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Soil Quality Variation under Different Land Use Types in Haramosh Valley, Gilgit, Pakistan

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Abstract: Soil quality is a fundamental component of environmental quality and impact of land use is also a key detrimental factor in today's rapid urbanization era. The study aims to evaluate the effects of different land-use type on selected soil quality indicators. Sixty soil samples were collected from various land use types, i.e, pasture, forest and agriculture from a depth of 0-15cm. Analysis of variance (ANOVA) showed that the land use type significantly affected the soil's physical and chemical properties. The moisture content was significantly higher ($p<0.001$) in the pasture (41.7%) than the forest (26.2%) and lowest in agricultural land (14.4%). The soil pH was significantly higher or slightly alkaline for agriculture (7.8), while for pasture (6.5) and forest (6.1), it was found to be slightly acidic. Electric conductivity (EC) and bulk density (BD) did not vary significantly with land use type, but the EC followed the decreasing order: forest (203.7µS/cm) < pasture (235µS/cm) < agriculture (328.7µS/cm). The soil organic matter (SOM) and soil organic carbon (SOC) significantly ($p<0.05$) differed with land use type and found in the order: forest (3.0%, 1.3 %) > pasture land (2.9%, 1.2%) > arable land (2.5%, 1.1%). NO_3-N, available P and exchangeable K did not vary significantly across land use types. However, mean values were higher for agriculture (10.2mg/kg, 4.5mg/kg, 66mg/kg) than forest (10mg/kg,3.5mg/kg, 60mg/kg) and pasture (9.8mg/kg, 4.3, 60.2mg/kg). Alpine soils are good ecological indicators because of vulnerability to environmental change, therefore, regular monitoring of soil properties along with carbon stocks is essential to maintain soil health, enhance agricultural productivity and sustain agro-ecosystems.

Keywords: Soil organic carbon, pH, land use, pasture, forest.

Introduction

Degradation of natural resources has been an emerging issue especially in developing countries like Pakistan in general and Gilgit-Baltistan in particular due to human activities, extreme weather events and fragile mountain ecosystem. Intensification of agricultural land, conversion of marginal land into agriculture, unsustainable use of the forests, urbanization and construction of roads have been recognized as the main practices that lead to a decline in soil fertility in the Gilgit-Baltistan. In developing countries, the land use change is very rapid, particularly in the Hindu-Kush Himalayan (HKH) ranges due to socioeconomic and biophysical factors (Upadhyay et al., 2005). Improved management of soil in developing countries offers a win-win situation both for environment and society (Lal, 2000).

Through the bio-geochemical cycle, healthy soils transform chemicals, filtered ground water regulate climate and act as a safeguard against environmental shocks (Keesstra et al., 2012). According to Gulvik, (2007) sustainability and conservation of biodiversity and natural resources in an ecosystem are observed through the soil. For agriculture sustainability, soil quality is considered a vital component and can be defined as "the fitness of a particular type of soil to perform its functions, in a natural and managed ecosystem, to sustain organisms' productivity, regulate air and water quality, support human health and habitat (Karlen et al. 1997, 2003, 2004). To feed the growing population, soils are very important and essential for terrestrial productivity (Pappendick and Parr, 1992). Houghton et al. (1999) pointed out that land use change, such as cultivation, forest clearing and introduction of pastures, results in changing soil's biological, physical and chemical properties. The key drivers of environmental change are land use pattern and natural processes which influence natural resources including the soil properties. Due to poor management of land, massive areas have been degraded, reduced the ability to produce enough food, and is a major threat to rural livelihood in many developing countries (Braimoh and Vlek, 2008). According to Sturz and Christie, (2003) assessment of soil quality is a valuable tool for evaluating soil health status, to understand natural and anthropogenic pressures. Understanding soil quality due to change in land use is essential for sustainable land management plan (Teferi et al., 2016).

