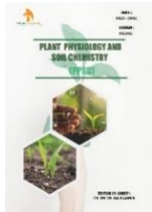
ZIBELINE INTERNATIONAL™ PUBLISHING

Plant Physiology and Soil Chemistry (PPSC)

DOI: http://doi.org/10.26480/ppsc.02.2022.82.96

ISSN: 2805-5063 (Online)
CODEN: PPSCCU



CrossMark

RESEARCH ARTICLE

ANALYTICAL STUDY ON SOIL FERTILITY STATUS ALONG WITH ELEVATION GRADIENT AND DEPTH OF CHITWAN–MUSTANG TRACK, NEPAL

Vishwas Regmi[a*], Sanket Kattel[a], Shalin Subedi[a], Swostika Dhungana[a], Suraj Gosai[a], Babita Dhungana[a], Aakash Adhikari[b]

[a]Nepal Polytechnic Institute, Bharatpur, Chitwan, Nepal
[b]Himalayan College of Agricultural Sciences and Technology, Kirtipur, Kathmandu
**** Correspondence author: vishwasregmi19@gmail.com***

ARTICLE DETAILS

Article History:

Received 24 June 2022
Accepted 26 July 2022
Available online 29 July 2022

ABSTRACT

The distribution of soil properties under different elevations and soil depths was evaluated by taking soil samples from peripheral agricultural land of Chitwan to the Mustang roadway track with the integrated use of the Geographical Information System (GIS). Soil organic matter (SOM), total nitrogen (N), available phosphorous (P_2O_5), available potassium (K_2O), and soil ph. were determined on 10 samples each from 0-15 cm and 15-30 cm soil depths of each categorical elevation (194-604 masl, 604-1399 masl, 1300-2846 masl) were analyzed (Total 60 samples). The highest SOM (4.21%) was recorded at surface soil (0-15 cm) of elevation 1300-2846 masl. The highest total nitrogen (0.245%) was also found at the surface layer of elevation 1300-2846 masl. Phosphorous and Potassium were highest at the surface layer of elevation 1300-2846 masl. The available nutrients Nitrogen, Phosphorous, and Potassium were medium in range and decrease with the increase in depth, which might be due to in-situ in a corporation of leaf litters, residue, etc. as well as applied manure on the surface. In general, the study result revealed altitude did not impose any significant effect in aggravating soil reaction and phosphorous. Whereas soil depth affected significantly not only ph. but also SOM and available potassium. Thus, the study concludes the increasing trend of primary nutrients with increasing elevation and decreases with increasing depth.

KEYWORDS

Soil, Geographical Information System, Soil elevation, Soil depths, Soil Parameters

1. INTRODUCTION

Nepal has been a major agricultural country and 66% of the population depends on agriculture and affiliated livelihoods (MOAD, 2015). In order to remain safe and improve the production and production of food and vegetable crops, the Government of Nepal has created Pockets, Blocks, Zone, and Super Zone for certain plants depending on the suitability of the plants according to the agro-ecological and soil conditions. Green mountains cover major land areas (41.68%) in the country allowing higher population density and more pressure on the vulnerable mountain land resources. Tropical flat land of terai and Siwalik occupy 23.12% of the land area and serve as the breadbasket of the country (MOAC, 2010). 27% of the total land of Nepal is agricultural land, 39.6% is forest land, 12% is grassland, 2.6% is water, and 17.2% is snow land and rock (DOA, 2069).

Mustang is particularly declared as the pocket area for Apple production. People of mustang as a livelihood, involve in farming buckwheat, necked barley (Uwa), Finger millet, rapeseed. Myagdi is known among the top citrus producers while Parbat, Kaski Tanahun, and Chitwan are famous for their vegetable production. Soil is important for sustainable agriculture with significant effects on food security and quality of life and increased agricultural production in this area will require extensive knowledge of the soil, its quality and fertility status (Dumanski and Pieri, 2000; Mulumba and Lal, 2008). Soil fertility is the backbone on which all high-level agricultural production systems can be built (Al-Zubaidi et al., 2008; Robert, 2013).

Topography as the main feature of the area is one of the most suitable for building the soil. Therefore, geomorphometric variations have been used successfully in many studies to predict soil characteristics, soil classes and soil composition (Behrens et al., 2014; Huggett, 1975; Pennock et al., 1987). With regard to soil chemical properties had a negative impact on the slope angle in the soil of organic carbon (SOC), nitrogen (N) and the pH of the topsoil of Chalk soils in Berkshire and Wiltshire Downs in the south of England (Anderson and Furley, 1975; Gao et al., 2015; Wu et al., 2013). It was discovered in the Gutianshan National Nature Reserve that the height of the study areas, SOC, soil moisture and the total phosphorus content of the topsoil were important factors that formed the mold community and soil pH were strongly associated with microbial biomass, he height and pH of the soil are important factors influencing this positive relationship on both the northern and southern islands (Wu et al., 2012). Despite the fact that soil nutrients are very important for plant biomass, their impact on surface biomass and plant richness will be weak and meaningless (Bhandari et al., 2019). Terrain markers make important predictions of soil fertility and tree growth in environmental research. The variability of soil fertility is explained by local characteristics and that tree growth is positively influenced by soil fertility, as well as by local characteristics (Scholten et al., 2017).

Assessing soil fertility status necessitates soil testing for specific areas. Soil testing is an important diagnostic tool for quick determination of the nutrient status of soil to make fertilizer recommendations in the soil for apple production as in other crops and to make a recommendation of soil amendments in problematic soils in most cases. It has an advantage over the other methods of estimating the soil fertility status because of its rapidity to measure the number of nutrient elements that are extractable from the soil. Fertility analysis of soil was done to assess pH, organic matter, available phosphorus, total nitrogen, and available potassium along different elevation gradients also, to analyze the influence of elevation and depth aspects on soil fertility.

Quick Response Code	Access this article online	
	Website: www.ppsc.org.my	**DOI:** 10.26480/ppsc.02.2022.88.96

Cite The Article: Vishwas Regmi, Sanket Kattel, Shalin Subedi, Swostika Dhungana, Suraj Gosai, Babita Dhungana, Aakash Adhikari (2022). Analytical Study on Soil Fertility Status Along With Elevation Gradient and Depth of Chitwan–Mustang Track, Nepal. American Beauty. *Plant Physiology and Soil Chemistry, 2(2):* 88-96.

2. Materials and Methods

2.1 Description of Study Area

Chitwan to Mustang roadway track was selected for the study as it is a more conventional track to find higher variation in altitude. The area of study belongs to various sites of six districts (Mustang, Myagdi, Parbat, Kaski, Tanahun, and Chitwan) at various altitudes. The study sites are located in 27.6863° - 28.8151 ° East latitude and 83.6455 ° – 84.4455 ° North Longitude. The altitude ranges from 194 – 2856 masl.

