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Analysis of rocks, soils and vegetation characteristics of Kankali (Chitwan) and Tibrikot (Kaski) community forests of Nepal

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ABSTRACT

This study was conducted in Kankali and Tibrikot Community Forests to explore the status and interrelationship among rocks, soils and vegetation. The rocks, soils and vegetation sample/data were collected from both of the community forests and analysed in different laboratories. The collected data are interpreted by applying descriptive statistics. The species richness in all life form of the species, Shannon-wiener Index and soil characteristics in all geological units in both of the forests were computed and discussed. Geologically, the community forests can be divided into four units based on rock types, grain size and mineral content. Kankali Community Forest contains sandstone and mudstone of the Lower and Middle Siwaliks with quartz, biotite, muscovite, feldspar and opaque minerals. The Tibrikot Community Forest contains phyllite of the Kunchha Formation (Lesser Himalaya) with quartzite with feldspar, quartz, micas and opaque minerals. This paper presents clear and consistent evidences of the role of lithology and grain size of rock, and soil nutrients in shaping the vegetation growth pattern and their distribution.

Key words: Community Forest, Geology, Species Richness, Nutrient, Nepal

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INTRODUCTION

Nepal has complex geology due to the presence of Precambrian to recent rocks and active tectonics. Based on geology, soil characteristics, altitude, topographic, climatic and vegetation characteristics, Nepal can be divided into eight distinct physiographic regions, i. e., the Terai, Siwalik (Churia) Range, Dun Valleys, Mahabharat Range, Midlands, Fore Himalayas, Higher Himalayas and the Inner and Trans Himalayan Valley (Upreti 1999a). Similarly, Nepal is tectonically divided into the Terai, Siwaliks, Lesser Himalaya, Higher Himalaya and Tibetan-Tethys Himalaya, from south to north, respectively. Each of these physiographic regions as well as tectonic zones consists of different types of rocks, soils and vegetations. The Siwalik zone mostly contains sandstone, mudstone and conglomerate. The Lesser Himalayan meta-sedimentary zone is dominated by slate, phyllite, schist, limestone, dolomite, marble and quartzite. Loamy soils of these zones are the products of the physical, biological and chemical weathering of rocks and erosion of contemporary land masses. The physical, chemical as well as biological properties of soils play an important role for the better management of the forests. Living plants require a supply of nutrient elements from the soils and much of it is dependent on a cycling of these elements in the biosphere. The major sources of input of elements into the forest-soil ecosystem are atmospheric, geologic and biologic (Armson 1977). The nutrient elements from rock to the soils have direct relationship with soil fertility, vegetation growth and development. Soil fertility is possible in terms of rate of plant growth, characteristics of the species, their population and distribution. Mostly, Siwalik zone contains *Shorea robusta* dominated forests and the Lesser Himalayan meta-sedimentary zone is dominated by *Schima castonopsis* forests.

In each of the tectonic zones, significant number of forest patches are handed over to users organised in a Forest User Groups (FUG) by the District Forest Office according to rules specified in the *Forest Act* 1993 (HMG 1993) and *Forest Regulation* 1995 (HMG 1995). Plant communities in Nepalese community forests that now covers around 30% of the Nepalese forest area (1.2 Mha) (DOF 2012), have great diversity in rocks, soils and vegetations. The soils in community managed forests are also the direct product of the physical, biological and chemical weathering of rocks.

The residual soils reflect the characteristics of bed rock on which they occur (Carson et al. 1986). Most of the clay minerals and silt-sized quartz in soils are derived from the weathering and the erosión of contemporary land masses (Tucker 1988). Though, soil is divided into two major categories, i.e., mineral and organic soil, most of the soils of Nepal, particularly that of forests is mineral dominant in composition (Carson 1992). The mineral soils are basically derived from *in şitu* materials, i.e., rocks and transported materials due to geomorphic processes. The organic soils are generally derived from plant and animal residue (Brady 2000). Strongly acidic soils are common in Nepal because of the predominance of coarse textural soil, acid forming parent materials and reforestation with pine trees (Carson 1992). Soil pH determines the availability of plant nutrients and toxicity. Soil fertility is the quality of a soil that enables it to provide essential chemical elements in quantities and proportions for the growth of plants (Brady 2000). Most of the plant nutrients are directly derived from parent materials.

Despite several studies related to soils, minerals, rocks and vegetations, the studies focusing particularly in identifying the relationships among rocks, soils and vegetations in community-managed forests are limited. The study of mineral composition of different rock types in thin section is very important for knowing the formation of residual soil types. Most of the geological studies give little emphasis on the importance of relationship among soils, rocks and minerals. The present study is carried out to understand petrology of rocks, role of rocks on soil pH and availability of nutrients to the vegetation in two selected community forests residing at two different physiographic regions of Nepal. Findings of the study are expected to help the communities for the better management of their forest patches.

