

Physico-chemical properties of soil in Jita and Taksar area of Lamjung district, Nepal

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Physicochemical property of top layer of soil is very important for plant growth having life supporting agriculture production, forestry and environmental sustainability. Soil texture and its chemical properties are determined by various factors inversely soil property determines productivity for them. This study was conducted in Jita and Taksar area of Lamjung district of Nepal. Soil samples were collected from the field. Coarse fragments, soil texture and pH were measured from soil samples. Properties of soil were analyzed by mechanical and chemical methods such as sieve, hydrometer and digital pH meter. Dominant soil textural class is loam followed by silt loam. Higher proportion of sand is found in higher elevation and steeper slope. Inverse relationship is found of silt. Dominant soil is found to be slightly to moderately acidic. Soil pH level decreases with increasing altitude and slope gradient. Cultivated land is less acidic than other land cover category. It is found that lower elevation and lower slope gradient have more proportion of coarse fragments. Chi-square test proves the significant difference of pH, soil texture class, soil particle size and coarse fragment at different elevation, slope gradient and land use. However, variation of sand at different slope gradient and land use is not explained well.

Keywords: Coarse fragment; Loam; Soil acidity; Soil pH; Soil texture

Introduction

Soil is an important life supporting natural resource for the growth of arable crops, grassland and trees which produce life supporting materials for humans (Corstanje et al., 2006; Dorji et al., 2014; Mzuku et al., 2005) such as food, fiber for cloth, timber for building materials and fuel (Wild, 1996). Soil properties determine the composition of plant community structure and regeneration of plants (Sigdel, 2015; Tiwari, 2015) resulting on the variation of crop productivity and vegetation growth. Therefore, clear and intimate knowledge of soil properties and their distribution are essential pre-requirement in developing national and local level land use plans for agriculture, forestry and other uses (Mandal, 2013). Soil properties are physical and chemical characteristics of soil. Physical properties are texture, structure, density, porosity, consistency, temperature, color, and resistivity. Chemical properties are various chemical components in soil such as pH, nitrogen, phosphorous, potassium, etc. (Sigdel, 2015; Wild, 1996). Soil texture affects on soil water retention, leaching, erosion, nutrient storage, dynamics of organic matter and carbon sequestration capability. Therefore, soil texture analysis is key component in determining soil quality for agriculture and forestry development (Kettler et al., 2001). Soil pH is the measurement of soil acidic or alkaline level. It is the most important chemical indicator of soil quality which expresses the activity of the hydrogen ions in the soil solution. It affects the availability of mineral nutrients to plants as well as many soil processes (FAO, 2006). Additionally, rock fragments influences the nutrient status, water movement. It also shows the stage of development of the soil (Chow et al., 2007). Soil properties depend on various environmental factors like slope, aspect, climate, landscape, microclimate, topography and vegetation (Chen, 1997; Tsui, 2004). Mountainous country like Nepal has a very crucial landform, soil and climatic resources because of the mountain specificities such as diversity, fragility, marginality and inaccessibility (Mandal, 2013). Complex topographical feature has resulted complex types of physiochemical properties of soil even short span of spatial distance. In the past rapid population growth in the hill and mountain of Nepal resulted extension of cultivated land even steeply sloping area. It caused land degradation and decreasing productivity (Ekholm, 1975). Last two decades heavy outmigration of hill farmers have resulted labor shortage for agriculture and their land management system (Chidi 2016). However, agriculture is still the predominant economic activity in Nepal and there is an increasing demand for information on soils as a means to produce food. Food deficit, declining productivity of land and environmental degradation are directly related with the soil properties (Joshy, 2015, Dawadi et al., 2015) in Nepal. So, this study aims to assess the distribution of basic physiochemical properties of soil such as texture and pH of soil including coarse fragments.

Study area

The study area is selected from middle mountain region of Nepal having subtropical and warm temperate climatic region. The study area is Taksar and Jita area of Lamjung district of Madi river basin (Figure 1). This study is joining with Golandi Khola to the east, Kunchha area to the west, Deuralidanda area to the north and Ristikhola to the south. District road connects this area from the other parts of the country.