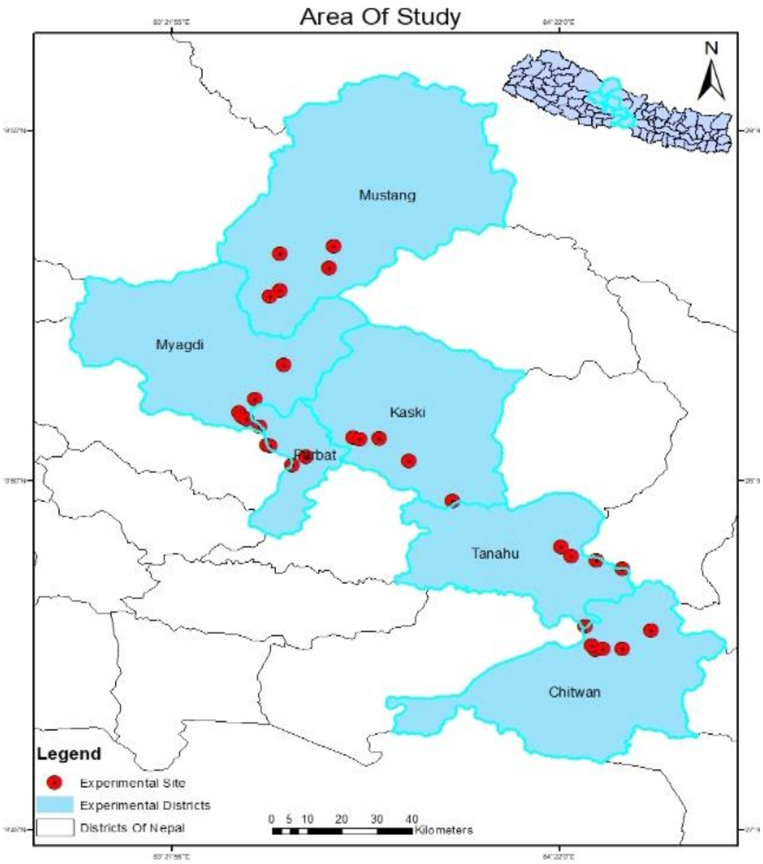


Figure 1: Area of study

2.2 Soil Sample Collection and Preparation

Five places of varying altitudes from each study district were chosen. In total, 60 samples from 30 (6×5) place each with 2 depths, 0-15 cm and 15-30 cm were collected from the agricultural field peripheral to the track in December 2020. The composite samples were taken by using a Z-shaped Technique from each land with the help of a sampling auger and collected in a plastic bag with proper coding. Samples selected from different elevations and locations of the sampling sites were recorded by GPS (global positioning system) coordinated in the center. The samples were brought to the soil lab of Nepal Polytechnic Institute, Bhojad. Each sample was let air-dry. Air-dried samples were ground and sieved through a 2.0 mm sieve and stored for analysis. Some samples were sieved through a 0.2 mm sieve for SOM analysis.

Table 1: Description of Factor A (Elevation)

Treatments	Elevation	Description of Treatment
T_1	174-604masl	This region mainly lies in the inner Terai. The major crop of this region is rice, maize, finger millet, potatoes, and fruits like citrus banana, mango, pomegranate, and vegetables. The use of inorganic fertilizers is seen as prominent in this region.
T_2	604-1300masl	The dominant crops are maize, potatoes, cereals, finger millet, turmeric, ginger, chilies. Fruits like citrus, pear, peach, banana, guava, and vegetables. Farmers use FYM, poultry manure, and goat manure.
T_3	1300-2846masl	This region lies from mid-hill to high hill. Major crops of this region are apple, plum, buckwheat, necked barley (Uwa), Finger millet, and rapeseed. Livestock rearing such as goat, buffalo, yak, sheep, and chyangra is common in the household. FYM, goat manure, poultry manure, Urea, DAP are the fertilizer input. Farming mostly depends on rainwater.

Table 2: Description of Factor B (Depth)

Treatments	Depths	Description of Treatment
D1	0-15 cm	This layer consists of both organic matter and other decomposed materials. The topsoil is soft and porous to hold enough air and water
D2	15-30 cm	It is comparatively harder and more compact than topsoil. It contains less humus, soluble minerals, and organic matter.

Table 3: Laboratory analysis technique for different soil chemical properties

Parameters	Analysis Methods
Soil pH	pH meter method
Organic matter content	(Walkley-Black method, 1934)
Total nitrogen	Kjeldahl distillation (Bremner, 1965)
Available phosphorus	Modified Olsen bicarbonate method (Whatnable and Olsen, 1965)
Available potassium	Ammonium Acetate Extraction Method (Pratt, 1965)

2.3 Statistical Analysis and Interpretation of Results

NPK and pH data obtained from laboratory analysis were rated according to the standard rating of NARC, Soil Science Division, Khumaltar, Lalitpur. The soil data were analyzed using analytical tools 'R' and 'GenStat'. The analyzed data were then placed to Ms. Word and Ms. Excel 2019.

Table 4: Rating Chart for classification of soil fertility status of soils

Nutrient Status	Soil Organic Matter (%)	Total N (%)	Available P2O5 (kg ha $^{-1}$)	Available K2O (kg ha $^{-1}$)
Very low	<1.0	<0.05	<10	<55
Low	1.0-2.5	0.05-0.1	10-30	55-110
Medium	2.5-5.0	0.1-0.2	30-55	110-280
High	5.0-10.0	0.2-0.4	55-110	280-500
Very high	>10.0	>0.4	>110	>550

Source: Soil Science Division, Khumaltar, Lalitpur, Nepal

Table 5: Rating chart for soil reaction rating of soils

Soil pH Value	Soil Reaction Rating
<6	Acidic
6.0-7.5	Neutral
>7.5	High

2.4 Methodology of GIS Map Preparations

Coordinates (Latitude/Longitude) and elevation for study points were obtained by using the 'Handy GPS' application. GPS in Degree-minute format. Thus, obtained coordinates were brought in MS- Excel sheet and converted to decimal degrease for the case application. The converted coordinates were fetched into ESRI ArcGIS 10.3.1 in tabular form. The tabulated data were displayed through add XY data, where longitude was input as X, Latitude as Y, and elevation as Z. The displayed data were then exported to a shapefile and overlaid on a base map Shapefile for a base map of Nepal and Local units were added from ArcGIS online. A spatial analytical tool was then used for analysis and forming a map.

3. Result and Discussion

3.1 Descriptive Statistics Related to Soil Parameters

3.1.1 Organic Matter

Soil organic matter (SOM) is the heart of the soil, and it plays a vital role in crop performance and maintaining soil health. It is the dynamic property of soil that has a direct influence on different soil properties like bulk density, water holding capacity, and most important is the nutrient supplying capacity of soils to crop. Despite affecting the soil properties and overall crop productivity SOM itself is affected by the change in altitude and soil depths

3.1.2 Organic matter status under different elevation

It was observed that higher elevation soil was superior to lower elevation in terms of SOM irrespective of the differences in soil depths. The soil organic matter percentage of T1 (194-604m) soil ranged from 0.53% - to 4.65% with an average of 1.96%. The organic matter percentage of second category soil, T2 (604 – 1300m) ranged from 0.82% -6.54% with an average of 2.15%. Also, the soil of T3 (1300 – 2846m) was ranged from 0.63% - 7.16% in SOM content with an average of 3.31%.

