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Research Article

Evaluating the Soil Qulaity of Three Sub-Watersheds in Udayapur District, Nepal

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Abstract

The soil health of sub-watershed indicates the function of the soil which can be evaluated using the soil quality index (SQI) but research regarding this so far limited. Thus, this research was objectively done to assess the soil nutrient status and soil quality index according to soil depth and compare these values in sub-watersheds. Three sub-watersheds namely Baruwa Khola, Puware Khola and Chituwa Khola of Udayapur district were selected as the study area. The soil was extracted from 0-10, 10-20 and 20-30 cm depths so total 108 samples, 36 from each catchment were collected in W shape. The soil parameters N, P, K, C, pH, and soil texture were analysed using Kjeldahl method for nitrogen, Olsen's and Somers method for phosphorous, Flame photometric method for potassium, Walkley and Black method for carbon and pH metre for pH. The SQI was calculated by using the formula proposed by Bajracharya. The result showed that soil was moderately acidic to nearly neutral with 5.95 and 7 pH at different soil depth. The dominant textures were sandy loam and loam. Soil quality index of three sub-watersheds were fair having the values 0.73 (0-10 cm), 0.67 (10-20 cm) and 0.69 (20-30 cm) in Baruwa Khola whereas 0.71 (0-10 cm), 0.71 (10-20 cm) and 0.78 (20-30 cm) in Puware Khola, similarly, 0.65 (0-10 cm), 0.67 (10-20 cm) and 0.69 (20-30 cm) in Chituwa Khola. Available Phosphorus was high at bottom, available Potassium at 20-30 and total Nitrogen was high at the top soil associated with values 4.9 kg/ha ,252.90 kg/ha and 0.126 % respectively in Baruwakhola followed by 11.34kg/ha 360.41kg/ha and 0.197 % in Puwarekhola followed by 2.81 kg/ha, 295.68 kg/ha and 0.89% in Chituwakhola. One-way ANOVA showed that there was no significant difference in nitrogen ($p=0.013$) in Baruwa Khola sub-watershed. The value of SQI was found to be fair in all sub-watersheds Baruwakhola, Puware Khola and Chituwa Khola with 0.7, 0.73 and 0.67 respectively. This study will be useful for researcher for the further work in soil science.

Keywords: Organic Matter; Soil Nutrient Level; Soil Quality Index

Introduction

The term watershed and catchment are used when referring to broader management issues across an entire watershed, while the term sub watershed is used to refer assessment level studies and specific projects within the smaller sub watershed units. Watershed and sub watershed units for local plans are the most practical. Each watershed consists of many individual sub watersheds that can have their own distinctive targets for water resources. A catchment is an area in which water falling on or flowing across the land surface drains into a particular stream or river and flows ultimately through a single point or outlet. As the water flows over the landscape it finds its way into the streams and down into the soil, eventually feeding the river. A catchment for water is simply described as a land region around a river, lake, or other water body. Living in a catchment with healthy water can help a better quality of life for a community. A good catchment of water offers drinking water of high quality and promotes livelihoods such as agriculture, recreational fishing, and water sports.

Soil quality can be defined as the capacity of specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation [1]. Soil quality is an energetic interaction between various physical, chemical, and biological soil properties, which are influenced by many external factors such as land management, land use, the environment, and socio-economic priorities. "The SQI may also be an indicator of the potential for soil quality to change because of the influence of environmental stressors (for example, atmospheric deposition, changes in global cycles, and so forth)" [2]. Soil quality

is considered a key element of sustainable agriculture Warkentin [3] because it is essential to support and sustain crop, range and woodland production and helps maintain other natural resources such as water, air, and wildlife habitat.

"Soil quality is a complex functional concept and cannot be measured directly in the field or laboratory. A mathematical or statistical framework was put forward in early 1990s to estimate soil quality index" [4]. Soil quality index (SQI) helps to evaluate changes in the dynamic characteristics of soil induced by external variables [5]. It is used to evaluate the general soil condition and management reaction, or resilience to natural and anthropogenic forces.

Soil, water, and plants are vital natural resources that help to produce food and fiber for human. They also maintain the ecosystems on which all life on Earth ultimately depends. Soil serves as a medium for plant growth; a sink for heat, water, and chemicals; a filter for water; and a biological medium for the breakdown of wastes. In a developing country such as Nepal, where the bulk of the population is still dependent on forests and agriculture, soil quality maintenance and enhancement is a major problem. Plant growth depends directly on good soil functions. Knowledge of the spatial characterization of soil properties is required in order to find homogeneous regions for sustainable management.