STUDY AREA

The Kankali Community Forest (KCF) of the Siwalik zone (Lower and Middle Siwaliks) and the Tibrikot Community Forest (TCF) of the Lesser Himalaya (Kunchha Formation) were selected for the study (Fig. 1). The KCF (Figs. 1 and 2) contains dominantly *Shorea robusta* with *Dalbergia sissoo* and other species. The ten year average climatic data nearby the KCF was taken from the nearest metrological station, Rampur Chitwan. An average annual maximum and minimum temperatures were 31^{0}C and 18^{0}C, respectively, and the average relative humidity and average annual rainfall of the area were recorded as 78% and 190 mm, respectively.

The TCF (Figs. 1 and 3) of Kaski District represents the typical mid-hill region of Nepal in terms of the community forest management and the socio-economic background of the rural hill population. The major species found in the TCF are *Castonopsis indica* and *Schima wallichii.* The annual average temperature of 10 years taken from the nearest metrological station at Pokhara shows an average annual maximum and minimum as 27^{0}C and 16^{0}C, respectively. Similarly, average annual rainfall and average relative humidity were recorded as 345 mm and 74%.

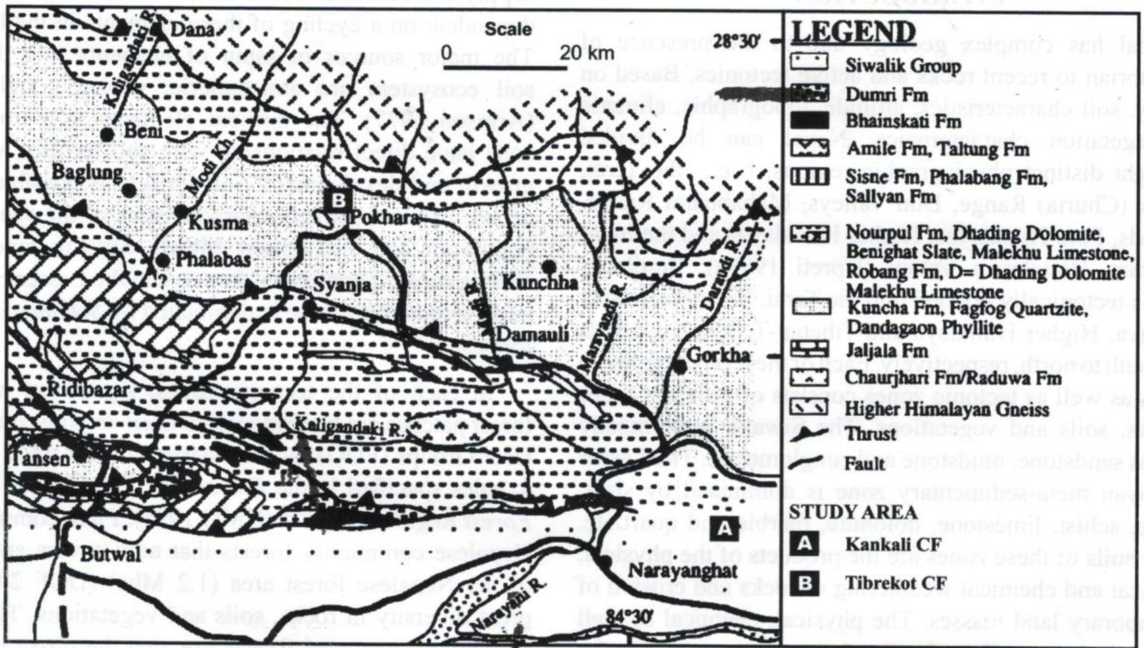

Fig. 1: Regional geological map showing the locations of study area (Redrawn after Upreti 1999b).

MATERIALS AND METHODS

Rock sample collection and analysis

Transect walk was applied for observing the natural boundaries of different geological units in the forest through the measurement of orientation of rock strata (strike, dip and dip direction) by using Brunton compass. Detailed geological map was prepared by using Geographical Information System (GIS) and Corel draw softwares (Figs. 1, 2 and 3). Stratified random sampling technique was used for rock sample collection in each Community Forest (CF) according to the variation in rock types. Altogether, 11 samples in TCF and 15 samples in KCF were selected to collect the rock samples. All of the samples were taken from D horizon of selected points and nearby rock exposures. Thin sections of the collected rocks were prepared in the laboratory of Tri-Chandra Multiple College, Kathmandu, Nepal. The prepared slides were examined under petrological microscope.

