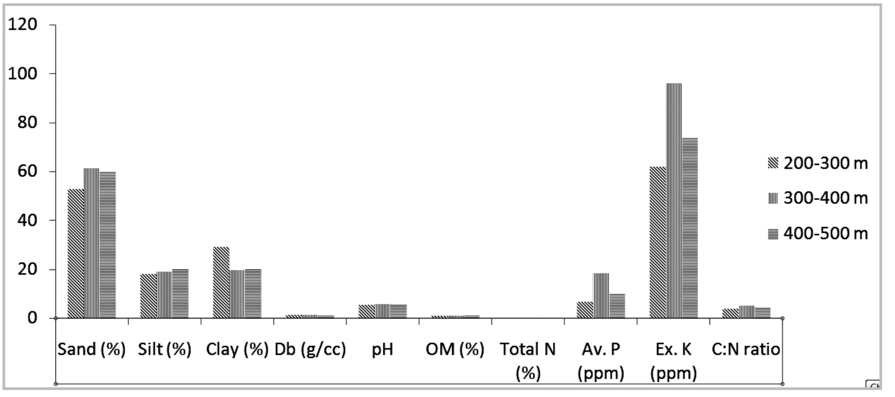

Figure 2: Comparison of soil parameters with respect to altitudes in KCF

The total nitrogen content shows the similar trend as that of the carbon. Higher mean total nitrogen (0.16 %) is observed at 201-300 maltitude followed by 401-500 m (0.14 %) and 301-400 m altitude (0.13 %). The total nitrogen of this study found in low to medium rating. This is due to the domination of regenerated tree species, low ground cover, denitrification due to domination of south facing slope and frequent firing. Low to medium rating was reported by Sharma (2013) in the *S. robusta* dominated forest of Nepal. The total nitrogen levels in Nepal ranged from 0.05 to 0.40% (LRMP, 1986). Enrichment of soil with nitrogen,improved the soil fertility(Gupta & Sharma 2009).

An amount of mean available phosphorus at 301-400 m altitude (18.20 mg kg^{-1}) is nearly three times as compared to soils at 201-300 m altitude (6.80 mg kg^{-1}) and nearly doubled as compared to soils at 401-500 m altitude (10.25 mg kg^{-1}). The mean available phosphorus seems low to medium rating in these forest strata. Paudel and Sah (2003) reported the 76.64 to 79.29 kg/ha available phosphorus in pure and mixed *S. robusta* forests of Nepal. Moderately low to low levels of available phosphorus were reported by LRMP(1986).

Mean exchangeable potassium of different layers is higher in the soils at 301-400 m altitude (96.02 mg kg^{-1}) followed by 401-500 m altitude (73.48 mg kg^{-1}) and 201-300 m altitude (61.89 mg kg^{-1}). Exchangeable potassium is higher in surface layer as compared to subsurface layers. It gradually decreased in deeper layers Exchangeable potassium was found higher in surface layer as compared to subsurface layers (Joshi *et al*., 1999). The exchangeable potassium ranged from 233.86 to 267.73 kg/ha was presented by Paudel and Sah (2003).

Table 4: Pearson correlation among soil parameters in KCF

Parameters	Sand (%)	Silt (%)	Clay (%)	Db (g/cc)	pH	OC (%)	OM (%)	Total N (%)	Avl. P (ppm)	Ex. K (ppm)
Sand (%)	1									
Silt (%)	-.644**	1								
Clay (%)	-.656**	-0.155	1							
BD (g/cc)	.575**	-0.244	-.502**	1						
pH	-0.12	0.159	-0.002	.422*	1					
OC (%)	0.122	0.028	-0.186	-0.147	0.052	1				
OM (%)	0.132	0.023	-0.194	-0.133	0.067	.997**	1			
Total N (%)	-0.141	0.131	0.053	-.388*	-0.067	.813**	.813**	1		
Avl. P (ppm)	0.321	0.208	-.621**	.410*	0.36	.506**	.519**	0.328	1	
Ex. K (ppm)	-0.063	.363*	-0.277	0.142	.527**	.552**	.552**	.406*	.717**	1
C:N ratio	0.277	-0.041	-0.318	0.084	0.227	.879**	.883**	.482**	.573**	.600**

*** Correlation is significant at the 0.01 level (2-tailed) and * Correlation is significant at the 0.05 level (2-tailed).*