The soil quality index is the significant dimension to indicate the characteristics of the soil. Good health of soil assures the water and vegetation quality as well. The healthy sub-watershed and watershed assures the healthy condition of vegetation, soil quality, nutrients, and water recharge. There is research gap to show whether, the health of the watershed and sub-watershed bad or good. Soil health parameter especially N, P, K, pH and C are very important to indicate the condition of the watershed and sub-water, but such studies are very limited in Nepal. The soil quality index is important tool to show the status of the watershed and sub-watershed. Therefore, this study was needed.

Materials and Methods

Study area

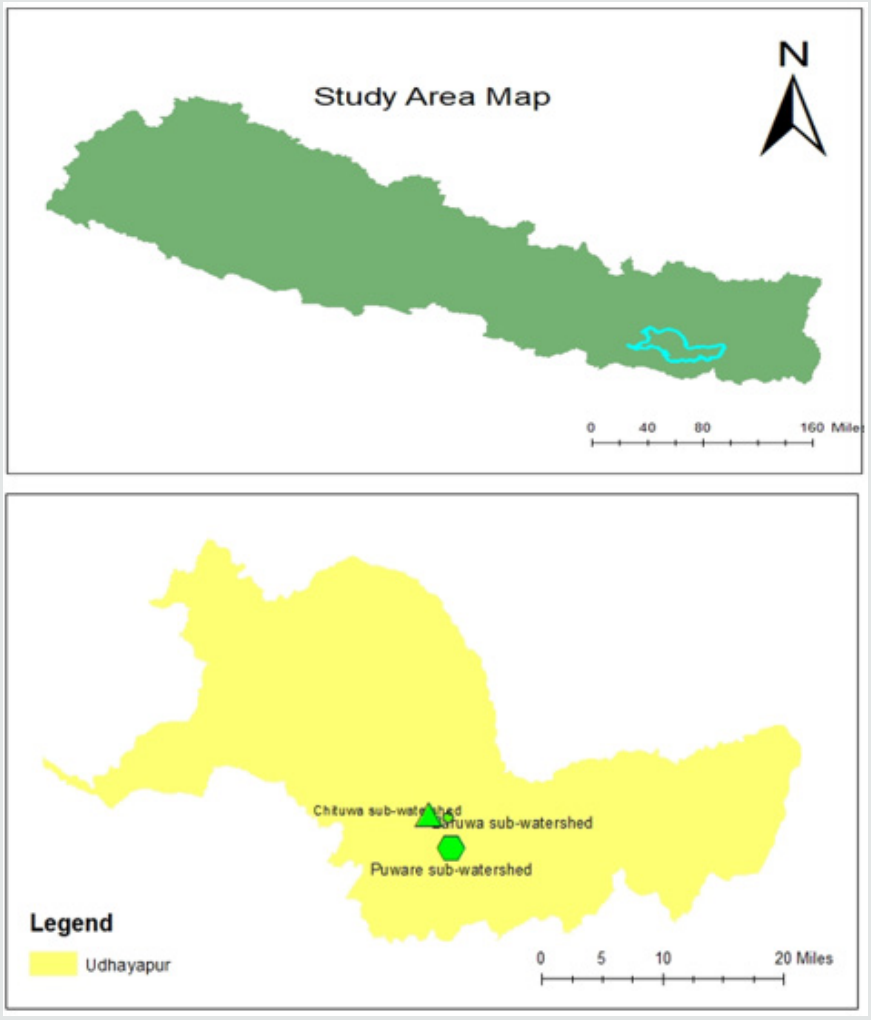

Figure 1: Study area.

Udayapur is one of the 14 districts in Eastern Nepal's No. 1 province which lies in the Chure range. It is encircled by mountains of Mahabharat from the north and Shiwalik from the south, whereas both hills meet from the west, forming a valley of Udayapur. The latitude, longitude and altitude of the district is 26° 54' 59.99" N, 86° 39' 59.99" E and 1049m.Forest cover accounts for 67% of the district's complete land region Figure 1. The district's main source of water remains small and large rivers and ponds. The district's main water resources are ponds such as Rauta Pokhari, Suke Pokhari, Tapli Pokhari, Jogidaha Chure Forest Pond and Jhilke Pokhari. Triyuga is the district's largest river. According to the census of 2011 the total population of Udaypur district is 317,532. Baruwa Khola, Chituwa Khola and Puware Khola sub-watersheds of Triyuga watershed which lies in similar altitude (1049m), latitude 26° 54' 59.99" N and longitude 86° 39' 59.99" E was selected as the study sites.