Soil sample collection and analysis

The Community Based Natural Forest and Tree Management in the Himalaya (ComForM) Project of the Institute of Forestry, Pokhara Nepal has established 63 sample plots in KCF and 52 sample plots in TCF of size 25x20 sq.m. (ComForM 2006). Soil samples were taken from each plot from two layers, i.e., A (0-15 cm), B (15 to 30 cm). Samples were taken from four corners and middle part of the sample plot forming M shape. These soil samples were mixed together to make a composite sample of about 0.5 kg. In addition, 30 soil profile samples were taken from different part of both the forests as ancillary data and information for geological unit delineation and rock unit variation. Total 250 samples with soil profile were taken for soil analysis. The prepared soil samples were analysed by using the following instruments and methods:

(i) Soil colour using Munsell colour chart,

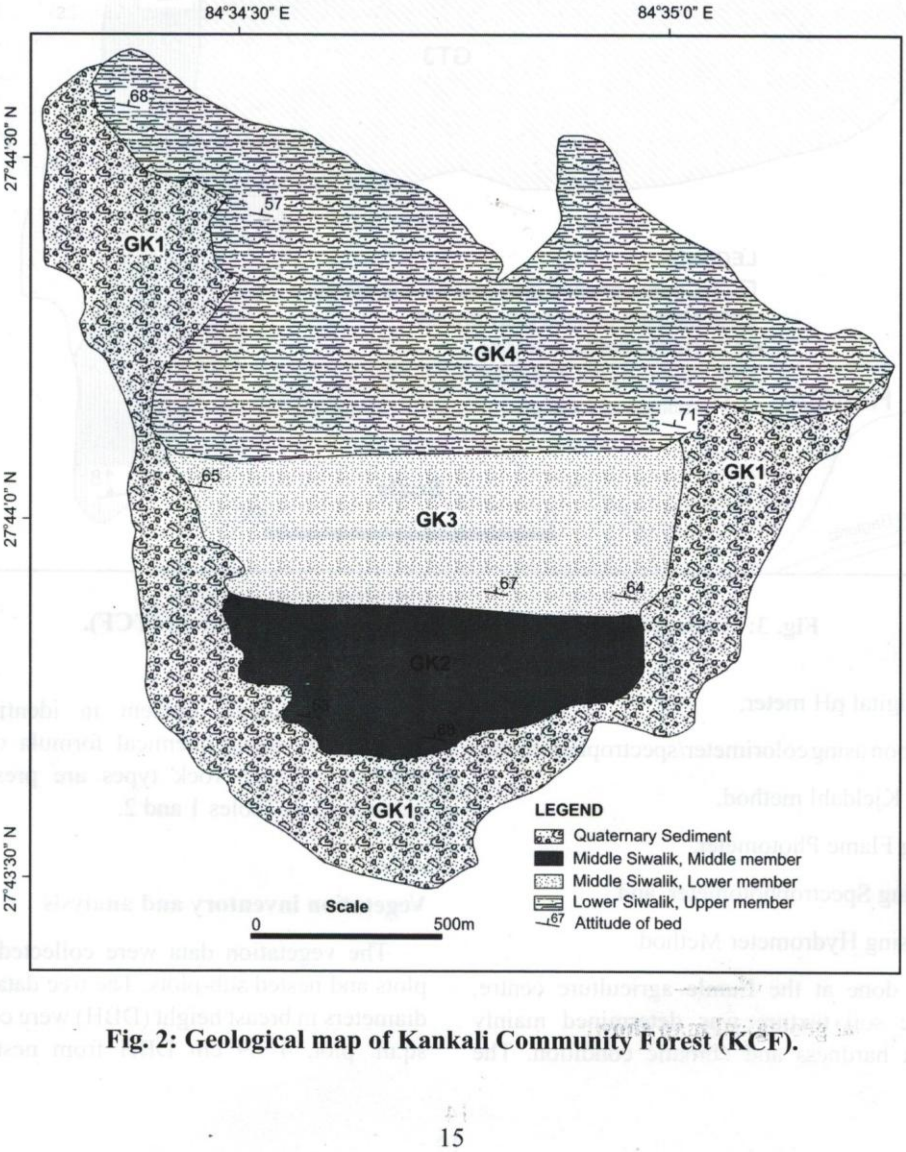

Fig. 2: Geological map of Kankali Community Forest (KCF).