The soil parameters are statistically significant at the 0.01 level (2 – tailed) and 0.05 levels (2 - tailed) (Table 4). The percentage of sand is negatively correlated with clay percent (r = -0.656), silt per cent (r = -0.664), the bulk density is positively correlated with pH (r = 0.422), available phosphorus (r = 0.410), sand (r = 0.575) and negatively correlated with clay (r = 0.502). The positive correlation (r = 0.527) is showed between soil pH and exchangeable potassium. The organic carbon/organic matter are positively correlated with total nitrogen (r = 0.813), exchangeable potassium (r = 0.552) and C: N ratio (r = 0.879). The total nitrogen shows positive correlation with exchangeable potassium (r = 0.406) and C: N ratio (r = 0.482). An available phosphorus is correlated positively with exchangeable potassium (r = 0.717), C: N ratio (r = 0.573) and negatively with clay (r = 0.621). An exchangeable potassium is correlated positively with silt (r = 0.363) and C: N ratio (r = 0.600).

The soil parameters are tested through one way ANOVA (Table 5) at 0.05 level (p = <0.05). The pH at 201-300 m altitude is statistically significantly different with the pH at 301-400 m altitude with mean difference 0.31* (Variance ratio, F = 11.142 and p = 0.004) and similarly, 301-400 m altitude is significantly different at 401-500 m altitude with mean difference 0.46* (Variance ratio, F = 11.142 and p = 0.001).

Table 5: Altitude wise least significant difference (LSD) of soil parameters

SI. No.	Soil parameter	Strata	Mean difference	P value
1	Soil pH	201-300 m Vs 301-400 m	0.3130*	0.004
		301-400 m Vs 401-500 m	0.4610*	0.001
2	Bulk Density	201-300 m Vs 301-400 m	0.1540*	0.001
		201-300 m Vs 401-500 m	0.0580*	0.047
		301-400 m Vs 401-500 m	0.0960*	0.002
3	Available Phosphorus	201-300 m Vs 301-400 m	11.400*	0.001
		301-400 m Vs 401-500 m	7.950*	0.006

**Mean difference is significant at the 0.05 level*

The significant different is observed in bulk density at 201-300 m and 301-400 m altitude with mean difference 0.15* (Variance ratio, F = 15.599, p = 0.001) and 401-500 m altitude with mean difference 0. 06* (Variance ratio, F = 15.599, p = 0.047). Significantly different with mean difference 0.10* (Variance ratio, F = 15.599, p = 0.002) of bulk density at 401-500 m altitude and 301-400 m altitude is observed. Available phosphorus content in 201-300 m altitude is significantly different at 301-400 m altitude in mean difference 11.40* (Variance ratio, F = 9.84, p = 0.001) and 301-400 m altitude is significantly different at 401-500 m altitude with mean difference 7.95* (Variance ratio, F = 9.84, p = 0.006).

Soil fertility status based on altitude

Mean sand, silt and clay percentage of all layers are observed 52.90%, 18.10% and 29.00%, respectively at 201-300 m altitude followed by 60.00%, 20.00% and 20.00% at 401-500 m altitude, and 61.40%, 19.00% and 19.60% at 301-400 m altitude. An average soil bulk density, soil organic matter, soil pH, available phosphorus, exchangeable potassium and CN ratio are higher in middle altitude (301-400 m) followed by 401-500 m altitude and least in 201-300 m altitude. An average total nitrogen percentage is higher in 201-300 m followed by 401-500 m 301-400 m altitude.

Soil quality index in Kankali Community Forest

The altitude wise SQI in different depths of soil in KCF with individual soil quality rating of physiochemical parameters are presented in Table 6. The SQI in surface layer in all altitudes reveal that higher, ranged from 0.54 to 0.64 (fair) qualities as compared to subsurface layer that is varied from 0.50 to 0.52 (fair) qualities. The SQI slightly decreases with increasing soil depths. An average SQI in KCF is found 0.55 (fair) up to 120 cm depth. The order of weighting index of mean soil parameters shows texture and NPK (0.19) > SOC (0.12) > pH (0.05).