Data collection

The plots were allocated on the map. The coordinates of sample plot were uploaded in GPS receiver. Altogether 108 samples 36 from each catchment were gathered. Those soil samples extracted from simple random sampling method were taken from 0-10 cm soil profile up to 30 cm depth at interval of 10 cm and 20 cm. About 500 gm of soil was excavated and collected in polythene bag.

Lab analysis

Nitrogen was analyzed using Kjeldahl method (Bremner and Mulvaney, 1986) and Potassium was analyzed using Flame photometric method (Toth and Prince, 1949). Similarly, Phosphorous, pH, Organic carbon and Texture analysis was done using Olsen's and Somers method (1982), pH meter, Walkley and Black method and Hydrometer method, respectively.

Soil quality index was calculated by using the formula proposed by Bajracharya et al., (2006).

SQI = [(a x RSTC) + (b x RpH) + (c x ROC) + (d x RNPK)]

Where,

RSTC = assigned ranking values for soil textural class,

RpH = assigned ranking values for soil pH,

ROC=assigned ranking values for organic carbon,

RN=assigned ranking values for nitrogen,

RP=assigned ranking values phosphorus,

RK=assigned ranking values for potassium,

And a=0.2 b=o.1 c=0.4 and d=0.3 are weighted values corresponding to each of the parameter.

Statistical analysis: The result showed that the data were normally distributed so, parametric test; One way ANOVA was used to analyze the determined data.

Scoring method

The scoring method developed by NARC (1993) was used to interpret SQI Table 1. For commonly used soil parameters in Nepal were:

Table 1: Soil Quality Index based on assigned range of values suggested by NARC.

Parameters	Ranking values				
	0.2	0.4	0.6	0.8	1
Soil textural class	C,S	CL, SC, SiC	Si, LS	L, SiL, SL	Si, CL
Soil pH	<4	4.1 -4.9	5-5.9	6-6.4	6.5 -7.5
Fertility (NPK)	Low	Mod low	Moderate	Moderate High	High
SOI	Very Poor	Poor	Fair	Good	Best

Where,

C- Clay, S-Sand, CL-Clay loam, SC- Sandy Clay, SiC- Silty Clay, Si-Silt, LS-Loamy sand, SiL- Silty loam, SL-Sandy loam, LS Loamy Sand, SiL-Silty loam, SL-Sandy loam, SiCL -Silty Clay loam, SCL- Sandy Clay loam, SQI-Soil Quality Index.

Interpretation table for Soil pH

Strongly acidic is <4.5 pH but the pH values 4.5-5.5, 5.5-6.5, 6.5-7.5 and >7.5 pH wer weakly acidic, moderately acidic, nearly neutral, and alkaline, respectively.

Soil fertility ranking was done using NARC guideline Table 2.

Table 2: Soil Fertility in soil (NARC).

OM (%)		N(kg/ha)		P(kg/ha)		K(kg/ha)	
Range	Level	Range	Level	Range	Level	Range	Level
<2.5	Low	<0.1	Low	<31	Low	<110	Low
2.5-5	Medium	0.1-0.2	Medium	31-55	Medium	110-280	Medium
>5.0	High	>0.2	High	>55	High	>280	High

Results and Discussion

Status of soil nutrient according to soil depth in sub-watersheds

The soil nutrients were varied according to sub watersheds. The Table 3 showed that the Baruwa Khola sub-watershed had the highest value of nitrogen in 0-10 cm soil depth with the value 0.126%, maximum 0.194% and minimum 0.067% whereas the lowest was 0.09% in 10-20 cm and 20-30 cm depth, respectively. The highest phosphorous was 4.9% in 20-30 cm depth and lowest was 1.803% in 0-10 cm soil depth. Similarly, the highest potassium was 252.90% at 10-20 cm soil depth and lowest was 116.83% in 20-30 cm soil depth.

Table 3: Status of soil nutrient according to soil depth in all sub-watersheds.

