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# Status of soil nutrients and its relation with rock types and soil properties in the Kankali (Chitwan) and Tibrekot (Kaski) Community Forests, western Nepal

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## ABSTRACT

This study was conducted in Kankali (Chitwan) and Tibrekot (Kaski) Community Forests to explore the status of soil nutrients and its relation with rock types and physical and chemical properties of soils. The soil sample data collected from the community forests were analyzed for soil texture, soil pH, soil organic matter (SOM), N, P, K, Zn and boron using reliable equipment and standard methods. The data are interpreted by applying descriptive statistics. The inter-relationship between soil nutrients is presented at 99% and 95% confidence levels. N, P, Zn and B show direct and indirect relation with soil texture. K, Zn and B show both positive and negative correlation with soil pH. SOM also show direct and indirect relation with NPK and Zn. The relations of soil texture, SOM, soil pH, N, P, K, Zn and B with rocks are interpreted using nutrient element content in minerals of studied rocks. This paper presents clear and consistent evidences of the role of soil nutrients in shaping the vegetation growth pattern and their distribution in the middle Mountain and Siwalik physiographic regions of Nepal.

**Key words**: Nutrient, soil rating, correlation, middle Mountain, Siwalik

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## INTRODUCTION

The weathering of the rocks have great role in formation of soil. The physical and chemical 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. The rocks of Kankali Community Forest (KCF) mainly contain quartz, biotite, muscovite, clay mineral, chlorite and feldspars. The Tibrekot Community Forest (TCF) is dominated by chlorite, quartz, plagioclase, orthoclase, biotite and muscovite minerals (Sharma and Chhetri 2012). The minerals of both the forests plays greater role in availability of nutrient elements in soils. The rating of different soil properties and nutrient elements reflect the fertility status of studied forests.

In each of the tectonic zones of Nepal, significant number of forest patches are handed over to users organized 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 covering around 30% of the Nepalese forest area (1.2 Mha) (DOF 2012) vary according to the variation in rocks and soil. 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).

Despite several studies related to soils, minerals, rocks and vegetations, the studies focusing particularly in identifying the relationships between rocks and soils parameters (physical, chemical and nutrient elements) 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 nutrient elements. The research is aimed to make the comparison of soil parameters in relation to parent materials for better management of forests. The study is carried out to understand the role of rocks on 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 and forestry related professionals for the better management of their forest patches.

## STUDY AREA

The (KCF) of Chitwan and (TCF) of Kaski District were selected for the study. The KCF lies in the Siwalik zone (Lower and Middle Siwaliks) and the TCF lies in the Lesser Himalaya (Kunchha Formation) (Fig. 1).

The KCF contains dominantly Shorea robusta with Dalbergia sissoo and other species. The ten years average climatic data nearby the KCF was taken from the nearest meteorological station, Rampur, Chitwan. An average annual maximum and minimum temperature were 31°C and 18°C, respectively. The average relative humidity and average annual rainfall of the area were recorded as 78% and 190 mm, respectively.

The TCF 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 meteorological station at Pokhara shows an average annual maximum and minimum as 27°C and 16°C, respectively. Similarly, average annual rainfall and average relative humidity were recorded as 345 mm and 74%.

## MATERIALS AND METHODS

### 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 m$^2$ (ComForM 2006) with soil sampling locations and forest strata (Fig. 2). Soil samples were taken from each plot from two layers: A (0-15 cm) and B (15 to 30 cm). Samples were taken from four corners and middle part of