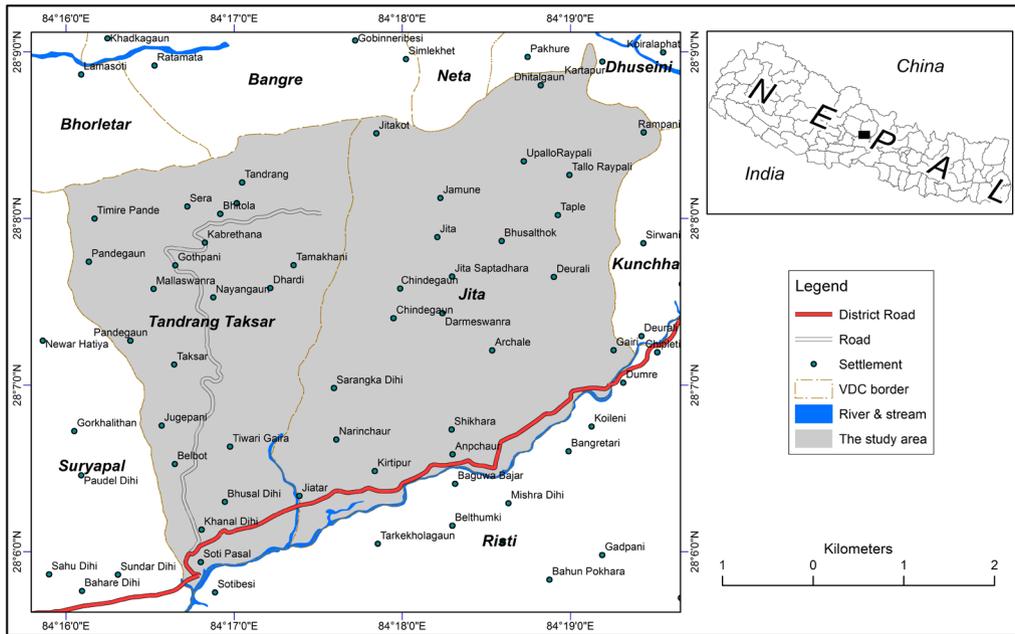


Figure 1: Study area :Taksar and Jita area.

The geographical extension of the study area is 84°15'59" east to 84°19'33" east longitude and 28°5'46" north to 28°9'30" north latitude. Aerial extension is nearly 21 square km having east-west extension nearly 6 kilometer and north south 5.5 kilometer. Elevation ranges from lowest 420 m in the south-west corner to highest 1420 m to the north. Naturally, general slope is south facing having higher elevation to the north and lower to the south. Temperature and rainfall data was taken from the nearest meteorological stations. Rainfall data was taken from nearest rainfall data of meteorological station at Kunchha is nearly 2600 mm having nearly 80% rainfall in summer and dry in winter. Kunchha is the nearest station but this station does not have temperature data. Therefore, temperature data was taken from second nearest station located at Khudi. Average temperature of Khudi is 22.5°C having the maximum 28.64°C and minimum is 16.39°C. Narrow river terraces along the tributaries and gently sloping cultivated land

and most of other parts are moderately to steeply sloping hillside. Traditional intensive subsistence farming with irrigated paddy field at lower river terraces and rain-fed maize field in the upper hill slope area is common in Nepal. It is primarily based on organic manure with livestock, forest and crop are being major components of an integrated system and this area is also not an exception.

Methods and materials

This study is based on the analysis of 50 samples taken from different areas. The location of sample pits were identified on the basis of various map layers such as topographic map, land system map, land capability map and land utilization map (LRMP, 1986a; LRMP, 1986b; LRMP, 1986c). The centroid method was applied to find the location for soil pits in the polygons. Coordinates of each sampled pits were identified. Standard soil profile description prepared by National Land Use Project, Nepal (NLUP, 2074) was used to record the soil profile details. This form consists of the information of sampled site location, general information of the soil, general information of the profile and information on individual soil horizon. One kg top soil from each pits were collected. The map of sampled pit location has been shown in the Figure 2. Google Earth image was also used to collect required information and verification of spatial data.