Depth		Statistics			Baruwa Khola		Puware Khola		Chituwa Khola	
		N%	P kg/ha	K kg/ha	N%	P kg/ha	K kg/ha	N%	P kg/ha	K kg/ha
0-10	Mean±S.E	0.126±0.01	1.803±0.52	139.47±9.4	0.197±0.02	4.66±1.01	150.66±16.65	0.082±0.01	1.096±0.18	100.79±9.61
	Max	0.194	6.02	207.2	0.365	12.34	261.3	0.134	2.08	186.8
	Mini	0.067	0.48	96.5	0.05	0.6	53.95	0.013	0.4	61.05
	S.D	0.036	1.803	32.56	0.093	3.514	57.68	0.035	0.637	33.31
10-20	Mean±S.E	0.09±0	2.13±0.66	252.90±18.58	0.16±0.002	8.05±2.46	239.86±42.912	0.089±0.01	1.06±0.13	211.34±33.31
	Max	0.168	8.64	387.6	0.363	1	487.02	0.161	2.1	455.5
	Mini	0.054	0.6	167.7	0.067	32	27	0.047	0.5	110.6
	S.D	0.029	2.29	64.39	0.094	8.54	148.65	0.036	0.5	115.41
20-30	Mean±S.E	0.09±0	4.9±1.57	116.83±10.77	0.196±0.021	11.34±2.81	360.41±55.15	0.072±.008	2.81±0.43	295.68±43.08
	Max	0.148	16.8	202.7	0.309	30.36	842.25	0.108	7.02	697.2
	Mini	0.054	0.24	66.4	0.108	1.5	163.95	0.007	1.2	168.6
	S.D	0.027	5.45	37.325	0.073	9.75	191.06	0.03	1.52	149.23

The Puware Khola sub-watershed had the highest value of nitrogen in 0-10 cm soil depth with the value 0.197%, maximum 0.365% and minimum 0.05% whereas the lowest was 0.16% in 10-20 cm depth. The highest phosphorous was 11.34% in 20-30 cm depth and lowest was 4.66% in 0-10 cm soil depth. Similarly, the highest potassium was 360.41% at 20-30 cm soil depth and lowest was 150.66% in 0-10 cm soil depth.

The Chituwa Khola sub-watershed had the highest value of nitrogen in 0-10 cm and 10-20 cm soil depth with the value 0.08%, whereas the lowest was 0.07% in 20-30 cm depth. The highest phosphorous was 2.81% in 20-30 cm depth and lowest was 1.06% in 10-20 cm soil depth. Similarly, the highest potassium was 295.68% at 20-30 cm soil depth and lowest was 100.79% in 0-10 cm soil depth Table 3. Similar study was done by Nepal and Mandal [6] where research was objectively carried out to identify the variation of different soil properties as AK, AP, TN, Soil Organic Matter and soil pH according to depth. Available Phosphorus, Available Potassium and total Nitrogen was high at the top soil associated with values 31.31 kg/ha ,435.74 kg/ha and 0.15 % respectively in Bade khola catchment of Doti district followed by 10.67 kg/ha 370.24 kg/ha and 0.234 % in Brindaban catchment of Baitadi district. Total Nitrogen, available Potassium and available Phosphorus were gradually decreased with increasing in soil depth at both districts of catchments.

Soil texture in sub watersheds according to its depth

The Table 4 showed that the highest clay was 23.62% at 10-20 soil depth whereas the lowest clay was 21.28% at 0-10 cm soil depth in Baruwa Khola sub-watershed. The highest sand in Baruwa Khola was 46.63% at 0-10cm depth and lowest was 43.88% at 20-30 cm depth. Similarly, the highest silt was 32.08% at 0-10 cm depth and the lowest silt was 30.50% at 10-20 cm soil depth. The highest clay in Puware Khola sub-watershed was 7.04% at 0-10 cm depth and the lowest was 3.37% at 20-30 cm depth. Similarly, the highest sand was 84.21% at 20-30 cm depth and the lowest sand was 81.38% at 0-10 cm depth. Likewise, the highest silt was 12.50 at 10-20 cm depth and lowest was 11.58% at 0-10 cm depth. The highest clay in Chituwa Khola sub-watershed was 25.54% at 20-30 cm depth and the lowest was 20.12% at 0-10 cm depth. Similarly, the highest sand was 46.46% at 0-10 cm depth and lowest was 43.29% at 10-20 cm soil depth. Likewise, the highest silt was 33.42% at 0-10 cm soil depth and lowest was 30.58% at 20-30 cm depth.

Table 4: Soil texture of three sub-watersheds.