Table 6: Frequency of organic matter content in different elevation

	Soil Organic Matter/Nutrient category*				
Elevation (masl)	Very Low	Low	Medium	High	Very High
194-604	2 (10)	4 (20)	12 (60)	2 (10)	0 (0)
604-1300	1 (5)	14 (70)	4 (20)	1 (5)	0 (0)
1300-2846	9 (45)	5 (25)	5 (25)	1 (5)	0 (0)

*Figures in parentheses indicates the percentage

3.1.3 Organic matter status under different depths

A significantly higher SOM was found from D 1(0-15 cm) soil compared to D2 (15-30cm) depth soil (Table 8). The organic matter content in soil was varied from 0.68% to 7.16% in D1 (0-15cm) depth with a mean value of 6.88%. The result revealed that the mean organic matter was medium in organic matter status however the range showed the high variation in organic matter distribution. Similarly, in D2 (15-30 cm) depth the range of organic matter was varied from 0.12% to 4.21% with a mean value of 1.89% which indicated low organic matter status.

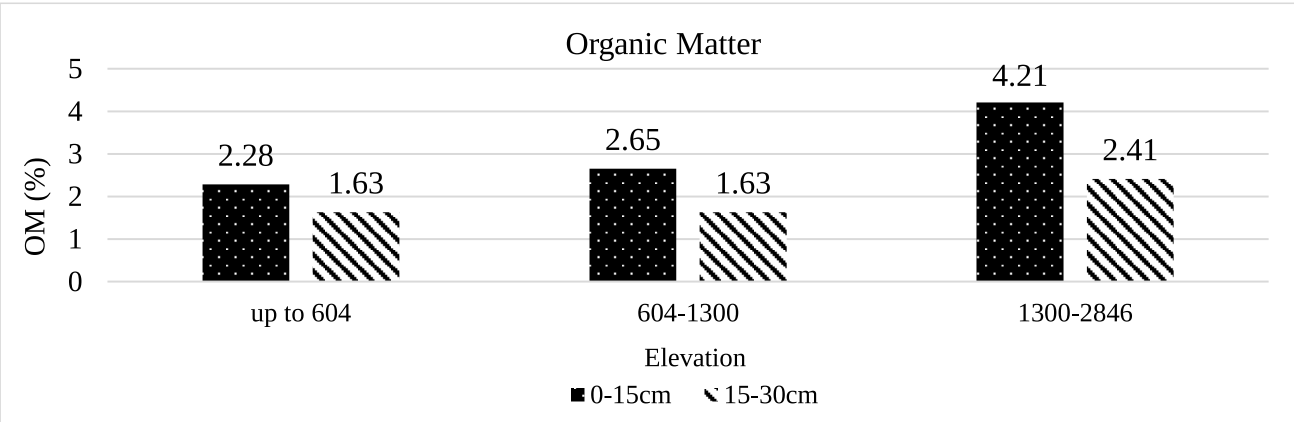


Figure 2: Different land elevation and SOM content at different depths

3.1.4 Total nitrogen status under different elevation

The nitrogen content of the soil was higher at the higher elevation. The total nitrogen (TN) content of 194-604m soil ranged from 0.034% to 0.303% with a mean of 0.095%. The TN content of second category soil, 604-1300m ranged from 0.025% to 0.294% with a mean value of 0.117%. Also, the TN content of 1300-2846m soil ranged from 0.0036% to 0.384% with an average of 0.196%. The nitrogen content of the soil at elevation 604-1300m and 1300-2846m were not significant among themselves. But the value of nitrogen content of this elevation was significantly higher than the nitrogen content of elevation 194-604m (Table 8).

There were higher nitrogen contents at higher elevations which may be attributed to higher organic matter content at higher elevations. Organic matter accumulation leads to an increase in total nitrogen. As the altitude increases, temperature decreases, and the corresponding precipitation gets increased which influences the rate of nitrogen mineralization as mineralization rate is lower at high altitude, resulting from higher TN content at a higher elevation.

Table 1: Frequency of Nitrogen content in different elevation

Elevation (m)	Very Low	Low	Medium	High	Very High
	Nitrogen/Nutrient category*				
194-604	11 (55)	5 (25)	2 (10)	2 (10)	0 (0)
604-1300	4 (20)	8 (40)	6 (30)	1 (5)	1 (5)
1300-2846	2 (10)	2 (10)	8 (40)	7 (35)	1 (5)

*Figures in parenthesis indicates percentage value

3.1.5 Total nitrogen status under different depths

It was observed that TN did not vary significantly with soil depths. The higher TN (%) was found from 0-15cm soil compared to that of 15-30cm soil (Table 8). The total nitrogen content in 15cm soil was varied from 0.0204% to 0.461%withinn average value of 0.164%. Also, the total nitrogen content in 15-30cm soil was varied from 0.0036% to 0.2947% with the mean value of 0.108% which indicates the medium status of TN. Maximum total nitrogen in surface and decreasing regularly with depth was also observed and aligned that it may be due to the decreasing trend of organic matter with increasing the depth and more mineralization of organic matter in surface soil and also cultivation of crops is mainly confined to surface horizon only and depleted nitrogen content was supplemented by the external addition of fertilizer (ud din Khanday et al., 2018).