Samples were air dried in the room. Roots, stem leaves etc. were cleaned. Air dried sampled was grinded to disintegrate fragment of earth materials. Grinded sample was filtered by 2 mm sieve and weighted separately. Earth material greater than 2 mm is known as coarse fragments and smaller than 2 mm is known as soil (FAO, 2006). Soil particle size of 2 mm to 0.05 mm was defined as sand, 0.05 mm to 0.002 mm was silt and smaller than 0.002 mm is clay (USDA, 2017). It is measured by hydrometer which is recommended



Figure 2: Soil mapping unit and location of sampled pits.

standard method for particle size identification (Amuyou et al., 2013). Then proportion of sand, silt and clay of each soil sample was identified. Soil pH was measured using digital pH meter in the lab. Soil pH ranking was done on the basis of Nepal Agriculture Research Council guideline (NARC, 2013). Only four groups of pH ranking were found in the study area. Soil texture class was identified through soil texture triangle for each sample (see Figure 3).

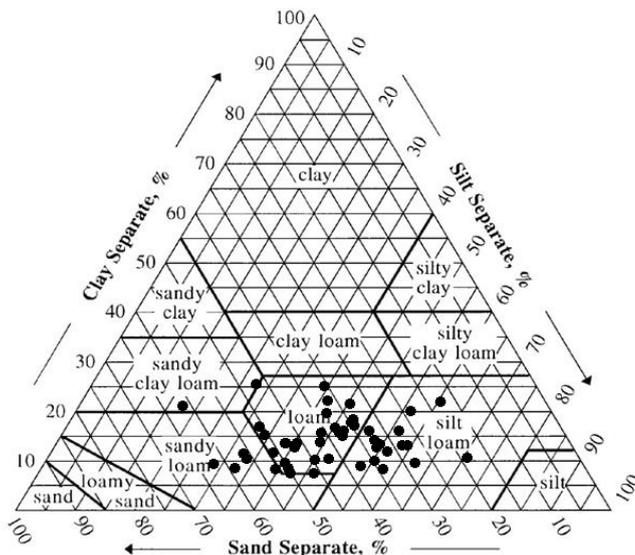


Figure 3: Soil texture triangle.

Land use map was prepared on the basis of topographic map 1996 and corrected by field verifications and Google Earth image. Land use classes were agriculture, forest and others (pasture and grassland).

IDW interpolation of soil properties in GIS is popular methods (Mzuku et al., 2005 and Attaeian et al., 2015) to make regular pattern on the basis of the properties of sample location which is the best method due to the low skewness inherent in all soil properties (Kravchenko and Bullock, 1999). This method was used cautiously in this study because some studies found that IDW was the best for subsoil pH interpolation than top soil (Robinson and Metternicht, 2006). Elevation of 200 meter interval was considered. Slope has been classified into four categories such as $<1^\circ$, 1° to 5° , 5° to 30° and $>30^\circ$ according slope category of land capability classes I, II III and IV (LRMP, 1986a). Cross tables of corresponding variables were developed to identify the pattern of association among variables.

Two types of soil properties tables were prepared at different elevation, slope gradient and land use. First one was for contingency tables of soil properties at different elevation, slope gradient and land use to identify the nature of distribution pattern of soil properties. Second one was to prepare frequency table of soil properties of 50 samples for Chi-square test to identify whether the general distribution pattern of soil properties at different elevation, slope gradient and land use are significantly different or not. For this purpose, variables were further grouped to meet the criteria for chi-square test (Pal, 1982 and Gupta, 2011). Elevation was classified into tropical below 1000 meter and warm temperate regions above 1000 meter according to LRMP criteria. Similarly, slope was grouped into 0° to 5° and 5° to 60°. First group is class I and class II, and the second group is class III and class IV of land capability class (LRMP, 1986a). First group of soil texture class was loamy (loam and silt loam) and second group was sandy (sandy clay loam and sandy loam) because these classes have different water retention and moisture holding capacity (Akhter, 2004). Soil was classified into two groups on the basis of alkaline and acidic in nature which is very important for crop production and vegetation regeneration (Nelson and Su, 2010). First group is neutral to slightly acidic and second one is moderately to highly acidic. Sand percent is grouped into sandy nature (>50% sand) and silt or clay nature (<50% sand). Accordingly, silt percent was grouped into clay nature (<40% silt) and silt nature (>40% silt). Clay was grouped into less than 20% and more than 20% (NARC, 2013). Coarse fragment proportion was grouped into boulder (less than 15% coarse fragment) and rubble (more than 15% coarse fragment) based on USDA (2017) class. Finally, chi-square test was used to test whether the significance association among variables presents.