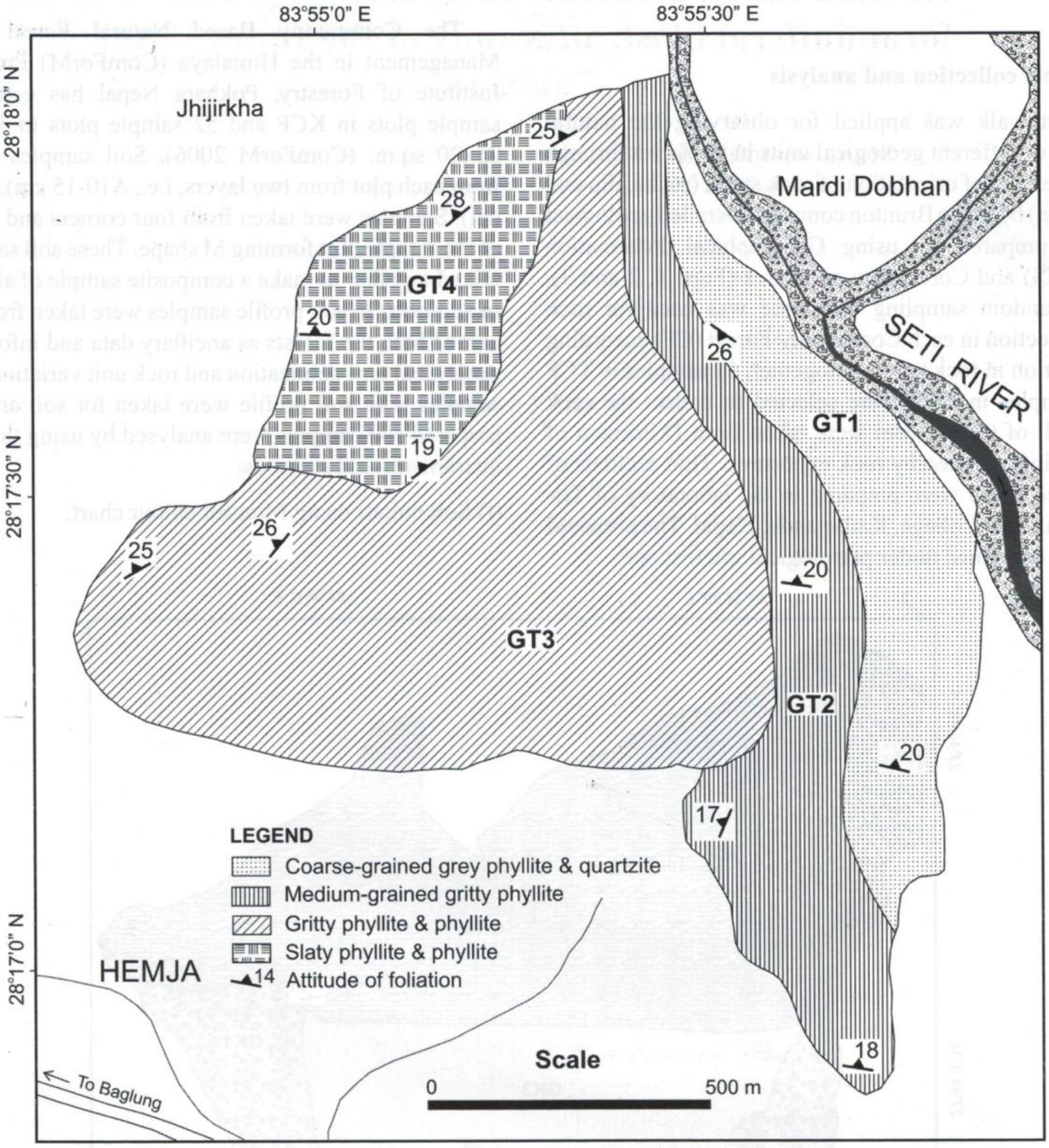

Fig. 3: Geological map of the Tibrikot Community Forest (TCF).

(ii) Soil pH using digital pH meter,

(iii) Soil organic carbon using colorimeter/spectrophotometer,

(iv) Nitrogen using Kjeldahl method,

(v) Potassium using Flame Photometer,

(vi) Phosphorus using Spectrophotometer, and

(vii) Soil Texture using Hydrometer Method.

Analyses were done at the Lumle agriculture centre, Kaski, Nepal. The soil texture was determined mainly depending on rock hardness and climatic condition. The chemical elements content in identified minerals was analysed by using chemical formula of mineral. Mineral contents of each rock types are presented in terms of percentage in Tables 1 and 2.

Vegetation inventory and analysis

The vegetation data were collected from 20x25 sq.m. plots and nested sub-plots. The tree data greater than 10 cm diameters in breast height (DBH) were collected from 20x25 sq.m. plot, 4-9.9 cm DBH from nested sub-plot 10x15

Table 1: Mineralogical composition of rocks in KCF. Qtz=Quartz, Bt=Biotite, Ms=Muscovite, Feld=Feldspar, LF=Lithic fragment, DM=Dark minerals, CM=Cementing materials, UN=Undefined, GM=Ground mass, PM=Pelitic mineral and Cl=Chlorite

Rock types		Mineral % of KCF							
	S. N.	Qtz	Bt	Ms	Feld	LF	DM	CM	UN
Sandstone	1	32	14	13	24	9	2	5	-
	2	34	14	11	25	10	1	4	-
	3	32	14	13	23	9	4	5	-
	4	35	13	14	19	10	3	5	1
	5	40	10	12	20	8	4	5	-
	6	41	9	15	20	7	-	7	-
	7	40	8	14	23	6	-	8	-
	8	35	9	14	22	8	4	8	-
		GM	PM	CM	Un	Cl	Ms	Qtz	LF
Mudstone	1	56	19	11	14	-	-	-	-
	2	35	7	11	5	27	15	-	-
	3	23	11	12	2	30	14	8	-
	4	58	17	10	14	-	-	-	-
	5	34	10	10	7	28	11	-	-
	6	22	9	13		32	12	10	2

sq.m. and 2-3.9 cm DBH from nested subplot 5x5 sq.m. The shrub data were collected from each 5x5 sq.m. nested sub-plot within 15x10 sq.m. sub-plot. The herb data were collected from each 1x1 sq.m. sub-plots within 5x5 sq.m. nested sub-plot. The spatial variation of herb and shrub species was estimated on the basis of presence or absence of species in each nested sub-plots. The forest crown cover or tree canopy cover data were taken as grid pattern from 30 points within 5 m spacing of each established plot. Vegetation types and number of different species were counted and listed. The species richness in this study was estimated according to presence or absence of species. The relationship between mineralogical composition and major soil properties (pH, SOC, N, P, K and colour) and species richness was determined by descriptive statistical analysis. The relationship between species richness and geological units (Figs. 2 and 3) of both the forests were also identified by using descriptive statistical analysis.