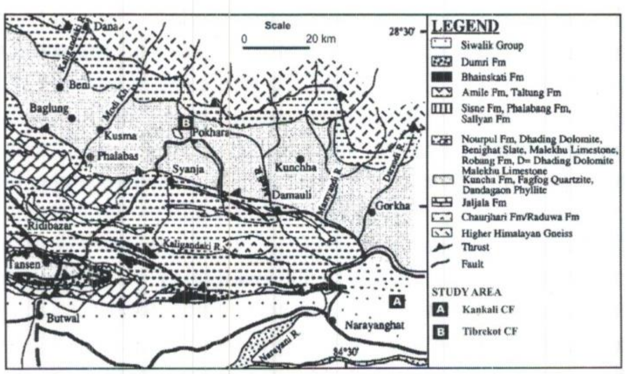


**Fig. 1: Regional geological map showing the locations of study area (Redrawn after Upreti 1999).**

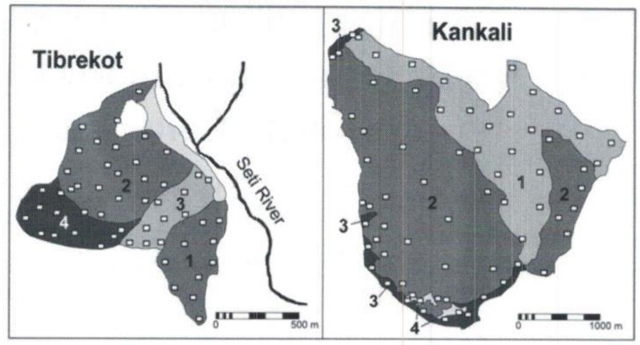


**Fig. 2: Soil sampling points of studied CFs with forest strata. Source: ComForM project, Institute of Forestry, Tribhuvan University, Pokhara, Nepal. Open squares in the map indicate soil sampling points and 1, 2, 3 and 4 indicate forest strata.**

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 parts of both the forests as ancillary data and information for geological unit delineation and rock unit variation. A total of 230 samples were taken for soil analysis. The prepared soil samples were analyzed by using the following instruments and standard methods:

1. Soil pH using digital pH meter (Jackson 1973),
2. (Soil organic matter using modified Black and Walkley method (Walkley 1947),
2. N using Kjeldahl method (Hoskin 1997),
3. P using Flame Photometer, (Hoskin 1997),
4. K using Spectrophotometer (Jackson (1973),
5. Soil texture using Hydrometer (Hoskin 1997),
6. Boron using Colorimeter method (Hoskin 1997) and
7. Zn using DPTA (Hoskin 1997).

The soil rating is based on Department of Soil, Lumle Agriculture Centre, Kaski, Nepal and soil testing handbook (Hoskin 1997).The soil texture was determined mainly depending on rock hardness and climatic condition. Minerals content in percentage of each rock types of both the CFs (Sharma and Chhetri 2012) was analyzed by using chemical formula of mineral in this study also.

## RESULT AND DISCUSSION

### Soil rating

The texture of KCF is dominated by silty loam and silty clay loam while in TCF by silty loam and sandy loam. The higher percentages of sand and silt grains were resulted from quartz -dominated rocks especially by the presence of gritty phyllite, schist and sandstone (Brady 2000) in TCF and KCF, respectively. Parametric T-test shows directly proportional relationship between soil pH and texture at 99% confidence level at KCF and high degree of positive correlation at TCF in A layer (Tables 2 and 3). Soil texture has indirect proportional relationship with N and direct proportional relationship with boron at 95% confidence level in A layer at KCF (Table 2). The soil texture at TCF has positive correlation with organic matter, negative correlation with P and high degree of negative correlation with Zn at 99% confidence level in A layer (Table 3) and negative correlation with P at 0.05 significant level and negative correlation with Zn and boron (Tables 3 and 5) at 0.01 significant levels in B layer.

Soil pH of both CF falls in extremely, very strongly, strongly acidic classes due to the presence of silicate containing acidic rocks. Acidity of soil has direct relation with infiltration and percolation of rainwater. The acidity is higher in TCF in comparison to KCF due to higher rainfall in that CF. Acidity of soil decreases due to the addition of organic matter (Brady 2000; Armson 1977). The soil pH has direct proportional relationship with P and boron (99% confidence level) in A layer and with PP (95% confidence level) in B layer of KCF (Tables 2 and 4). The soil pH of TCF has indirect proportional relationship with Zn in A layer and with P, Zn and boron in B layer at 99% confidence level (Tables 3 and 5).