Results and discussion

Soil texture

Soil texture refers to the relative proportion of sand, silt and clay of soil. Four types of texture classes were identified from 50 soil samples. Those are loam, silt loam, sandy loam and sandy clay loam. Dominant soil texture class in the study area is loam (54.03%) followed by silt loam 35.94%). These two texture classes occupy nearly 90% of the soil. Remaining 10 percent are sandy loam (7%) and sandy clay loam (3%). There is higher proportion of loam and silt loam below 1000 meter elevation inversely higher proportion of sandy loam and sandy clay loam above 1000 meter altitude. Chi-square test (Table 1) between elevation and soil texture class proves the association between these two variables. Similar association with slope gradient and land use was found by chi-square test at 5% significance level. Therefore, it can be said that elevation and slope gradient have significant control on the distribution of soil texture class. Distribution of

soil texture class was also determined by various land use classes such as agriculture, forest and others (pasture and grassland). Cultivated land has higher proportion of loam and silt loam than forest and other land uses (at 5% significance level). Inversely, pasture and grassland have more sandy loam and sandy clay loam. Irrigated paddy field has more silt loam and rain fed maize field has more loamy soil. Silt loam is mostly limited to river terraces and tars. The lower river terrace with paddy field has silt loam and upper river terrace of maize field has mostly loamy soil.

Table 1: Chi-square results of soil texture class at different elevation, slope gradient and land use (N = 50).

Variables	Chi square value	p value
Elevation	0.03	0.854
Slope	2.09	0.148
Land use	5.55	0.062

Soil texture class provides valuable information for many applications in soil science and other disciplines. However, values of sand, silt, and clay of soil are preferable due to limitations of soil texture class (Levi, 2017). Sand proportion is increasing with increasing elevation and naturally silt proportion is opposite to elevation. Clay proportion is also similar decreasing trend with increasing elevation (see Table 2).

Table 2: Average percentage of sand, silt and clay by elevation

Elevation in meter	Number of samples	Sand	Silt	Clay
400 to 600	14	35.0	50.9	14.1
600 to 800	10	43.0	43.4	13.6
800 to 1000	16	44.7	41.7	13.6
1000 to 1250	10	46.8	40.7	12.5
Total	50	42.1	44.4	13.5

Chi-square test (at 5% significance level) of elevation and sand proportion proved the significant variation of sand above and below 1000 meter altitude. Similar result was found in Laddakh, India (Charan et al., 2013) at 3000 meter to 4000 meter altitudinal range. Silt and clay proportion decreases with increasing altitude (see Table 2). However, chi-square test at 5 % significant level does not show the significant association. Slope is another important factor determining the proportion of sand, silt and clay. Table 3 shows the increasing proportion of sand with increasing slope gradient and inverse relation of

silt and clay context. The lowest slope gradient is nearby river channel therefore it has higher sand proportion and lower proportion of silt and clay in comparison to 1° to 5° slope range. It proves that land capability Class I and Class II have lower proportion of sand and higher proportion of silt and clay than in Class III and Class IV. However, Chi-square test does not prove the significant difference in the proportion of sand and silt at less than and more than 5° slope gradient but clay proportion is significantly different in these two slope gradient classes..

Table 3: Average percentage of sand, silt and clay by slope gradient

Slope in degree	Number of samples	Sand	Silt	Clay
0 to 1	2	31.1	54.3	14.6
1 to 5	6	28.9	55.8	15.3
5 to 30	26	42.6	44.3	13.1
More than 30	16	47.6	39.0	13.4
Total	50	42.1	44.4	13.5

Proportion of sand is the lowest in agriculture and the highest is in pasture and grassland. Proportion of silt is the highest (47.3%) in agriculture land followed by grassland (45.9%) and the least is in forest. Clay percent is the highest in agriculture and the least proportion is in the forest (see Table 4). Silt and clay proportion are significantly different in various land use but sand proportion is not as well (chi-square test at 5% significance level).