RESULTS AND DISCUSSION

Geology of the community forests

Kankali Community Forest (KCF)

The Kankali Community Forest (KCF) (Fig. 2) comprises dominantly the rock of Middle Siwalik, partly the rocks of the Lower Siwalik and Quaternary sediments.

The Quaternary Sediment (GK1) were found topographically in low lying areas, i.e., just at the foot of the hillslope. Quaternary sediments are mainly composed of loose gravel, sand, silt and clay. The unit is characterised by the dominancy of transported soil and few patches of residual soil.

The Upper Member of the Lower Siwalik (GK2) is composed of thin- to medium-bedded, fine- to medium-grained and greenish grey sandstones interbedded with greenish grey to grey mudstones. Sandstone and mudstones are in approximately equal proportions. Mudstones and sandstones are calcareous in nature.

The Lower Member of the Middle Siwalik (GK3) is made up of medium- to thick-bedded, coarse-grained, salt-and-pepper sandstone inter-bedded with grey coloured mudstones. Proportion of sandstone is comparatively less than mudstone.

The Middle Member of the Middle Siwalik (GK4) consists of thick-bedded, coarse-grained sandstones inter-bedding with grey mudstones. Sandstones show salt-and-pepper appearance. Proportion of sandstone is comparatively higher than mudstone.

Tibrikot Community Forest (TCF)

The TCF (Fig. 3) comprises the rocks of the Kunchha Formation of Lower Nawakot Group. The rocks are

Table 2: Mineralogical composition of Tibrikot Community Forest. Qtz=Quartz, Bt=Biotite, Ms=Muscovite, DM=Dark minerals, UN=Undefined, Pl=Plagioclase, Or=Orthoclase, Fe, Mn oxide and Cl=Chlorite.

Rock types	S. N	Minerals % of TCF							
		Cl	Bt and Ms	Pl	Or	Qtz	DM	Opaques	UN
Phyllite	1	28	4	24	15	22	5	-	-
Phyllite	2	18	27	23	9	19	-	3	-
Gritty Phyllite	3	25	7	20	14	30	5	-	-
Gritty Phyllite	4	23	10	17	14	23	4	-	
Quartzite	5	-	14	5	5	74	-	-	1
Quartzite	6	-	20	11	5	62	-	2	-

distinguished into four different lithological units.

Coarse-grained gritty phyllite and quartzite (GT1) unit forms steep cliffs along the Seti River, i.e., eastern border of the TCF. The rocks are alternations of foliated, thickly-banded gritty phyllite and quartzite. Gritty phyllites are coarse-grained and rich in quartz porphyroclasts. Foliation is defined by chlorite and sericite.

Medium-grained gritty phyllite unit (GT2) is exposed juxtaposed to GT1 and forms less steep cliffs. Thick-bedded, medium-grained gritty phyllites are found in this unit. It is comparatively less weathered as compared to GT1. It may be due to scarcity of quartzite beds.

Gritty phyllite and phyllite (GT3) unit shows gentler slope compared to that of GT1 and GT2 and covers major parts of the TCF. The unit has higher weathering characteristics with soil development process.

Slaty phyllite and phyllite (GT4) unit consists mostly slaty phyllite and phyllite. These rocks are susceptible to weathering. It has resulted in deep soil profile. The unit lies in the north-western part of the community forest.

Petrography

Kankali Community Forest (KCF)

The rocks of the KCF contain sandstones and mudstones (Table 1).

Sandstones have varied texture due to different grain sizes. They are fine- to coarse-grained. Sandstones from the Lower Siwalik are fine-grained and greenish grey in colour. Sandstones from the Middle Siwalik are medium- to coarse-grained. Mineralogical composition of sandstones is quartz, biotite, muscovite, feldspar, and lithic fragments. Cementing materials are carbonates or silica.

Mudstones are variegated to grey to greenish grey coloured with fine grain size. It is composed mainly of phyllosilicates with calcareous cement. Pelitic materials are seen as ground mass with some mineral grains. Visible mineral grains are not distinct under microscope.