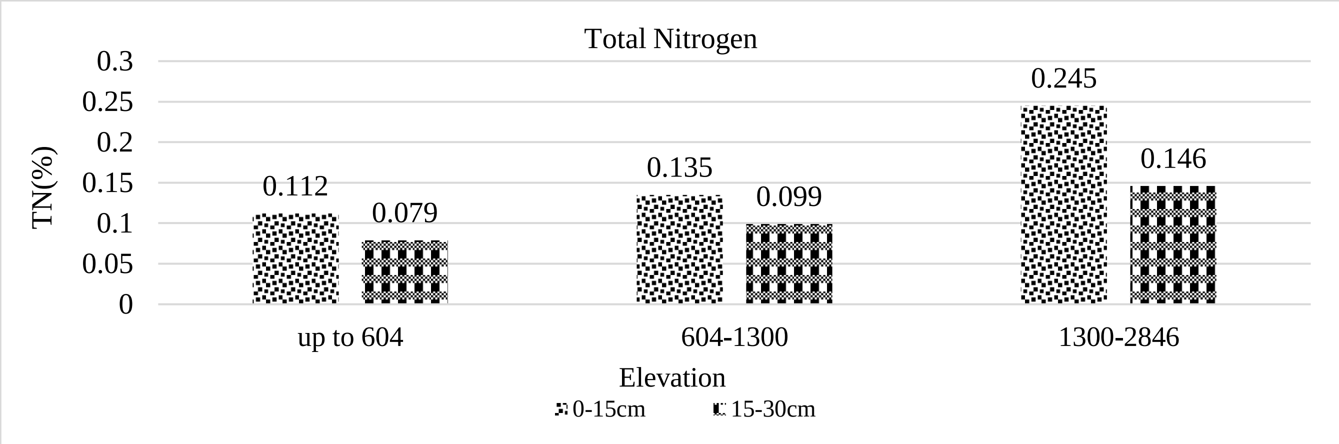


Figure 3: Different land elevation and TN content at different depths

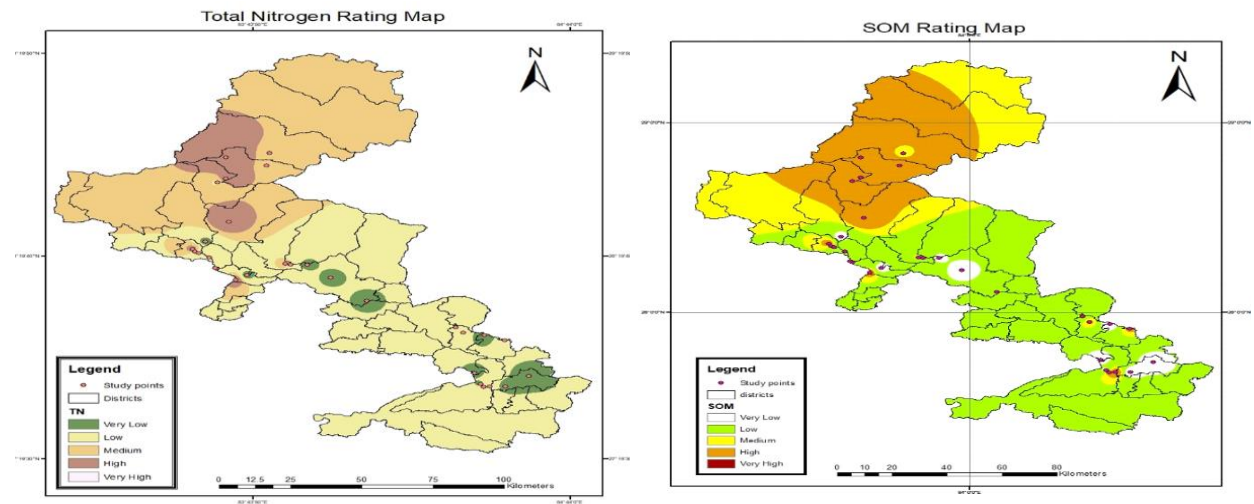


Plate 1: SOM Rating Map

3.2 Soil Reaction

3.2.1 Soil pH under different elevation

The soil pH value was higher at a lower elevation. More than 50% of sampled soil showed neutral soil pH. Irrespective of depth the pH of 194-604m soil ranged from 6.08 to 9.18 with a mean of 7.33. The ph. of second category soil, 604-1300m ranged from 5.82 to 8.22 with a mean value of 6.87. Also, the ph. of 1300-2846m soil ranged from 5.87 to 9.18 with an average of 7.08. Soil acidity was slightly higher in mid-hills than terai. This might be due to the loss of basic soluble salts from hill slopes due to soil erosion and leaching losses of salts by monsoon rains reported the continuous runoff and erosion removes Ca and Mg from soil and buildup of soil acidity in hills (Rijal, 2001). Also, the acidic nature of the soil in the mid-hills was due to the dominance of quartzite parent materials (Shrestha, 2009). However, the soil of the mustang district was found to be slightly alkaline in status. It can be due to the lower precipitation in this area which facilitates the accumulation of basic cations on the surface soil. A similar result was seen by who found the apple cultivated soil of mustang was moderately alkaline in status (Amgain et al., 2020).

3.2.2 Soil pH under different depths

The pH in soil varied significantly with depths. The range was varied from 5.88 to 7.92 with a mean value of 6.88 in 0-15cm depth. Similarly, the pH of the soil of 15-30cm depth was varied from 5.87 to 9.18 with the mean pH value of 7.31 (Table 8). This result indicated that with an increase in depth, alkalinity increases in soil. In all elevation categorical soil, 15-30cm soil depth is seen higher in soil pH than 0-15cm (Figure 4). This study indicated that the higher the organic matter percent lowers the corresponding soil ph. A similar result was observed by, where he reported the finding of his study as Soil pH increased with the depth of soil profile, and relatively high pH was observed at subsoil horizon (Kumar et al., 2018). This may be due to the organic matter improving the buffering capacity of soil and acidification being higher near the soil surface (Amgain et al., 2020).

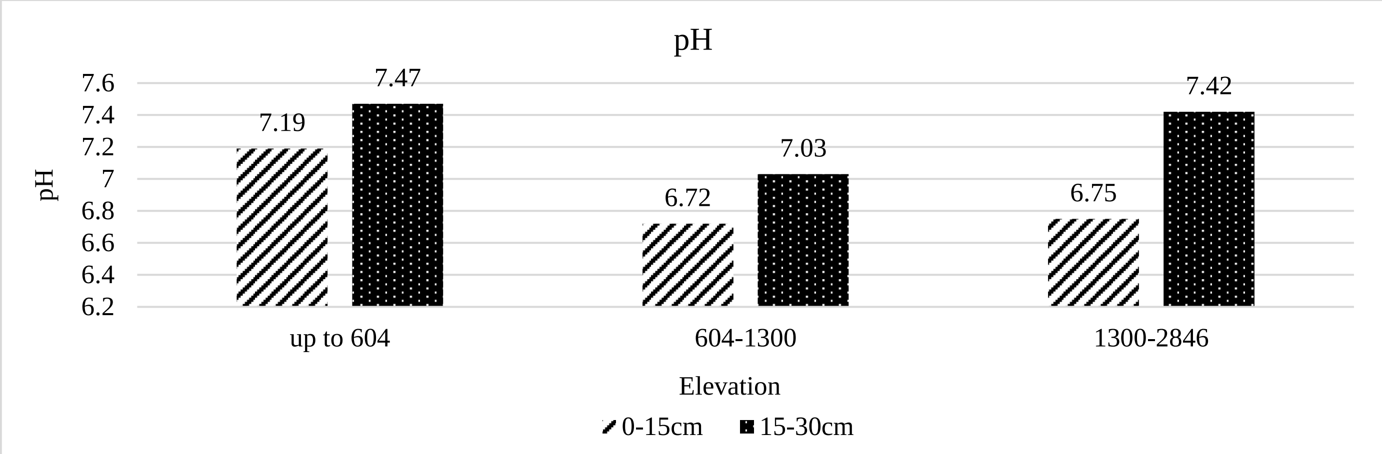


Figure 4: Different land elevation and pH at different depths

Table 8: Effect of elevation and soil depth in selected parameters

Treatments	pH	SOM	TN
		%	
Elevation (m)			
Up to 604	7.33	1.96[a]	0.096[a]
604 – 1300	6.87	2.15[b]	0.117[b]
1300-2846	7.08	3.31[b]	0.196[b]
Grand Mean	7.09	2.47	0.136
LSD	0.502[ns]	1.005*	0.068*
SEM	0.177	0.035	0.024
CV (%)	11.20%	64%	78.90%
Depth (cm)			
0 – 15	6.88	3.05	0.164
15-30	7.31	1.89	0.108
Grand Mean	7.09	2.47	0.136
LSD	0.403*	0.817**	0.0577[ns]
SEM	0.142	0.289	0.0204
CV (%)	11%	63.90%	81.90%