Sub-watersheds	Soil texture (%)	Soil Depth (cm)		
		0-10	10-20	20-30
Baruwa Khola	Clay	21.28	23.62	24.71
	Sand	46.63	45.88	43.88
	Silt	32.08	30.5	31.42
Puware Khola	Clay	7.04	4.96	3.37
	Sand	81.38	82.54	84.21
	Silt	11.58	12.5	12.42
Chituwa Khola	Clay	20.12	24.04	25.54
	Sand	46.46	43.29	43.88
	Silt	33.42	32.67	30.58

N, P, K, pH, OC and texture of three sub-watersheds according to its depth

The Table 5 showed that the highest nitrogen in Baruwa Khola sub-watershed was 0.13% at 0-10 cm depth and lowest was 0.09 at 10-20 and 20-30 cm depth. Similarly, the highest phosphorous was 4.90kg/ha in 20-30 cm depth and lowest was 1.80kg/ha at 0-10 cm depth. Likewise, the highest potassium was found to be 350.51kg/ha at 20-30 cm depth and lowest was 139.47kg/ha at 0-10 cm depth. Moreover, the OC was 8.33% at all the depth. The pH value was highest at 0-10 cm depth with 6.32 and lowest was 6.02 at 20-30 cm depth. The soil texture showed the loam in nature. The highest nitrogen in Puware Khola sub-watershed was 0.20% at 0-10 cm and 20-30cm depth and lowest was 0.17 at 10-20 cm depth. Similarly, the highest phosphorous was 11.35kg/ha in 20-30 cm depth and lowest was 4.67kg/ha at 0-10 cm depth. Likewise, the highest potassium was found to be 360.41kg/ha at 20-30 cm depth and lowest was 150.66kg/ha at 0-10 cm depth. Moreover, the OC was 8.33% at all the depth. The pH value was highest at 20-30 cm depth with 7 and lowest was 6.94 at 0-10 cm depth. The soil texture showed the loamy sand in nature.

Table 5: N, P, K, pH, OC, and texture of sub-watersheds.

Sub-watersheds	Parameters	Unit	Depth (cm)		
			0-10	20-Oct	20-30
Baruwa Khola	N	%	0.13	0.09	0.09
	P	kg/ha	1.8	2.14	4.9
	K	kg/ha	139.47	252.91	350.51
	pH	Value	6.32	6.09	6.02
	OC	%	8.33	8.33	8.33
	Texture		Loam	Loam	Loam
Puware Khola	N	%	0.2	0.17	0.2
	P	kg/ha	4.67	8.05	11.35
	K	kg/ha	150.66	239.86	360.41
	pH	Value	6.94	6.98	7
	OC	%	8.33	8.33	8.33
	Texture		Loamy sand	Loamy sand	Loamy sand
Chituwa Khola	N	%	0.08	0.09	0.07
	P	kg/ha	1.1	1.07	2.81
	K	kg/ha	100.79	211.34	295.69
	pH	Value	6.2	6.09	6.25
	OC	%	8.33	8.33	8.33
	Texture		Loam	Loam	Loam

The highest nitrogen in Chituwa Khola sub-watershed was 0.09% at 10-20cm depth and lowest was 0.07 at 20-30 cm depth. Similarly, the highest phosphorous was 2.81kg/ha in 20-30 cm depth and lowest was 1.07kg/ha at 10-20 cm depth. Likewise, the highest potassium was found to be 295.69kg/ha at 20-30 cm depth and lowest was 100.79kg/ha at 0-10 cm depth. Moreover, the OC was 8.33% at all the depth. The pH value was highest at 20-30 cm depth with 6.25 and lowest was 6.09 at 10-20 cm depth. The soil texture showed the loam in nature.

Soil Quality Index

The Table 6 showed that the Soil Quality Index value of Baruwa Khola was highest with 0.73 in 0-10 cm soil depth and lowest was 0.67 at 10-20 cm soil depth. Similarly, the SQI value of Puware Khola sub-watershed was highest with 0.78 at 20-30 cm soil depth and lowest was 0.71 at 0-10 cm and 10-20 cm depth. Moreover, the SQI of Chituwa Khola sub-watershed was highest with the value 0.69 at 20-30 cm soil depth and lowest was 0.65 at 0-10 cm soil depth.

Table 6: Soil Quality Index of sub-watersheds.

Sub-watersheds Soil depths	SQI Value	Condition	Remarks
Baruwa Khola	0-10	0.73	Fair
	10-20	0.67	Fair
	20-30	0.69	Fair
Puware Khola	0-10	0.71	Fair
	10-20	0.71	Fair
	20-30	0.78	Fair
Chituwa Khola	0-10	0.65	Fair
	10-20	0.67	Fair
	20-30	0.69	Fair

Table 7: Comparison of soil nutrients.