**Table 1: Soil rating of KCF and TCF.**

| S.N | Soil properties | Soil rating | KCF (Percentage) | | TCF (Percentage) | |
|---|---|---|---|---|---|---|
| | | | Layer A | Layer B | Layer A | Layer B |
| 1 | Soil pH (No) | Extremely Acidic (< 4.5) | 38 | 60 | 92 | 94 |
| | | Very Strongly Acidic (4.5-5) | 42 | 31 | 6 | 6 |
| | | Strongly Acidic (5.1-5.5) | 20 | 25 | 2 | 0 |
| 2 | SOM (%) | Low (< 2.5) | 86 | 100 | 0 | 2 |
| | | Medium (2.5-5) | 12 | 0 | 25 | 62 |
| | | High (>5.0) | 2 | 0 | 75 | 36 |
| 3 | N (ppm) | Low (< 0.1) | 36 | 77 | 0 | 0 |
| | | Medium (0.1-0.2) | 61 | 23 | 23 | 60 |
| | | High (>0.2) | 3 | 0 | 77 | 40 |
| 4 | P (ppm) | Low (< 5) | 81 | 94 | 10 | 10 |
| | | Medium (5-15) | 16 | 3 | 52 | 65 |
| | | High (>15) | 3 | 3 | 38 | 25 |
| 5 | K (meq/100g) | Low (< 110) | 56 | 84 | 50 | 79 |
| | | Medium (110-280) | 44 | 16 | 48 | 21 |
| | | High (> 280) | 0 | 0 | 2 | 0 |
| 6 | Boron (ppm) | Low (< 0.5) | 100 | 98 | 98 | 98 |
| | | Medium (0.5-1) | 0 | 2 | 2 | 2 |
| | | High (> 1) | 0 | 0 | 0 | 0 |
| 6 | Zn (ppm) | Low (< 1) | 100 | 100 | 81 | 98 |
| | | Medium (1-1.5) | 0 | 0 | 19 | 2 |
| | | High (> 1.5) | 0 | 0 | 0 | 0 |
| 7 | Texture (%) | Silty Loam | 77 | 64 | 85 | 96 |
| | | Silty Clay loam | 16 | 26 | 0 | 0 |
| | | Silty Clay | 2 | 5 | 0 | 0 |
| | | Loam | 2 | 2 | 0 | 0 |
| | | Sandy Loam | 3 | 3 | 15 | 4 |

**Table 2: Correlations among the different parameters of A layer soil at Kankali Community Forest. Tex.: Texture, Corr.: Correlation Coefficient, Sig.: Significance Level.**

| Parameters | Test | Tex. | pH | SOM | N | P | K | Zn | B |
|---|---|---|---|---|---|---|---|---|---|
| Tex. | Corr. | 1 | 0.398(**) | -0.037 | -0.278(*) | 0.003 | 0.099 | -0.235 | 0.315(*) |
| | Sig. | | 0.001 | 0.771 | 0.026 | 0.979 | 0.435 | 0.061 | 0.011 |
| pH | Corr. | | 1 | -0.022 | -0.080 | -0.085 | 0.480(**) | -0.088 | 0.446(**) |
| | Sig. | | | 0.860 | 0.531 | 0.505 | 0.000 | 0.490 | 0.000 |
| SOM | Corr. | | | 1 | 0.409(**) | 0.714(**) | 0.235 | 0.137 | -0.086 |
| | Sig. | | | | 0.001 | 0.000 | 0.062 | 0.279 | 0.498 |
| N | Corr. | | | | 1 | 0.188 | 0.088 | 0.056 | -0.234 |
| | Sig. | | | | | 0.137 | 0.489 | 0.659 | 0.062 |
| P | Corr. | | | | | 1 | 0.158 | 0.115 | 0.125 |
| | Sig. | | | | | | 0.214 | 0.365 | 0.323 |
| K | Corr. | | | | | | 1 | 0.225 | 0.299(*) |
| | Sig. | | | | | | | 0.074 | 0.016 |
| Zn | Corr. | | | | | | | 1 | 0.404(**) |
| | Sig. | | | | | | | | 0.001 |