Gilgit-Baltistan (GB) is situated between 35º-37º N and 72º-75º E of Pakistan and the border with China through Xinxiang province. It is a mountainous range with minimum elevation of 1500m and most of the area is located above the 4,500m sea level. It covers an area of 72496 km^2, in which approximately 1.5million people are residing in the GB, with the density of 10 persons/ km^2. About 0.96% (69,480 hectares) of land is cultivable whereas, approx. 60,000 hectares is barren, which could be cultivable land and the rest is comprised of mountains, rangeland, lakes/rivers and forests etc. The per capita land holding is 0.124 hectares, which is declining due to urbanization (IUCN, 2003). Mountainous landscapes have serious problems of soil degradation and deforestation. In the last few years, the problem has been intensifying due to increase in population growth leading to land scarcity in the fragile mountains. Haramosh valley has spectacular landscape and is very famous due to Alpine lakes, glaciers, lush green Alpine pasture, forest for timber production and medicinal plants. Abbas et al. (2014) reported that medicinal plants are over-harvested for commercial and domestic purpose without any conservation policy. With increase in population, human settlements on slopes, overgrazing and deforestation may cause depletion of natural habitats. Thus, there is a dire need for better management of soil for the conservation of mountain ecosystems and food security. This study is aimed at evaluating the impact of different land use types on selected soil quality properties.

Materials and Methods

Study Area

The study was carried out in Haramosh valley of district Gilgit situated in the northern side of Indus river, as it has unique vegetation due to diversified topography. The area is also famous for medicinal plants and fruits. The valley is 4km away from Gilgit city and on the way to Skardu, Baltistan region (Fig. 1). According to phyto-geographical distribution, this area is located in the eastern Irano-Turanian sub-region. The valley consists of four ecological zones; Alpine zone, Sub Alpin e zone, dry Temperate mountain zone and sub Tropical desert area (Khan and Khatoon, 2007). Common land use types are forest, Alpine pasture, arable land (cropping land) and fruit orchard. In agricultural land, farmers grow two crops per year and the agricultural land is located at somewhat lower elevations as compared to forest and pasture.

Soil Sampling

Soil samples were collected from three different land use types, i.e., forest, pasture and arable land to determine selected soil physico-chemical properties. GPS was used to record the longitude, latitude and elevation at each land use type. Agriculture soil samples were collected from Dasso village located slightly at low elevation (6130-6532ft) while forest and pasture samples were collected from the Kutwal area, at the elevation of (9764-10286ft) and (10684-10935ft). At each land use type, twenty replicate plots (3*20 = 60) were selected by stratified random sampling to ensure representative samples for statistical analysis. Samples were collected from the 0-15 cm layer using spade or shovel. From each replicate plot, core sample was collected for determination of bulk density, using core ring (100 cm^3). Soil samples were sealed in Ziploc bag and immediately brought to the laboratory for further processing.

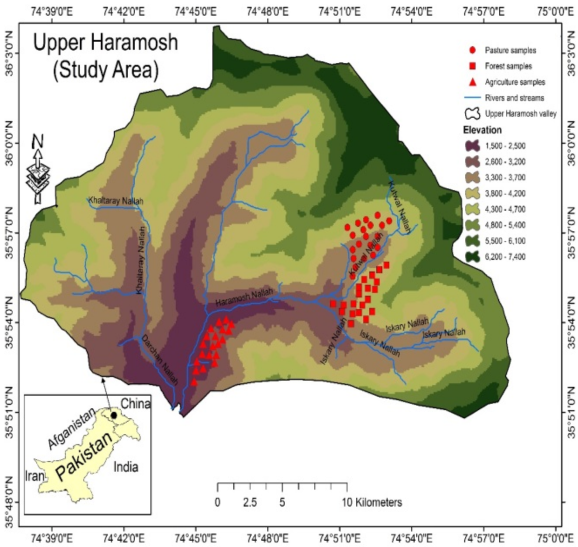

Fig. 1 Study area sample locations (Harmosh watershed).

Laboratory Analyses

Soil samples were air-dried and passed through 2-mm sieve to remove roots and stones. Core method was used to determine bulk density (Black and Harte, 1986) and gravimetric method to measure soil moisture. EC was determined by using electrical conductivity meter, 1:5 soil: water ratio (Rayment and Higginson, 1992). pH meter was used to measured soil pH, soil: water ratio 1:1 (Mc lean, 1982). Dry combustion methods (Nelson and Sommers, 1982) were used for determination of Soil Organic Matter (SOM), and Soil Organic Carbon (SOC), Nitrate Nitrogen **(**NO_3-N), Exchangeable Potassium (Ex. K) and Available Phosphorus (Av. P) were measured by Ammonium bicarbonate diethylene triamine penta acetic acid (AB-

Table 1. One-way ANOVA of soil properties with respect to land use.