Note: Means followed by the common letter (s) within a column are not significantly different at 5% level of significance was determined by DMRT, *, **indicates significant at p<0.05 and p<0.1, ns= non-significant

Table 9: Nutrient status of different soil depths under different elevation

0-15cm soils												
Nutrient Status	Elevation and soil properties											
	194-604m				604-1300m				1300-2864m			
	Total N	Available P2O5	Available K2O	SOM	Total N	Available P2O5	Available K2O	SOM	Total N	Available P2O5	Available K2O	SOM
Very Low	1(10)	1(10)	0(0)	0(0)	2(20)	2(20)	1(10)	0(0)	6(60)	0(0)	2(20)	3(30)
Low	0(0)	2(20)	3(30)	2(20)	3(30)	4(40)	6(60)	6(60)	2(20)	5(50)	2(20)	4(40)
Medium	3(30)	1(10)	2(20)	6(60)	4(40)	2(20)	2(20)	3(30)	0(0)	4(40)	6(60)	2(20)
High	5(50)	6(60)	4(40)	2(20)	0(0)	2(20)	1(10)	1(10)	2(20)	1(10)	0(0)	1(10)
Very High	1(10)	0(0)	1(10)	0(0)	10(10)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
15-30cm soils												
Nutrient status	Elevation and soil properties											
	94-604m				604-1300m				1300-2864m			
	Total N	Available P2O5	Available K2O	SOM	Total N	Available P2O5	Available K2O	SOM	Total N	Available P2O5	Available K2O	SOM
Very low	1(10)	1(10)	1(10)	2(20)	2(20)	1(10)	5(50)	1(10)	5(50)	1(10)	4(40)	6(60)
Low	2(20)	4(40	3(30)	2(20)	5(50)	6(60)	4(40)	8(80)	3(30)	4(40)	5(50)	1(10)
Medium	5(50)	4(40)	6(60)	6(60)	2(20)	2(20)	1(10)	1(10)	2(20)	4(40)	1(10)	3(30)
High	2(20)	1(10)	0(0)	0(0)	1(10)	1(10)	0(0)	0(0)	0(0)	1(10)	0(0)	0(0)
Very high	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)

*Figures in parenthesis indicates percentage value

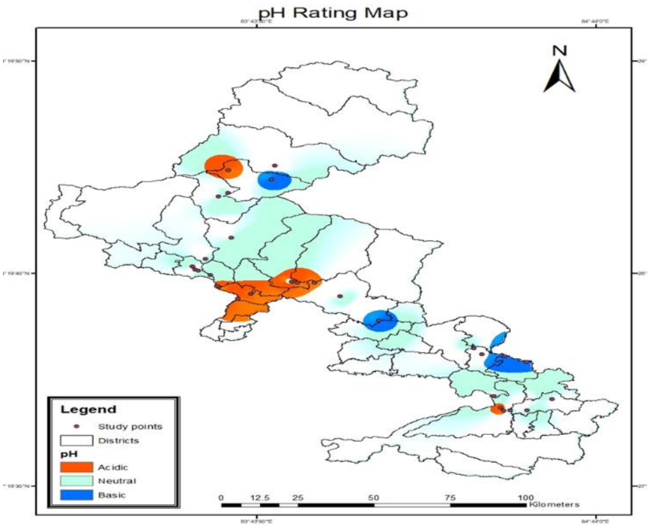


Plate 3: pH Rating Map

Table 10: Effect of elevation and soil depth in selected parameters		
Treatments	**K20**	**P2O5**
Elevation (m)	**kg/ha**	
Up to 604	90 ^{a}	32.5
604 – 1300	101 ^{b}	29
1300-2846	195 ^{b}	44.8
GM	129	35.4
SEM	21.2	5.87
LSD	60**	16.61^{ns}
CV%	73.50%	74.20%
Depth (cm)		
0 – 15	163	40.5
15 -30	95	30.2
GM	129	35.2
SEM	18.2	4.82
LSD	51.5*	13.62*
CV%	77.20%	74.60%

Note: Means followed by the common letter (s) within a column are not significantly different at 5% level of significance was determined by DMRT, *, **indicates significant at p<0.05 and p<0.1, ns= non-significant

3.3 Available Potassium

3.3.1 Elevation effect on available potassium

The available potassium content of 194-604m soil ranged from 20.173 to 212.194 kg/ha. The available potassium content of second category soil, 604-1300m ranged from 20.174 to 376.782 kg/ha. Also, the available potassium content of 1300-2846m soil ranged from 64.526 to 578.124 kg/ha. The potassium contents of soil at lower elevation were found to be lower.

The trend of higher potassium content at a higher elevation was supported (Luitel et al., 2020). It might be due to the higher addition of manures as K predominately occurs as soluble inorganic K from inorganic wastes and in animal wastes, potassium content was found to be around 0.22% of dry matter (Havlin et al., 2016).

Table 11: Frequency of potassium content at different elevation					
Potassium/Nutrient category*					
Elevation (masl)	Very Low	Low	Medium	High	Very High
194-604	6(30)	7(35)	7(35)	0(0)	0(0)
604-1300	6(30)	10(50)	3((15)	1(5)	0(0)
1300-2846	1(5)	6(30)	8(40)	4((20)	1(5)

*Figures in parenthesis indicates percentage value

3.3.2 Available potassium under different depths

Available potassium was medium in surface soil and showed a regular decrease with the depth. D1 (0-15cm) soil depth ranged from 40.25 to 578.12 kg/ha with a median value of 163 kg/ha in available potassium. Also, Available potassium of D2 (15-30cm) depth soil ranged from 20.17 to 239.62 kg/ha with a mean value of 95 kg/ha. The highest available K was observed in the surface soil and showed a more or less decreasing trend with soil depth (Figure 5). A similar result was revealed by where he observed decreasing trend of available potassium with depth (ud din Khanday et al., 2018). This might be attributed to more intense weathering, the release of liable K from organic residues, application of K fertilizers, and upward translocation of K from lower depths along with the capillary rise of groundwater (Joshi et al., 2017).