Sub-watersheds	Nutrients	Applied test	P- Values & subsets
Baruwa khola	Nitrogen	ANOVA	0.013
	Phosphorous	ANOVA	0.081
	Potassium	ANOVA	p=0.000
		Tukeys B	Subset (1)
			Subset(2)
			Subset(3)
Puware khola	Nitrogen	ANOVA	p=0.612
	Phosphorous	ANOVA	p=0.124
	Potassium	ANOVA	p= 0.004
		Tukeys B	Subset(1,2)
			Subset(3)
Chituwa khola	Nitrogen	ANOVA	p= 0.488
	Phosphorous	ANOVA	p=0.000
		Tukeys B	Subset(2,1)
			Subset(3)
	Potassium	ANOVA	P=0.001
		Tukeys B	Subset(1)
			Subset(2,3)

One way ANOVA showed that there was no significant difference in nitrogen (p=0.013) in Baruwa Khola sub-watershed, since p was greater than 0.005 and there was no significant difference in phosphorous (p=0.081) as well, since p was greater than 0.005 but there was significant difference in potassium (p=0.000), since p<0.005. On the other hand there was no significant difference in nitrogen (p=0.612) and phosphorous (p=0.124) in Puware Khola sub-watershed since p value is greater than 0.005 but it was significant difference in potassium (p=0.004), since p<0.005. In case of Chituwa Khola sub-watershed, it was no significant difference in nitrogen (p=0.488), since p value is greater than 0.005 while there was significant difference in phosphorous and potassium (p=0.000) and (p=0.001) respectively Table 7.

The Table 8 showed the comparison of SQI among sub-watersheds. The differences in SQI values between Baruwa Khola and Puware Khola was 0.03 whereas this was 0.06 between Puware Khola and Chituwa Khola and similar difference was between Baruwa Khola and Chituwa Khola.

Table 8: Comparison of Soil Quality Index.

Sub-watersheds	Averaged SQI value	Comparison of sub-watersheds(differences)		
		Baruwa & Puware	Puware &Chituwa	Baruwa & Chituwa
Baruwa Khola	0.7	0.03	0.06	0.06
Puware Khola	0.73			
Chituwa Khola	0.67			

Similar study was done by Ghimire, Bhatta, Pokhrel, & Shrestha [7] where Soil quality index (SQI) was determined on the basis of the soil physiochemical parameters. Soil properties like soil pH, organic matter (OM), available potassium (AK), total nitrogen (TN) and available phosphorous (AP) were significantly affected by land uses types. Forest soil had the highest soil quality index (0.82) followed by khet (0.64), bari (0.66) and degraded land (0.40).

Comparing the SQIs between the forest lands, agriculture land, Kharland land, alluvial soil colluvial soil according of their soil depth 0-10 cm and 10-30 cm the results validated that anthropogenic disturbances and heavy grazing could be reason of significantly lower the soil quality levels. Awasthi, Singh, & Sitaula [8] reported that SQI value was the highest at undisturbed forest land (0.69) and lowest at Khet land (0.17) in Mardi watershed of Middle Mountain. Forest was about twice as high as that of forest with free grazing, because in the latter forest category people extract firewood, timber, leaf litter and fodder leading to the negative impact on soil quality [9-21]. 10-30 cm lands with lowest SQI score of 1.03 indicated immediate need for soil restoration and fertility management practices for sustainable productivity [22-36].

Similar study was done by Nepal & Mandal [6] showed that the soil quality index of were the best having the values nearly 1.39 (0-10 cm) and 1.06 (10-30 cm) in Bade khola catchment of Doti district where as 1.3 (0-10 cm) and 1.432 (10-30 cm) in Brindaban catchment of Baitadi district [37].

Conclusion and Recommendation

The highest amount of soil nutrient (N and P) was found in 0-10 cm soil depth, getting decrease in 10-20cm and 20-30 cm depth respectively whereas the highest potassium was found in (20-30) cm depth followed by (10-20) cm and (0-10) cm respectively. The soil texture of Baruwa Khola and Chituwa Khola sub-watershed was found to be loam whereas the texture of Puware Khola sub-watershed was found to be loamy sand. The percentage of sand was found to be highest in Puware Khola among the sub-watersheds but less clay % in Puware Khola. The soil quality index of Puware Khola was the highest and it was followed by Baruwa Khola and Chituwa Khola sub-watersheds. This all indicated the fair soil quality. The soil quality index tools shall be used to assess the quality of soil in different sub-watersheds in Nepal. The soil quality index and forest condition can be used together for the option of the sub-watershed management.

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