	Soil moisture (%)	Bulk density (g/cm^3)	pH	EC (uS/cm)	SOM (%)	SOC (%)	NO3-N mg/kg	Av.P mg/kg	Ex.K mg/kg
Land use	11.8***	1.9^{NS}	174.6***	17.0***	3.9*	3.9*	0.40^{ns}	0.50^{ns}	0.60^{ns}

Note: *, **, ***, and "ns" indicates p<0.05(5%), p< 0.01(1%), p<0.001 and non-significant respectively.
SOC; Soil Organic Carbon, SOM; Soil Organic matter, EC; Electric Conductivity.

DTPA) extractable method according to Sultan pour and Schwab (1977).

Statistical Analysis

To determine the effect of soil physico-chemical parameters under different land uses, Analysis of Variance (ANOVA) was used. Post-hoc test such as least significant difference (LSD) test was applied to compare mean difference.

moisture was significantly different between agriculture and pasture, agriculture and forest, forest and pasture soil (Table 3).

Soil bulk density is an important indicator for seedling establishment, root penetration and crop growth, which determines the compactness of the soil. It is influenced by soil texture, the quantity of organic matter, porosity and constituent minerals, therefore understanding that bulk density is vital for soil management, as well as in the planning of farming techniques (Chaudhari, 2013). Our results showed that bulk density was not statistically and significantly different among various land use types. However mean values were slightly higher at pasture (0.89g/cm^3) followed by agriculture (0.84g/cm^3) and lowest at the forest (0.89g/cm^3) (Table1-3). The overall bulk density in all land use types is low. Bulk density under cultivated land was found to be high due to damaging effects (Islam and Weil, 2000) and increase in SOM lowers bulk density (Patil and Jagdish, 2004). Increase in bulk density in agriculture land was reported by many researchers (Begum et al., 2009, 2010, 2013). Soil pH is one of the important indicators of soil quality affects the availability of nutrients thus influencing the growth of plants (Shar et al., 2018) and helps to identify the impact of change in land use affecting other physiochemical properties (Idowu, et al., 2009). Soil pH significantly varied ($p<0.05$) between agriculture and pasture, agriculture and forest, pasture and forest (Table 3). Mean pH was statistically higher or alkaline in agricultural land (7.8) than pasture (6.5), and lowest in forest (6.1). Similar results were reported by Yimer et al. (2007) for cultivated land pH was higher as

Table 2. Descriptive statistics of different soil properties.

	Moisture (%)	Bulk Density (g/cm^3)	pH	EC (uS/cm)	SOM (%)	SOC (%)	NO3-N mg/kg	Av.P mg/kg	Ex.K mg/kg
AG	14.4	0.84	7.8	328.7	2.5	1.1	10.2	4.5	66
FR	26.2	0.72	6.1	203.7	3.0	1.3	10	3.5	60
PA	41.7	0.89	6.5	235	2.9	1.2	9.8	4.3	60.2

Note= *** ($p<0.001$), ** ($p<0.01$), * ($p<0.05$) and ns show not significant

AG: Agriculture FR: Forest PA: Pasture

Table 3. Post hoc test (LSD) to compare mean differences between land use types

	Soil moisture (%)	Bulk density (g/cm^3)	pH	EC (uS/cm)	SOM (%)	SOC (%)
AG vs FR	11.9*	0.12	1.6*	125.0*	0.6*	0.3*
AG vs PA	27.4*	0.05	1.25*	93.8*	0.5	0.2
FR vs PA	15.5*	0.16	0.40*	31.2	0.15	0.06

Note= *** ($p<0.001$), ** ($p<0.01$), * ($p<0.05$) and ns show not significant

Results and Discussion

Land use affects physico-chemical properties of the soil as studied by various authors (Begum et al., 2009, 2010, 2011, 2013, 2014; Ali et al., 2017; Ishaq et al., 2015) Analysis of variance (ANOVA) showed that except bulk density other investigated soil parameters such as pH, EC, moisture, SOM and SOC were statistically different with land use type (Table 1).

Soil moisture is a key variable for climate, plant growth, water uptake and evapo-transpiration from vegetation and soil to the atmosphere, thus affecting distribution of precipitation and clouds. It also helps in predicting the drought, flood, surface temperature and future climate change (Robock, 2015). It influences the biological and physico-chemical properties of the soil, rate of soil processes, removal, and accumulation of inorganic and organic compounds, which is mostly dependent on the soil moisture (Lvova and Nadporozhskaya, 2017). Soil moisture was significantly higher at pasture (41%) than forest (26%) and lowest at agriculture (14.4%) as expected (Table 1, 2). Similar results were reported by Begum et al, (2009, 2010, 2013). Post hoc test (LSD) indicated that compared to grazing and forest. Similar results of higher soil pH compared to forest land were reported by Begum et al. (2009, 2010, 2011, 2013, 2014).