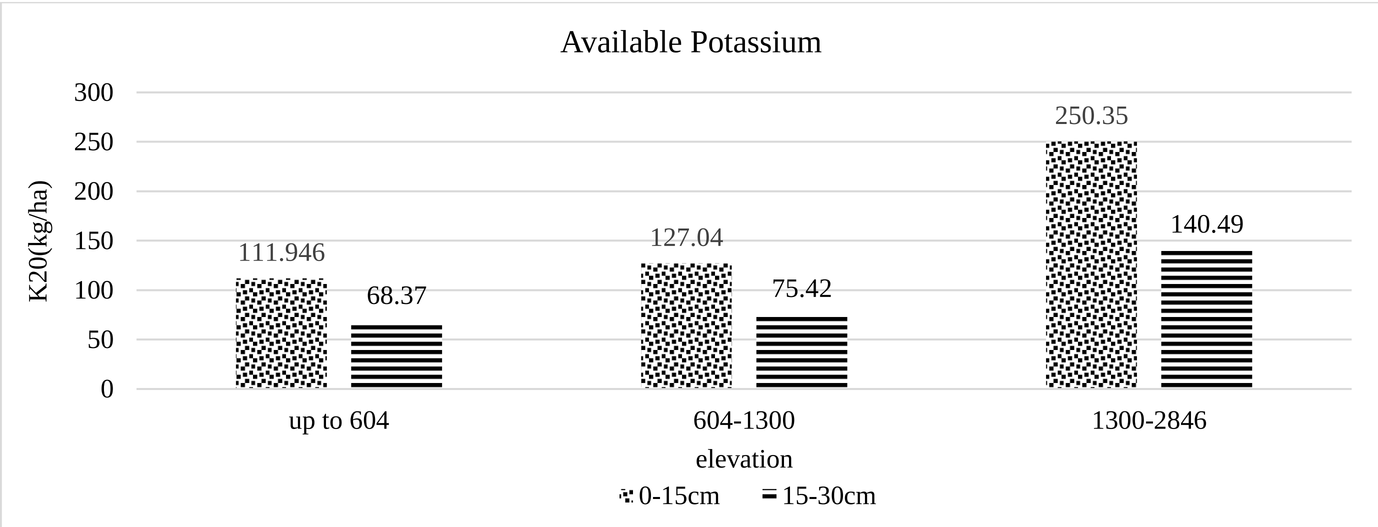


Figure 5: Different land elevation and available potassium at different depths

3.4 Available Phosphorus

3.4.1 Available phosphorus under different elevation

There was no significant difference in available phosphorus between the three categorical elevations. Although more or less variation among the treatment was seen. An increasing trend with altitudes like that of nitrogen, organic matter, and potassium was not seen in phosphorus. Available phosphorus was higher at a higher elevation and considerably lower phosphorus content at a lower elevation. The available phosphorus content of T1 (194-604m) soil ranged from 2.02 to 90.06 kg/ha with an average value of 32.5kg/ha. The available phosphorus content of second category soil, T2 (604-1300m) ranged from 2.025 to 92.675 kg/ha with an average value of 29kg/ha. Also, the available phosphorus content of T3 (1300-2846m) soil ranged from 5.287 to 108.67 kg/ha with an average value of 44.8kg/ha. The result was consistent with the findings of who reported the higher available phosphorus in higher altitudes compared to a lower altitude (Luitel et al., 2020). The higher available soil phosphorus content at higher elevations might be due to the inherent higher phosphorus level of soil at higher altitudes (Kidanemariam et al., 2012).

Table 12: Frequency of potassium content at different elevation					
Phosphorus/Nutrient category*					
Elevation(masl)	Very Low	Low	Medium	High	Very High
194-604	1((5)	9((45)	8(40)	2(10)	0(0)
604-1300	3((15)	10((50)	4((20)	3(15)	0(0)
1300-2846	2(10)	6(30)	5(25)	7(35)	0(0)

*Figures in parenthesis indicates percentage value

3.4.2 Available phosphorus under different depths

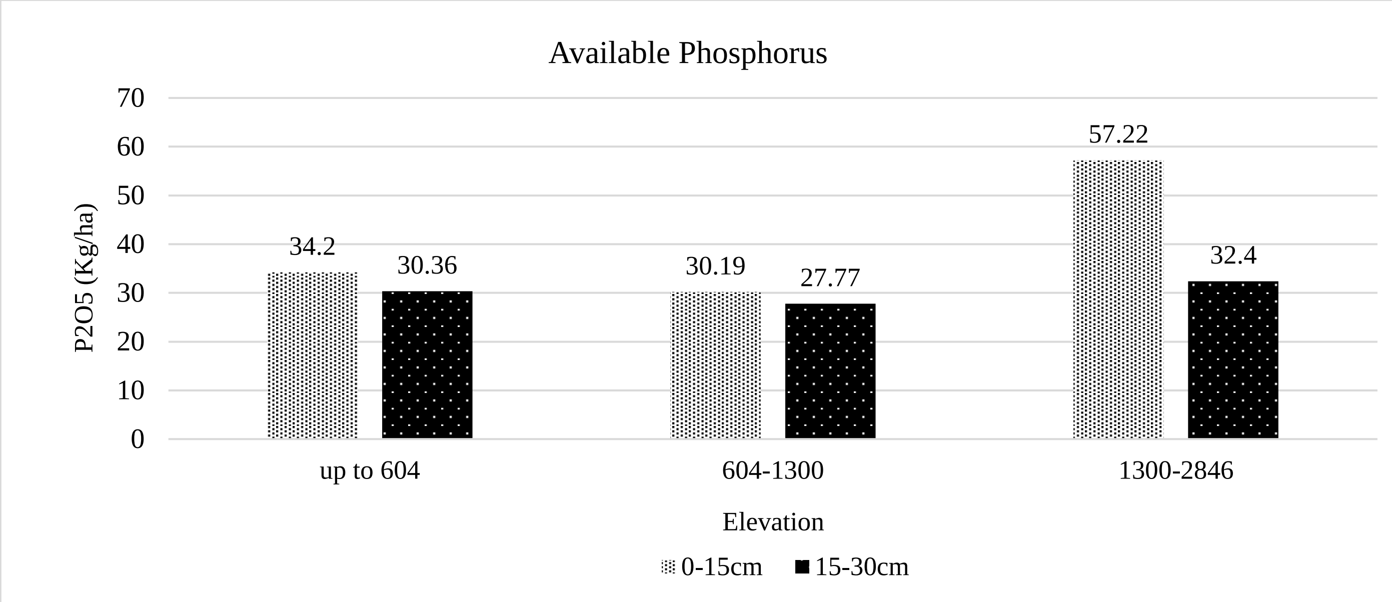


Figure 6: Different land elevation and available phosphorous content at different depth

The significantly higher available phosphorus was found from 0-15cm soil compared to 15-30cm depth soil (Table 8ss). The evaluation of phosphorus from two major soil depths showed D1 (0-15cm) ranged from 2.025 to 108.67kg/ha with the mean value of 40.5kg/ha and D2 (15-30cm) ranged from 2.02 to 75.06kg/ha with the mean value of 30.2kg/ha. The highest available P was observed in the surface soil and showed a decreasing trend with soil depth (Figure 6). The highest available P was observed in the surface horizons and decreased with depth. It might be due to the confinement of crop cultivation to the rhizosphere and supplementing the depleted P by external sources i.e., fertilizers and presence of free iron oxide and exchangeable Al3+ in smaller amounts (Singh and Mishra, 1996). The lower phosphorus content in sub-surface horizons in these profiles could be attributed to the fixation of P by clay minerals and oxides of iron and aluminum (Luitel et al., 2020).