Table 4: Average percentage of sand, silt and clay by land use

Land use	Number of samples	Sand	Silt	Clay
Agriculture	31	38.6	47.3	14.1
Forest	13	48.5	39.2	12.3
Grassland & pasture	6	45.9	40.6	13.6
Total	50	42.1	44.4	13.5

Table 2, 3 and 4 show that higher proportion of sand was found at higher elevation, higher slope gradient and non agriculture land. It is also because of the cultivated land is mostly locating in lower elevation less sloppy land. Higher proportion silt and clay at lower elevation, lower slope gradient and cultivated land indicates the land suitability for agriculture.

Soil pH

The presence of bacteria, decomposing materials like leaves, grasses and addition of lime has direct relation in maintaining the soil pH. Since soil pH is controlled by several factors such as clay and organic matter content. IDW Interpolated map of pH estimates that more than half of the total area is moderately acidic followed by slightly acidic. Remaining area is strongly acidic. Very few parts are neutral. Figure 4 shows the distribution of moderate to highly acidic soil in the north and western part of the study area which is mostly surrounded by moderately acidic. Slightly acidic soil is found in the central to south east portion. Some eastern, southern, western and northern border area have also similar level of pH. Neutral is in the very limited part of central, west and southeast region.

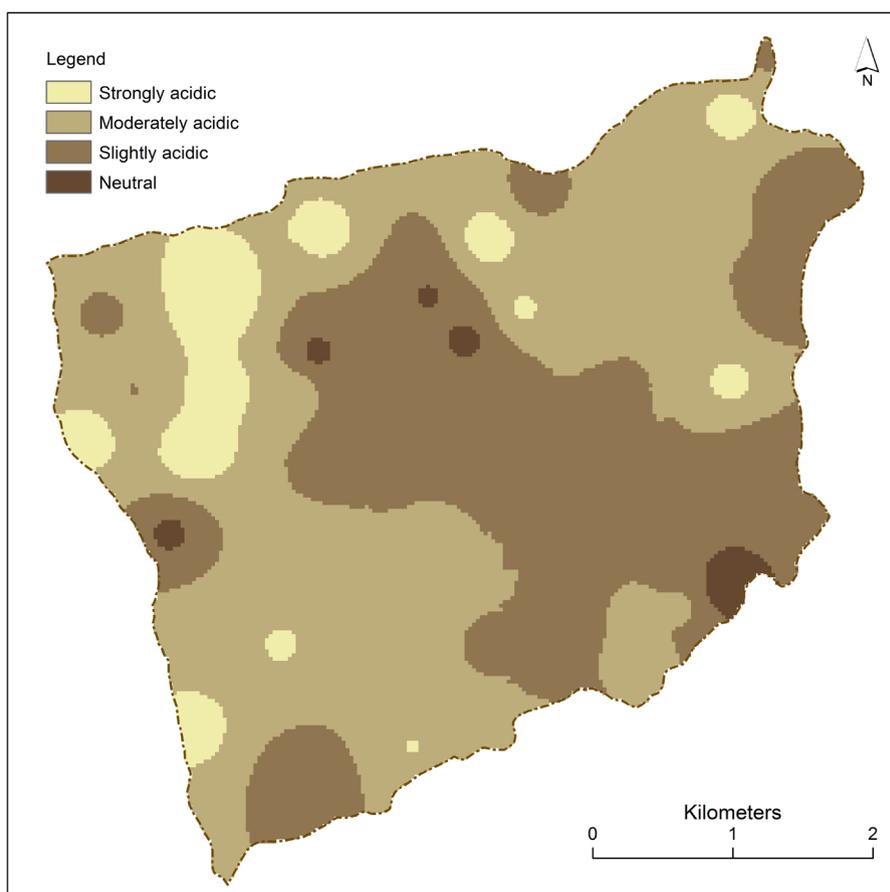


Figure 4: Distribution of alkaline and acidic nature of soil

Table 5 shows the number of soil samples taken from different types of land use and their pH values.