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

**Table 3: Correlations among the different parameters of A layer soil at Tibrikot Community Forest. Tex.: Texture, Corr.: Correlation Coefficient, Sig.: Significance Level.**

| Parameters | Test | Tex. | pH | SOM | N | P | K | Zn | B |
|---|---|---|---|---|---|---|---|---|---|
| Tex. | Corr. | 1 | 0.711(**) | 0.359(**) | 0.074 | -0.441(**) | -0.071 | -0.704(**) | 0.193 |
| | Sig. | | 0.000 | 0.009 | 0.604 | 0.001 | 0.617 | 0.000 | 0.170 |
| pH | Corr. | | 1 | 0.039 | -0.123 | -0.261 | -0.112 | -0.591(**) | 0.097 |
| | Sig. | | | 0.783 | 0.384 | 0.062 | 0.429 | 0.000 | 0.493 |
| SOM | Corr. | | | 1 | 0.654(**) | -0.181 | 0.455(**) | -0.128 | 0.272 |
| | Sig. | | | | 0.000 | 0.199 | 0.001 | 0.364 | 0.051 |
| N | Corr. | | | | 1 | 0.074 | 0.675(**) | 0.182 | 0.385(**) |
| | Sig. | | | | | 0.604 | 0.000 | 0.196 | 0.005 |
| P | Corr. | | | | | 1 | 0.232 | 0.394(**) | 0.045 |
| | Sig. | | | | | | 0.097 | 0.004 | 0.754 |
| K | Corr. | | | | | | 1 | 0.296(*) | 0.261 |
| | Sig. | | | | | | | 0.033 | 0.062 |
| Zn | Corr. | | | | | | | 1 | 0.214 |
| | Sig. | | | | | | | | 0.128 |

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

Soil Organic Matter (SOM) is very low at KCF and medium to high at TCF. The SOM in A layer is slightly higher than in B layer in both the CFs. SOM depends largely on leaf litter and dead wood in forests with suitable decaying process. SOM increases soil fertility of the forests. It plays role in weathering of rocks and ultimately results soil for vegetation growth (Brady 2000). The SOM at KCF has positive correlation with N and high degree of positive correlation with P at 99% confidence level in A layer and positive correlation with P (95% confidence level) and with Zn (99% confidence level) in B layer (Table 2 and 4). The SOM of TCF shows positive correlation with N and K at

**Table 4: Correlations among the different parameters of B layer soil at Kankali Community Forest. Tex.: Texture, Corr.: Correlation Coefficient, Sig.: Significance Level.**

| Parameter | Test | Tex. | pH | SOM | N | P | K | Zn | B |
|---|---|---|---|---|---|---|---|---|---|
| Tex. | Corr. | 1 | 0.440(**) | 0.064 | -0.078 | -0.130 | 0.059 | -0.149 | -0.200 |
| | Sig. | | 0.000 | 0.616 | 0.540 | 0.306 | 0.641 | 0.241 | 0.113 |
| pH | Corr. | | 1 | -0.236 | -0.007 | -0.119 | 0.275(*) | -0.244 | -0.221 |
| | Sig. | | | 0.060 | 0.956 | 0.347 | 0.028 | 0.052 | 0.079 |
| SOM | Corr. | | | 1 | 0.051 | 0.250(*) | -0.101 | 0.340(**) | 0.237 |
| | Sig. | | | | 0.686 | 0.046 | 0.429 | 0.006 | 0.059 |
| N | Corr. | | | | 1 | 0.241 | 0.156 | 0.171 | 0.065 |
| | Sig. | | | | | 0.055 | 0.218 | 0.176 | 0.610 |
| P | Corr. | | | | | 1 | 0.218 | -0.064 | 0.003 |
| | Sig. | | | | | | 0.084 | 0.615 | 0.981 |
| K | Corr. | | | | | | 1 | -0.218 | -0.017 |
| | Sig. | | | | | | | 0.083 | 0.892 |
| Zn | Corr. | | | | | | | 1 | 0.546(**) |
| | Sig. | | | | | | | | 0.000 |

(**) Correlation is significant at the 0.01 level (2-tailed), (*) Correlation is significant at the 0.05 level (2-tailed) and (a) cannot be computed because at least one of the variables is constant.