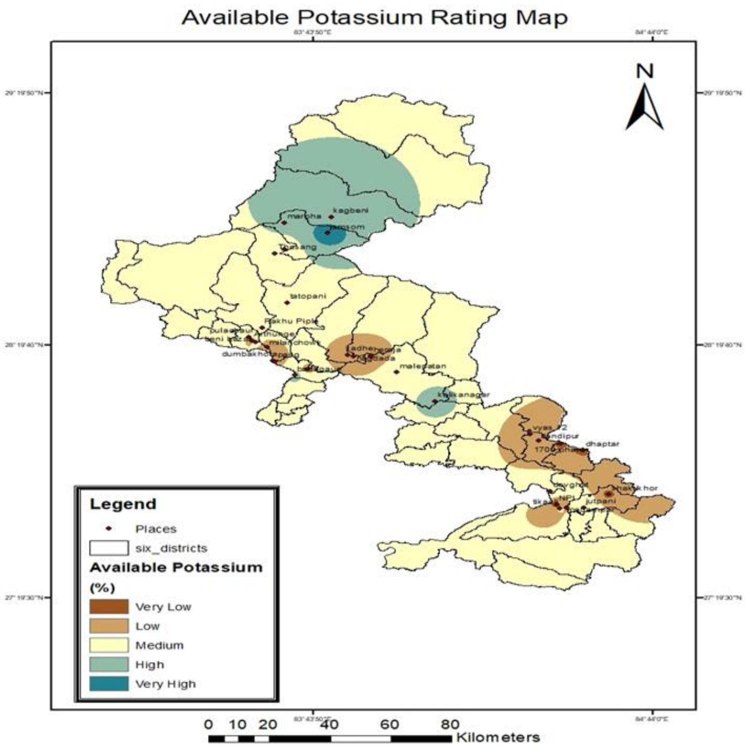


Plate 2: Available Potassium Rating Map

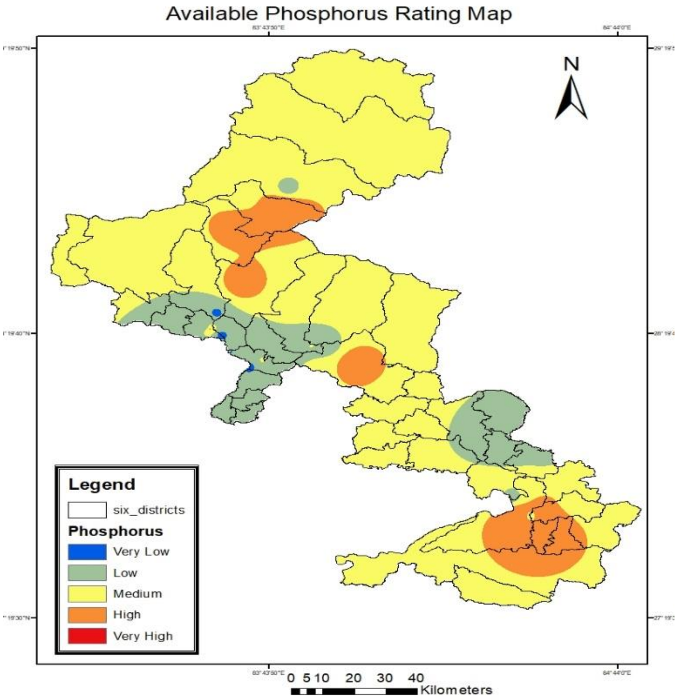


Plate 5: Available Phosphorus Rating Map

3.5 Interaction Effect of Elevation and Soil Depth on Soil Parameters

Soil organic matter/SOM content was significantly (p<0.5) affected by the interaction of elevation with soil depth (Table 12). The interaction effect of elevation by soil depth on the variability of SOM was significantly higher (4.21%) at the surface layer of T3 (1300-2846masl) and lower (1.63%) at the subsurface layer of T2 (604-1300masl) soil. This result is in agreement with (ud din Khanday et al., 2018). Although more or less variation is seen among the treatments, all other parameters were non-significantly affected by interaction. Total nitrogen was higher (0.245%) at the surface layer of T3 (1300-2846masl) and lower (0.079%) at the subsurface layer of T1 (194-604masl). Available phosphorus was higher (57.2kg/ha) at the surface layer of T3 (1300-2846masl) and lower (27.8kg/ha) at the subsurface layer of T2 (604-1300masl). PH was higher (7.47) at the subsurface layer of T1 (194-604m) and lower (6.72) at the surface layer of T2 (604-1300m). Available potassium was higher (250.3kg/ha) at the surface layer of T3 (1300-2846m) and lower (68.4kg/ha) at the subsurface layer of T1 (194-604masl).

Table 13: Interaction effect of elevation and depth on soil parameters

Parameters	Elevation						Trt SED	Dep SED	T×D SED	CV (%)
	194-604 masl		604-1300 masl		1300-2846 masl					
OM (%)	2.29^{b}	1.64^{b}	2.66^{b}	1.63^{b}	4.21^{a}	2.41^{b}	0.471*	0.385**	0.667*	60.3
pH	7.19^{a}	7.47^{a}	6.72^{a}	7.03^{a}	6.75^{a}	7.42	0.246^{ns}	0.201*	0.348^{ns}	11.0
TN (%)	0.112^{b}	0.079^{b}	0.13^{b}	0.99^{b}	0.245^{a}	0.146^{b}	0.033*	0.027*	0.047^{ns}	77.2
P (kg/ha)	34.2^{b}	30.4^{b}	30.2^{b}	27.8^{b}	57.2^{a}	32.4^{b}	8.17^{ns}	6.67^{ns}	11.55^{ns}	73.1
K (kg/ha)	112^{b}	68.4^{b}	127^{b}	76^{b}	250.3^{a}	140.5^{b}	28.2***	23.0**	39.9^{ns}	69.1

Note: Means followed by the common letter (s) within a column are not significantly different at 5% level of significance was determined by DMRT, *, **, ***indicates significance at p<0.05, p<0.1 and p<0.01, ns= non-significant

4 Conclusion

The fertility status of the soil was higher at a higher elevation. On moving up with the elevation, soil parameters like Nitrogen, SOM, and Available potassium were in the increasing trend. But Available phosphorus and pH did not show such a trend. Also, primary nutrients were in decreasing trend along with the depth of soil. Thus, it can be concluded that soil fertility of the research locale can be improved by better use of agricultural inputs and better management of soil types.