The rocks of KCF dominantly contain quartz, biotite, muscovite, plagioclase, orthoclase, calcite and chlorite. Weathering rocks is prominent in the forest. From weathering, the chemical element transfer into soil as in residual form. The major chemical elements like K, Mg, Fe, Al, Ca, Cl, Si, C and O transfer from the above minerals (Moorhouse 1985). The sedimentary rocks of KCF were derived from digenesis of deposited sediments. The sources of these sediments are the rocks and soils in the northern belt of the Siwaliks. The presence of quartz and feldspar minerals more than 50% indicate that the residual soils of the forest become acidic in nature.

Tibrikot Community Forest (TCF)

The TCF consists of three different metamorphic rocks namely phyllite, gritty phyllite and quartzite (Table 2).

The rock contains shining foliation surfaces. Flakes of chlorite and mica are parallel to the foliation. Clusters of chlorite flakes are identifiable in the weakly metamorphosed phyllite. Relatively coarse-grained phyllites consist of plagioclase, orthoclase, quartz, biotite and other opaque minerals.

Mineralogical compositions of gritty phyllites are somehow similar to that of the other phyllites. Only difference is having prophyroclasts of quartz. These rocks are less susceptible to physical and chemical disintegration and decomposition hindering the formation of soil. For this reason very thin soil cover is formed in the gritty phyllite terrain. Usually steep cliffs are seen in these rocks.

It consists of predominantly quartz with some mica and plagioclase. Because of the presence of highly resistant minerals in this type of rock, soil cover is absent. The area is topographically steep.

The rocks of TCF contain quartz, biotite, muscovite,

Table 3: Vegetation and soil characteristics of Kankali Community Forest.

	Geological units				
Description	GK1	GK2	GK3	GK4	Total
Species richness					
Trees(>=4 cm DBH)	25	12	17	31	85
Shrubs	13	8	14	17	52
Herbs	77	27	34	55	193
Total	115	47	65	103	330
Shannon-wiener Index					
Trees(>=4 cm DBH)	1.38	0.81	1.58	2.17	
Shrubs	2.19	1.97	2.36	2.41	
Herbs	3.83	3.17	3.31	3.59	
Soil characteristics(average)					Average
Soil PH	4.53	4.85	4.74	4.44	4.64
Soil Organic Matter (SOM in %)	1.23	1.01	1.27	1.62	1.28
Soil Organic Carbon (SOC in %)	0.70	0.58	0.73	0.94	0.74
Soil Nitrogen (N in %)	0.10	0.10	0.09	0.10	0.09
Soil Phosphorus (P in ppm)	2.66	3.13	3.13	2.81	2.93
Soil Potassium (K in ppm)	84.94	109.50	113.13	100.13	101.92
Altitude (Metre)					
Maximum	300	320	450	500	
Minimum	199	230	260	200	
Crown cover (Average %)	39.22	59.97	51.46	46.82	49.37

plagioclase, orthoclase, calcite and chlorite. The rock weathering is prominent in the forest. The soil depth is high in few patches. From weathering, the chemical elements transfer these elements into soil as in residual form. The major chemical elements potassium, magnesium, iron, aluminium, calcium, chlorine, silicon, carbon and oxygen are transfer from mentioned minerals (Moorhc ɔe 1985). The chemical elements are same in both ᵗʰ· ɔmmunity forests. All the metamorphic rocks foun^d in . C. are derived from sedimentary rocks.

Relationship between rocks, ; and vegetation

Kankali Community Forest (KCF)

Vegetation and soil characteristics of the KCF are presented in Table 3. Results show that plant species are not equally distributed; some geological units are richer in species than others. The maximum species richness 115 (tree 25, shrub 13 and herb 77) appears in quaternary sediment i.e. in low lying areas; followed by Middle Member of theMiddle Siwalik, Lower Member of the Middle Siwalik and minimum 47 (tree 12, shrub 8 and herb 27) in Lower Member of the Lower Siwalik just above the quaternary sediment. Thus, there is a gradient on species distribution. The presence of species in forest shows higher species richness in flat land and gentler slope that is due to the accumulation of nutrient element. It shows increasing the slope that result decreasing the species richness.

In addition, the crown cover, altitude and soil properties contribute important role in the variation of spatial species richness. The species richness of tree, shrub and herb is higher at lower crown cover and vice versa along with geological units. The vegetation cover on ground appears more due to the presence of sunlight in comparison to higher crown cover. The crown cover is low in *Dalbergia sissoo* dominated low lying areas and in gentler slope in higher elevation. Table 3 shows the systematic relationship of crown cover with species richness. The average soil pH of all geological units falls on very strongly acidic class (4.5-5.0) because of the predominance of coarse-textured, acid-forming parent materials and the high effective rainfall which selectively removes bases from the soil (Carson 1992). There are no any significant changes in soil pH value according to geological units they fall in same pH class. The pH is more acidic in quaternary sediment and in the Middle Member of the Middle Siwalik due to accumulation of transported materials and less surface run-off activity. The species richness is higher at comparatively low pH in Kankali CF. In general, the species richness shows higher in pH value nearest to the 7 pH (Brady 2000). So the species

Table 4: Vegetation and soil characteristics of Tibrikot Community Forest.