**Table 5: Correlations among the different parameters of B layer soil at Tibrekot Community Forest. Tex.: Texture, Corr.: Correlation Coefficient, Sig.: Significance Level.**

| Parameters | Test | Tex. | pH | SOM | N | P | K | Zn | B |
|---|---|---|---|---|---|---|---|---|---|
| Tex. | Corr. | 1 | 0.289(*) | 0.163 | 0.137 | -0.307(*) | -0.014 | -0.391(**) | -0.375(**) |
| | Sig. | | 0.037 | 0.248 | 0.331 | 0.027 | 0.924 | 0.004 | 0.006 |
| pH | Corr. | | 1 | 0.012 | -0.099 | -0.369(**) | -0.047 | -0.648(**) | -0.602(**) |
| | Sig. | | | 0.934 | 0.484 | 0.007 | 0.743 | 0.000 | 0.000 |
| SOM | Corr. | | | 1 | 0.316(*) | -0.275(*) | 0.253 | -0.034 | 0.138 |
| | Sig. | | | | 0.023 | 0.048 | 0.070 | 0.813 | 0.329 |
| N | Corr. | | | | 1 | 0.034 | 0.539(**) | 0.220 | 0.245 |
| | Sig. | | | | | 0.812 | 0.000 | 0.118 | 0.080 |
| P | Corr. | | | | | 1 | 0.237 | 0.521(**) | 0.307(*) |
| | Sig. | | | | | | 0.091 | 0.000 | 0.027 |
| K | Corr. | | | | | | 1 | 0.219 | 0.201 |
| | Sig. | | | | | | | 0.119 | 0.152 |
| Zn | Corr. | | | | | | | 1 | 0.663(**) |
| | Sig. | | | | | | | | 0.000 |

(**) Correlation is significant at the 0.01 level (2-tailed), (*) Correlation is significant at the 0.05 level (2-tailed) and (a) Cannot be computed because at least one of the variables is constant.

99% confidence level in A layer (Table 3). It shows direct proportional relationship with N and indirect proportional relationship with P at 95% confidence levels in B layer (Table 5).

The rating of N falls low to medium at KCF and medium to high at TCF (Table 1). The N level is higher in TCF in comparison to KCF due to containing phyllite which is fine grained and higher grade of weathering ability with addition of more organic matter. N at TCF has direct proportional relationship with K in A and B layers and with Boron in A layer at 99% confidence level (Tables 3 and 5). KCF has no significant relations due to lower N level in both the layers.

The rating of P reveals that it is low at KCF and medium to high in TCF (Table 1). P in soil increases with grain size reduction, higher degree of weathering and addition of organic matter (Wedepohl 1978). P in TCF shows direct positive relation with Zn in both the layer at 99% confidence level and with Boron in B layer at 95% confidence level.

The rating of K falls to low to medium classes in both the layers (Table 1). It is slightly higher in B layer. K content in TCF is also slightly higher in comparison with KCF. It is positively correlated with Zn in B layer in TCF only. Phyllite has higher degree of weathering ability with considerable amount of potash feldspar and micaceous minerals (Johnston 2002).

Boron and Zn seem to be almost low in both the CFs (Table 1). Some samples of TCF fall in medium rating of soil nutrient. Most of the soil of Nepal shows low rating (boron and Zn) due to the lack of nutrient elements in rocks (Carson et. al 1986; Carson 1992). Zn is positively correlated with boron in A and B layers of KCF and B layer of TCF at 99% confidence level.

## CONCLUSION

The study was concentrated on soil nutrients and its relation with rocks and physical and chemical properties of soils. Soil texture has positive and negative correlation with N, P, Zn and Boron. The soil pH has positive correlation with K, boron and Zn at different confidence levels. SOM has positive relation with NPK and Zn at 99% and 95% confidence level. The NPK, Zn and Boron have considerable relationship with rock types and physical and chemical properties of soil. The rocks and soils have direct relationship to enhance nutrient availability for vegetation growth in community managed forests.

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