Table 6: Depth wise soil quality index with soil quality rating in KCF

Strata	Soil depth (m)	Tex. Rating	Tex. SQI	pH rating	pH SQI	SOC rating	SOC SQI	NPK rating	NPK SQI	SQI
201-300 m	0-15	1	0.2	0.4	0.04	0.4	0.16	0.8	0.24	0.64
	15-30	1	0.2	0.4	0.04	0.4	0.16	0.6	0.18	0.58
	30-60	1	0.2	0.6	0.06	0.2	0.08	0.6	0.18	0.52
	60-90	1	0.2	0.6	0.06	0.2	0.08	0.6	0.18	0.52
	90-120	1	0.2	0.4	0.04	0.2	0.08	0.6	0.18	0.5
	Average	**1**	**0.2**	**0.48**	**0.05**	**0.28**	**0.11**	**0.64**	**0.19**	**0.55**
301-400 m	0-15	0.8	0.16	0.6	0.06	0.4	0.16	0.8	0.24	0.62
	15-30	0.8	0.16	0.6	0.06	0.4	0.16	0.6	0.18	0.56
	30-60	0.8	0.16	0.6	0.06	0.4	0.16	0.6	0.18	0.56
	60-90	1	0.2	0.6	0.06	0.2	0.16	0.6	0.18	0.6
	90-120	1	0.2	0.6	0.06	0.2	0.08	0.6	0.18	0.52
	Average	**0.88**	**0.18**	**0.6**	**0.06**	**0.32**	**0.14**	**0.64**	**0.19**	**0.57**
401-500 m	0-15	0.8	0.16	0.4	0.04	0.4	0.16	0.6	0.18	0.54
	15-30	0.8	0.16	0.4	0.04	0.4	0.16	0.6	0.18	0.54
	30-60	1	0.2	0.4	0.04	0.2	0.08	0.6	0.18	0.5
	60-90	1	0.2	0.4	0.04	0.2	0.08	0.6	0.18	0.5
	90-120	1	0.2	0.4	0.04	0.2	0.08	0.6	0.18	0.5
	Average	**0.92**	**0.18**	**0.4**	**0.04**	**0.28**	**0.11**	**0.6**	**0.18**	**0.52**
Average		**0.93**	**0.19**	**0.49**	**0.05**	**0.29**	**0.12**	**0.63**	**0.19**	**0.55**

Source: Field survey 2016

The weighting index of SOC appears in second place and NPK in first that may be due to the low contribution of organic matter. Tiwari (2006) reported the SQI as “poor” (0.45) of the forest land in Pokhre Khola watershed of Nepal. Bajracharyaet al. (2007) was reported 33% as "fair", 20% as"poor", and the majority (47%) as "good" quality from the forest soils of Nepal.

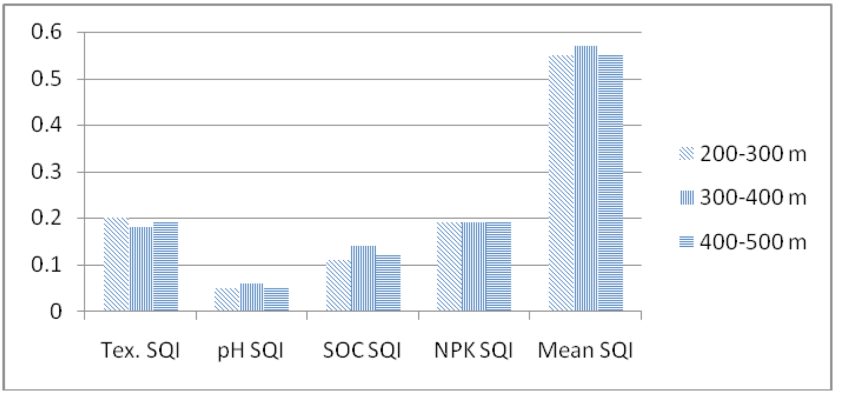

Figure 3: Comparison of soil quality rating and mean soil quality index

Larson and Pierce (1994) were reported that SOC was the single most imperative indicator of soil quality in the upper few centimeters of the soil. Wang et al.(2003) reported that SOC to be a key attribute of soil quality because it determines physical, chemical and biological soil properties. However, the weighting index in KCF (Table 6) indicates that all dynamic soil properties are important in determining the soil quality indices. N, P and K are the most important parameters to determine the soil quality in this study because N shows high positive correlation in this forest (> 0.75) with SOC.

CONCLUSION

Seven physiochemical attributes of soil were undertaken to evaluate soil fertility and soil quality index in Kankali community forest. Overall soil fertility status and soil quality shows higher in middle altitude that is due to regeneration vegetation composition of the forest. Soil pH, bulk density and available phosphorus shows statistically significant different with altitudinal gradient. Overall soil fertility rating was ranged from low to moderate and soil quality index as "fair" rating. It provides knowledge to maintain soil fertility and soil quality of the forest for better management.

Regulation of Leaf litter collection and adoption of appropriate silvicultural operation help to increase the fertility status and site quality of Kankali community forest.

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