References

Al-Zubaidi, A., Yanni, S., Bashour, I., 2008. Potassium Status in Some Lebanese Soils. Lebanese Science Journal, 9 (1).

Amgain, R., Khadka, D., Joshi, S., Malla, R., 2020. Depth-wise variations of soil physicochemical properties in the apple growing area of Mustang district, Nepal. Journal of Agriculture and Natural Resources, 3 (2), Pp. 92–103. https://doi.org/10.3126/janr.v3i2.32486

Anderson, K.E., Furley, P.A., 1975. An assessment of the relationship between the surface properties of chalk soils and slope form using principal components analysis. Journal of Soil Science, 26 (2), Pp. 130–143.

Behrens, T., Schmidt, K., Ramirez-Lopez, L., Gallant, J., Zhu, A.X., Scholten, T., 2014. Hyper-scale digital soil mapping and soil formation analysis. Geoderma, 213, Pp. 578–588. https://doi.org/10.1016/J.GEODERMA.2013.07.031

Bhandari, J., Zhang, Y., Bhandari, C., Zhang, Y., 2019. Effect of altitude and soil properties on biomass and plant richness in the grasslands of Tibet, China, and Manang District, Nepal. Ecosphere, 10 (11), Pp. e02915. https://doi.org/10.1002/ECS2.2915

Dumanski, J., Pieri, C., 2000. Land quality indicators: research plan. Agriculture, Ecosystems & Environment, 81 (2), Pp. 93–102. https://doi.org/10.1016/S0167-8809(00)00183-3

Gao, C., Zhang, Y., Shi, N.N., Zheng, Y., Chen, L., Wubet, T., Bruelheide, H., Both, S., Buscot, F., Ding, Q., Erfmeier, A., Kühn, P., Nadrowski, K., Scholten, T., Guo, L.D., 2015. Community assembly of ectomycorrhizal fungi along a subtropical secondary forest succession. New Phytologist, 205 (2), Pp. 771–785. https://doi.org/10.1111/NPH.13068

Havlin, J. L., Tisdale, S. L., Nelson, W. L., Beaton, J.D., 2016. Soil fertility and fertilizers. Pearson Education India.

Huggett, R.J., 1975. Soil landscape systems: A model of soil Genesis. Geoderma, 13 (1), Pp. 1–22. https://doi.org/10.1016/0016-7061(75)90035-X

Joshi, B.K., KC, H.B., Acharya, A.K., 2017. Conservation and utilization of agricultural plant genetic resources in Nepal. Proceedings of 2nd National Workshop, 22, Pp. 23.

Kidanemariam, A., Gebrekidan, H., Mamo, T., Kibret, K., 2012. Impact of altitude and land use type on some physical and chemical properties of acidic soils in Tsegede Highlands, Northern Ethiopia. Open Journal of Soil Science, 2 (03), Pp. 223.

Kumar, U., Kumar Nayak, A., Shahid, M., Gupta, V.V.S.R., Panneerselvam, P., Mohanty, S., Kaviraj, M., Kumar, A., Chatterjee, D., Lal, B., Gautam, P., Tripathi, R., Panda, B.B., 2018. Continuous application of inorganic and organic fertilizers over 47 years in paddy soil alters the bacterial community structure and its influence on rice production. Agriculture, Ecosystems & Environment, 262, Pp. 65–75. https://doi.org/https://doi.org/10.1016/j.agee.2018.04.016

Luitel, D.R., Siwakoti, M., Jha, P.K., 2020. Nutrients in finger millet and soil at different elevation gradients in Central Nepal. CABI Agriculture and Bioscience, 1 (1), Pp. 1–10. https://doi.org/10.1186/s43170-020-00018-3

Mulumba, L.N., Lal, R., 2008. Mulching effects on selected soil physical properties. Soil and Tillage Research, 98 (1), Pp. 106–111. https://doi.org/10.1016/J.STILL.2007.10.011

Pennock, D.J., Zebarth, B.J., De Jong, E., 1987. Landform classification and soil distribution in hummocky terrain, Saskatchewan, Canada. Geoderma, 40 (3–4), Pp. 297–315. https://doi.org/10.1016/0016-7061(87)90040-1

Rijal, S.P., 2001. Soil fertility decline in Nepal: Problem and strategy. Nepal Journal of Science and Technology, 3 (1).

Robert, P., 2013. Soil fertility: a guide to organic and inorganic soil amendments.

Scholten, T., Goebes, P., Kuhn, P., Seitz, S., Assmann, T., Bauhus, J., Bruelheide, H., Buscot, F., Erfmeier, A., Fischer, M., Hartle, W., He, J.S., Ma, K., Niklaus, P.A., Scherer-Lorenzen, M., Schmid, B., Shi, X., Song, Z., Von Oheimb, G., Schmidt, K., 2017. On the combined effect of soil fertility and topography on tree growth in subtropical forest ecosystems—a study from SE China. Journal of Plant Ecology, 10 (1), Pp. 111–127. https://doi.org/10.1093/JPE/RTW065

Shrestha, R.K., 2009. Soil fertility under improved and conventional management practices in Sanga, Kavrepalanchowk district, Nepal. Nepal Agriculture Research Journal, 9, Pp. 27–39.

Singh, V.N., Mishra, B.B., 1996. Pedogenetic characterization of some typical soils of Gandak Command Area of Bihar for evaluation of land suitability. Journal of the Indian Society of Soil Science, 44 (1), Pp. 136–142.

Ud din Khanday, M., Wani, J.A., Ram, D., Kumar, S., 2018. Depth wise distribution of available nutrients of soils of horticulture growing areas of Ganderbal District of Kashmir Valley. Journal of Pharmacognosy and Phytochemistry, 7 (1), Pp. 19–22.

Wu, Y.T., Gutknecht, J., Nadrowski, K., Geißler, C., Kühn, P., Scholten, T., Both, S., Erfmeier, A., Böhnke, M., Bruelheide, H., Wubet, T., Buscot, F., 2012. Relationships Between Soil Microorganisms, Plant Communities, and Soil Characteristics in Chinese Subtropical Forests. Ecosystems, 15 (4), Pp. 624–636. https://doi.org/10.1007/S10021-012-9533-3

Wu, Y.T., Wubet, T., Trogisch, S., Both, S., Scholten, T., Bruelheide, H., Buscot, F., 2013. Forest Age and Plant Species Composition Determine the Soil Fungal Community Composition in a Chinese Subtropical Forest. PLOS ONE, 8 (6), Pp. e66829. https://doi.org/10.1371/JOURNAL.PONE.0066829