	Geological Units				
Descriptions	GT1	GT2	GT3	GT4	Total
Species richness					
Trees(>=4 cm DBH)	5	11	24	14	54
Shrubs	15	16	23	12	66
Herbs	39	63	65	38	205
Total	59	90	112	64	325
Shannon-wiener Index					
Trees(>=4 cm DBH)	0.92	1.20	1.39	1.54	
Shrubs	2.55	2.54	2.77	2.33	
Herbs	3.49	3.87	3.72	3.41	
Soil characteristics (Averages)					Average
Soil PH	3.98	3.84	3.97	3.96	3.93
Soil Organic Matter (SOM in %)	5.50	4.47	5.24	4.97	5.04
Soil Organic Carbon (SOC in %)	3.18	2.58	3.05	2.87	2.92
Soil Nitrogen (N in %)	0.23	0.20	0.23	0.20	0.21
Soil Phosphorus (P in ppm)	16.83	21.00	16.52	10.00	16.09
Soil Potassium (K in ppm)	111.42	106.40	108.44	84.42	102.66
Altitude (Metre)					
Maximum	1318	1300	1400	1340	
Minimum	1119	1134	1097	1202	
Crown cover (average %)	69.119	55.39	72.868	77.53	68.73

richness in KCF has no significant role in vegetation growth and distribution.

The average nitrogen (N) and phosphorus (P) (ppm) contents in all geological units seem to be low. Soil potassium (K) shows low in quaternary sediments, Lower Siwalik (Upper Member) and Middle Siwalik (Middle Member) but medium rating falls on Middle Siwalik (Lower Member). Generally, the species richness becomes higher in higher value of SOC, N, P and K (Armson 1977). However, the species richness and nitrogen has directly proportional relation, phosphorus and available potassium with species richness has inversely proportional relation along with above mentioned geological units.

The elevation of the forest has no significant role in species richness. However, the species richness seems slightly higher in lower and high altitude in the KCF. Generally, species richness is lower at higher elevation (Bhattarai et al. 2004; Panthi et al. 2007). The elevation of the KCF ranges from 200-500 m. The species richness is slightly higher in high altitude that is due to small elevation range.

The SOC is highest in the Middle Siwalik middle member and the amount decreases successively to the Lower Member of the Middle Siwalik, Quaternary sediments and in the Upper Member of the Lower Siwalik. The SOC is higher in the Middle Member of the Middle Siwalik. It may be due to old/mixed forest with no litter collection, gentle slope and at far distant from local users.

Tibrikot Community Forest (TCF)

Table 4 presents the results of vegetation and soil characteristics of the TCF. It shows that species are not equally distributed; the maximum species richness 112 (tree 24, shrub 23 and herb 65) appears in gritty phyllite and phyllite; followed by medium-grained gritty phyllite, slaty phyllite and phyllite and minimum 59 (tree 5, shrub 15 and herb 39) in coarse-grained gritty phyllite and quartzite. Thus, there is a gradient on species distribution. In addition, the crown cover, altitude and soil properties contribute important role in the variation of spatial species richness. The average soil pH of all geological units falls on extremely acidic class (<4.5). An average organic carbon and nitrogen percentage, and phosphorus (ppm) in all geological units seems medium to high rating. Soil potassium shows low to medium content in all geological units. The species richness does not follow any systematic trend on the basis of crown cover. The species richness is higher in lower and high altitudes. Generally, species richness is lower at higher elevation (Bhattarai et al. 2004). The TCF does not follow the systematic trend that is due to short altitudinal range (1100-1400 m), weathering potential of rocks, slope (low in steep slope) and soil texture.

Species richness seems to have inverse relation to the crown cover percentages. The total species richness accounted trees, shrubs and herbs, lower crown density could have attributed to higher herb and shrub richness. So, for higher crown cover, the ground vegetation was less likely to grow and, therefore, lower species richness was observed. The higher crown cover density was found in GT4, which was found to have more acidic soil. However, the direct relationship between soil acidity and the species richness could not be established with geological units. This shows there is considerable association between these two factors in vegetation study. The crown cover is higher in GT4 geological unit but lower the species richness except in tree. The crown cover is higher in GT2 geological unit, however showed the lower level of the species richness. Species richness and soil pH has approximately inversely proportional relationship along with geological units. The pH value is lowest in GT2 geological unit but higher the species richness. Geological units GT1, GT3 and Gt4 have higher pH value that results lowest, highest and second higher species richness, respectively.

The value of SOC in TCF did not show significant change. The SOC is slightly lower in GT2 geological unit, although the species richness is higher. The SOC is very slightly higher in GT1 geological unit but the species richness is low. From this result, SOC has no significant relationship with species richness.The species richness is higher when the nitrogen, phosphorus and available potassium level is approximately high (i.e., species richness and these factors has about directly proportional relation) along with geological units. The species richness is higher in geological units GT2 and GT3 with higher nitrogen (N), phosphorus (P) and potassium (K). The nutrient status (the value of NPK) is lower in GT4 geological unit. As a result, species richness is also lower. The species richness is lower in GT1 geological unit but with higher nutrient status that is due to the very few tree species and low moisture content. The research shows that the species richness is low in tree, middle in shrub and high in herb.