Table 5: Soil pH by land use types

Land use	Number of samples	Soil pH		
		Minimum	Maximum	Average
Agriculture	31	5.3	7.0	6.0
Forest	13	5.3	6.4	5.8
Pasture and grassland	6	5.1	6.6	5.8
Total	50	5.1	7.0	5.9

Inverse relation between slope gradient and average pH value is found in the study area (see Table 6). Maximum pH is found in 1° to 5° slope range. Amuyou and others (2013) and Tripathi (2015) found the significant increase in soil acidity in Nepal and other parts of the world and this study also found similar result.

Table 6: Soil pH by slope gradient

Land use	Number of samples	Soil pH		
		Minimum	Maximum	Average
0 to 1	2	6.1	6.4	6.3
1 to 5	6	5.6	7.0	6.2
5 to 30	26	5.1	6.7	6.0
30 to 60	16	5.3	6.6	5.7
Total	50	5.1	7.0	5.9

However, soil pH pattern is not regular with altitudinal variation in the study area. Agriculture land is more alkaline than forest, grassland and pasture area. Irrigated paddy field has higher pH value than in rain fed maize field. However, average soil pH at agriculture land is slightly acidic.

There has been variation in soil acidity above and below 1000 meter elevation and different land use types. The significant difference of soil acidity and alkaline below and above 5° slope gradient was found in the study area. Chi-square test proves the significant difference of soil pH class in various land use class at 5% significance level (Table 7). It proves that the soil pH is significantly higher in agriculture land than forest, pasture and grassland.

Table 7: Chi square result of soil pH at different elevation, slope gradient and land use (N=50).

Variables	Chi square value	p value
Elevation	2.42	0.119
Slope	0.42	0.517
Land use	2.86	0.239

Acidic soil in agriculture land is the result of shortage of organic manure supply due to the decreasing livestock and other organic manure supply due to labor shortage in hill agriculture (Tripathi and Jones, 2010) of Nepal. Hill farming system of Nepal is characterized by the integration of crop production, livestock and forestry. In recent two decades linkage between these aspects are becoming weak. As a result organic manure supply in their cropping field is lacking which is being major cause decreasing soil productivity (Dawadi and Thapa, 2015). Similarly, soil erosion from the hill slope and weak management system of agriculture farmland (Tripathi, 2015) have also played significant role of decreasing soil productivity and acidification of agriculture land. Soil becomes acidic through natural process after expose with rainwater for a long time. Acidification of soil is a major problems of agriculture sustainability in the world (Sumner and Noble, 2003; Brady and Weil, 2008). The similar situation is also found in Nepal.

Coarse fragments

Coarse fragments play an important role in static soil properties such as soil bulk density, porosity, pore size distribution and saturated hydraulic conductivity. In general, these values increased with increasing coarse fragment content (Chow et al., 2007). Soil moisture and temperature of soil are also determined by the proportion of coarse fragments which is both valuable components for agriculture production. There is higher proportion of coarse fragment in the river terraces followed by slope land. Average coarse fragment proportion in the study area is 18.69 percent with ranging minimum nearly 2% to as high more than 90%.

Coarse fragment is highest in agriculture land followed by pasture and grassland. Least proportion is in the forest area (see Figure 5). Land use has significant difference of the distribution of boulder and rubble (chi square test at 5% significance level) in the study area.