Electrical conductivity (EC) of soil is a chemical property that reflects the ability of material to conduct an electrical current (Ouhadi and Goodarzi, 2007). It is indicator of the number of ions present in the soil. The EC mean values were significantly different ($p<0.5$) among forest, pasture and agricultural land (Table 2). EC was significantly higher in the agriculture (328.7µS/cm) followed by pasture (235µS/cm) and found lowest in forest soil (203.7µS/cm). Khan et al. (2004) reported 0.06 to 0.5 ds/m EC values from different parts of Gilgit. Adequate levels of EC are important for sustaining soil fertility and the decrease in organic matter content contributes to low EC in agricultural land causing soil degradation (Nega and Heluf, 2009).

Land use and vegetation cover have a significant impact on SOC dynamics through the input of organic carbon, the process of decomposition and stabilization of organic matter (Dorji et al., 2014). Organic carbon is considered to be the best single indicator for assessing soil quality (Tiwari et al., 2006). Soil organic carbon in the forest (1.1%) was significantly higher followed by pasture (1.2%), and observed to be lowest in agricultural land (2.5%). Mean SOC significantly varied between forest and agriculture but did not significantly differed between pasture & agriculture, forest & pasture (table 2). Kizilkaya and Dengiz, (2010) as well as Mojori et al., (2011) reported decreased levels of organic carbon content in agricultural soil compared to natural forest as a result of crop harvesting and soil manipulation. Decreased contents of carbon in cultivated land than forest and grazing land has been reported by numerous authors **(**Yimer et al., 2007**;** Gol, 2009**).**

Nitrogen is an essential component of soil fertility and is applied in the form of ammonium nitrate in agricultural soil (Gee, 2013). NO_3-N, Av. P and Ex. K were not statistically significant with the land use type. However, mean values of NO_3-N, Av. P and Ex. K was higher in the agriculture than forest (Table 1, 2, 3). It was observed during the sampling and interaction with farmers, who used chemical fertilizers along with the cattle manure to maximize productivity of the crop. Similar findings were reported by Bajracharya and Sherchan, (2009) in Nepalese soil in which total N, Av.P and Ex.K did not show variation between land uses. Higher nutrient reserves (NPK) in agricultural land than forest was reported by Tiwari et al. (2006) as an exception due to forest degradation in the mid hills of Nepal.

Pearson correlation shows that soil pH was negatively correlated ($p<0.05$) with soil moisture, SOM, and SOC, as expected and positively correlated with EC. Similar findings of negative relationship of pH with moisture, SOM and SOC were reported by Begum et al. (2010). Further, SOM and SOC were also negatively correlated with EC (Table 4).

Table 4. Correlation matrix among different parameters in various land use practices.

	Soil moisture **(%)**	Bulk density **(g/cm^3)**	pH	EC**(uS/cm)**	SOM **(%)**	SOC **(%)**
Soil moisture	1					
Bulk density	-.056	1				
pH	-.514*	.192	1			
EC	-.390	.078	.766**	1		
Soil organic matter	.234	.057	-.469*	-.898**	1	
Soil organic carbon	.234	.057	-.469*	-.898**	1.000**	1

Note= *** ($p<0.001$), ** ($p<0.01$), * ($p<0.05$) and ns shows not significant

Conclusion

Present study revealed the differences in the soil's physico-chemical properties with land use type (forest, cultivated and grazing). There was a significant difference in soil moisture content, pH, EC, organic matter and organic carbon among three different land cover types. SOC was negatively affected by cultivated land while NO_3-N, Av. P and Ex. K were high in agricultural land due to the input of chemical fertilizer. Higher SOC and SOM parameters in forest soil indicated higher soil quality or soil health. Based on our investigated soil properties (SOM, SOC and pH) good soil quality can be designated to the forest compared to pasture. While, the lowest quality was observed for agricultural land. Regular monitoring of soil properties, along with carbon stocks is needed to maintain soil health and enhancing agricultural productivity and sustain agro-ecosystem.

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