CONCLUSIONS

The mapping of Kankali Community Forest (KCF) shows four distinct geological units namely Quaternary sediment (GK1), Upper Member of the Lower Siwalik (GK2), Lower Member of the Middle Siwalik (GK3) and the Middle Member of the Middle Siwalik (GK4) on the basis of sediment content, grain size of rocks and soils, bedding thickness, sandstone and mudstone proportion, colour, cementing materials, presence of micaceous minerals and groundmass. The Tibrikot Community Forest (TCF) also contains four geological units namely coarse-grained gritty phyllite and quartzite (GT1), medium-grained gritty phyllite (GT2), gritty phyllite and phyllite (GT3) and slaty phyllite and phyllite (GT4) based on composition of rocks, proportion of rocks, hardness of minerals on rocks (weathering) and orientation of mineral grains.

Petrographically, KCF contains sandstone and mudstone with mineral composition quartz, biotite, muscovite, feldspar, lithic fragment, dark mineral and cementing materials. Similarly, the TCF contains phyllite, gritty phyllite and quartzite rocks on the basis of mineral composition as micaceous and feldsparminerals, quartz, dark minerals and Fe, Mn oxide.

The species richness in KCF is maximum 115 (tree 25, shrub 13 and herb 77) that appears in Quaternary sediments, i.e., in low lying areas; followed by the Middle Member of the Middle Siwalik, Lower Member of the Middle Siwalik and minimum 47 (tree 12, shrub 8 and herb 27) in the Lower Member of the Lower Siwalik. The maximum species richness 112 (tree 24, shrub 23 and herb 65) in TCF appears in gritty phyllite and phyllite; followed by medium-grained gritty phyllite, slaty phyllite and phyllite and minimum 59 (tree 5, shrub 15 and herb 39) in coarse-grained gritty phyllite and in quartzite. In total, the species richness is slightly higher in TCF than in KCF. The tree species are higher in KCF than in the TCF that could be due to the high regeneration potential in lower land inner Tarai regions of Nepal. The shrub and herb species is higher in TCF than in KCF which may be because of higher rainfall and lower crown density. In summary, the study not only indicates the effects of slope, elevation and crown cover but also provides the consistent evidence of rocks and soil nutrients in shaping the vegetation pattern, their growth and distribution.

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REFERENCES

Armson, K. A., 1977, *Forest Soils: Properties and Processes*, University of Toronto press, Toronto and Buffalo, 390p.

Bhattarai K. R., Vetaas O. R. and Grytnes, J. A., 2004, Fern species richness along a central Himalayan elevationalgradient. Nepal J. Biogeogr, v. 31, pp. 389–400.

Brady, N. C., 2000, *The nature and properties of soils*, Tenth edition, Prentice' hall of India Private limited, New Delhi, 621p.

Carson, B., Shah, P. B. and Maharjan, P. L., 1986, Land system report: The soil landscapes of Nepal. Land resource mapping project, Kenting Earth Sciences Limited, Kathmandu, Nepal, pp. 1-140.

Carson, B., 1992, *The land, the farmer and the future*: A *soil fertility management strategy for Nepal*, Occasional paper No. 21, ICIMOD, Kathmandu, Nepal.

ComForM., 2006, ComForM research manual, Institute of Forestry, Pokhara, Nepal, draft version.

DOF, 2012, Community Forestry User Groups (CFUGs) database record, 2012 Department of Forest, Community Forestry Division, Kathmandu, Nepal.

HMG,1993, *Forest act 1993: Official translation*, His Majesty's Government of Nepal, Government Press, Kathmandu, 22p.

HMG, 1995, Forest regulations: Official translation, His Majesty's Government of Nepal, Government Press, Kathmandu, 24p.

Moorhouse, W. W., 1985, *The study of rocks in thin sections*, CBS publishers and distributors, 485, Jain Bhawan, BholaNath Nagar Shahdara, Delhi-110032, India, 514p.

Panthi, M. P., Chaudhary, R. P. and Vetaas, O. R., 2007, Plant species richness and composition in a trans-Himalayan inner valley of Manang district, central Nepal, Himalayan Journal of Sciences, v. 4, Issue 6, pp. 57-64.

Tucker, M. E., 1988, *Sedimentary Petrology: an Introduction*, ELBS first edition, Osney mead, Oxford, 260p.

Upreti, B. N., 1999a, An overview of the stratigraphy and tectonics of the Nepal Himalaya. Journal of Asian Earth Sciences, 17, pp. 577-606.

Upreti, B. N., 1999b, The Physiography and Geology of Nepal and their bearing on the landslide problem. In: *Landslide hazard mitigation in the Hindu-Kush Himalayas*, Tinachie, L., Chalise, S. R. and Upreti, B. N., (eds.), ICIMOD, Kathmandu, Nepal, pp. 31-49.