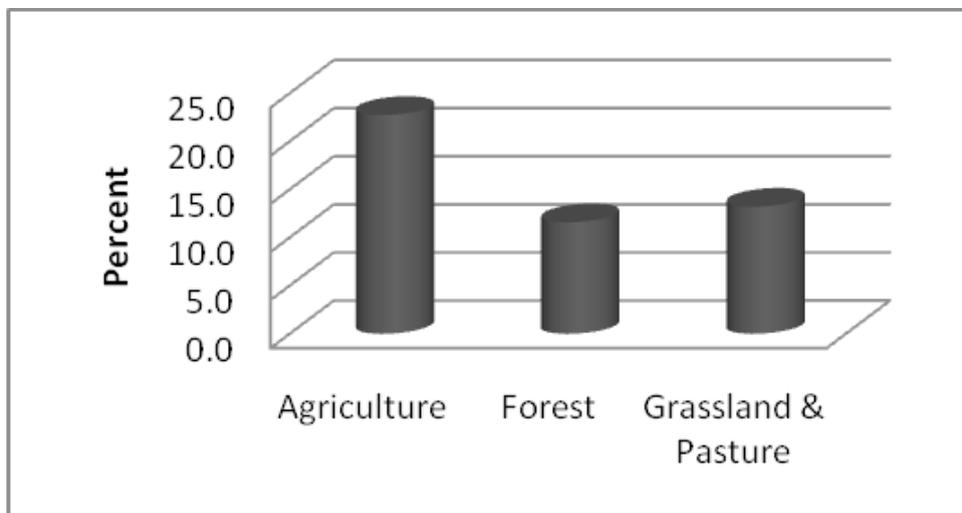


Figure 5: Average percent of coarse fragment by land use.

The proportion of coarse fragment is consistently decreasing with increasing altitude (Table 8). The maximum proportion is in similar pattern like average but minimum proportion is not consistent with elevation. The distribution of boulder and rubble is significantly different below and above 1000 meter elevation (chi-square test at 5% significance level).

Table 8: Coarse fragment by elevation.

Altitude in meter	Numbers of sample	Minimum	Maximum	Average
400 to 600	14	3.3	90.4	35.6
600 to 800	10	1.9	44.6	14.4
800 to 1000	16	3.2	26.8	12.7
1000 to 1250	10	2.5	29.5	8.8
Total	50	1.9	90.4	18.7

The proportion of coarse fragment increases with decreasing slope gradient. However, lower proportion of coarse fragment was found below 1° than higher slope gradient class 1° to 5° class. Slope gradient class 1° to 5° has the highest proportion of coarse fragment (see Table 9). The distribution of these two types of class is significantly different in the regions more than and less than 5° slope gradient. Chi-square test proves that there is significantly higher proportion of coarse fragment less than 5° slope gradient than steeper slope.

Table 9: Coarse fragments by slope gradient.

Land use	Number of samples	Minimum	Maximum	Average
0 to 1	2	6.0	76.7	41.3
1 to 5	6	9.3	90.4	53.1
5 to 30	26	1.9	44.6	14.4
30 to 60	16	2.9	29.3	10.0
Total	50	1.9	90.4	18.7

Mass-volume relationships are crucial in estimating soil fertility. The amount of gravel present in soil affects bulk density and availability of nutrients. Hence, void space occupied by gravel can hardly be ignored. The quantity of soil organic carbon and potentially available nutrients for plant uptake decreases with an increase in volume of coarse fragments (Nagaraja et al., 2016 and Poeplau, 2017). There is higher proportion of coarse fragment at lower elevation, lower slope gradient and cultivated land. These areas are less suitable for agriculture in case of the presence of higher proportion of coarse fragment. However, other suitable environment such as soil pH, soil texture class, topography, slope gradient and climate have made possible for cultivation.

Conclusion

Physicochemical properties of soil are the important components. Detail spatial information of soil properties is very essential for having sustainable agriculture and environmental management. Dominant soil texture class in the study area was found loam followed by silt loam. Remaining are sandy loam and sandy clay loam. Proportion of sand increases with increasing altitude and slope gradient and silt proportion is quite inverse which is similar to some other parts of the world. Higher proportion of sand is in steeper slope, rain fed maize field and lower proportion in agriculture land. It is natural because steeper surface faces more sheet erosion of finer material during summer rainfall. Frequent tilling of cultivated land result more contain of silt than other land cover categories. Most of the study area is slightly to moderately acidic which occupies nearly 91% of total area and very few area has neutral. Northern and western parts are more acidic than central and southeastern portion. Acidity increases with increasing altitude and slope steepness as a result irrigated paddy field have more pH than in rain fed maize field. Acidification of soil of cultivated land is resulted due to the lack of organic manure supply and because of the soil erosion due to lack of proper

management of cultivated land. Higher proportion of coarse fragment at lower elevation and lower slope gradient because of the weathered materials are deposited at lower slope gradient of lower altitude area because lowlands are more flat than the land of higher elevation. This study is limited in two sites of Lamjung district and difficult to generalize soil characteristics at larger scale. Exploring more soil characteristics with such detail spatial coverage of different parts is recommended for the future research in the field of soil science.

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