Research & Reviews: Journal of Microbiology and Biotechnology
e-ISSN:2320-3528
p-ISSN:2347-2286

Spatio-Cliamtic Variability in Soil Physical Properties and Bioavailability of Potassium Under Different Land Use Systems

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Research Article

Received date: 24/10/2016

Accepted date: 27/02/2017

Published date: 06/03/2017

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Keywords: Climate, Parent material, Bioavailability, Soil physical properties, Potassium, Land use systems

ABSTRACT

The current study was conducted to determine the effects of climatic regimes on crop yield under different land use systems to explore the variations in soil nutrients bioavailability and climate on vegetation. Through this research we explored a piece of scientific information about the physical properties of soil. Soil physical properties and bioavailability of labile potassium were studied in relation to varying locations, land use systems and climatic regimes selected on the basis of difference in their temperature, precipitation and altitude in Pakistan. The 30 years (1980-2010) climatic trend analysis of the two regimes revealed significant changes that probably may have significant impact on the soil nutrients and subsequent production and farming practices. The soluble and extractable form of K+ was assessed through deionized water and ammonium acetate extraction and total form of elements was determined by acid digestion using nitric acid and hypchloric acid (HNO_3 and $HClO_4$) at 1:5 ratios. Soils of different land use systems were found neutral to alkaline in nature, except few forest and rangeland soils that were slightly acidic in nature. The pH and EC values in the two climatic regimes were like Cultivated land>rangeland>forestland. Of the two regimes, the highest pH and electrical conductivity (EC) values were found for Ghanche cultivated land (i.e. pH 8 and EC 0.9 dSm-1) in Gilgit Baltistan and lowest pH and EC values were for Astore forest land soil (i.e. pH 5.7) and Skardoo forest land soil (i.e. 0.024 dSm-1) respectively. Similarly in climatic regime II; Hazara division the highest pH and EC values were of haripur cultivated land soil (i.e. 7.8 and 0.56 dSm-1) and lowest value was for Abbottabad forest (i.e. 6.5 and 0.21 dSm-1). Moreover, cultivated lands of Hazara division found relatively higher EC values than that of Gilgit Baltistan division. Analysis of variance (ANOVA) at 0.5 level of significance revealed significant variations in various soil physical properties and the concentration of K+. The altitude data obtained also revealed the highest altitude in climatic regime-I for district Astore 2546 m and in Climatic regime-II for Abbottabad i.e. 1250 m. All these variations are attributed to the parent material, altitude, soil texture, pH and land use practices.

INTRODUCTION

Spatial variability of soil properties is related to the combined action of physical, chemical and biological processes as well as anthropogenic land use patterns, which vary in space land time across the landscape [1]. Soils, as a medium for plant growth, can be affected in several ways and long term substantial deviation from present climate because of variations in weather and climatic elements due to some natural and anthropogenic activities/phenomena. In the present context of climate change, there lies a possibility of decrease in crop yield in tropical and subtropical agriculture in future. Human activities are also leading the changes in the global environment at virtually unprecedented rates, with potentially severe consequences to our future life [2]. The integral influence of climate–hydrology–vegetation–land use changes are reflected by the field water balance and soil moisture regime [3,4]. Climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides. Greenhouse gases (CO_2, methane, nitrous oxide), water vapors are present in a very small quantities in the atmosphere that absorb the heat radiated from the earth's surface to the atmosphere and thus emit some of the heat to the earth's surface. Tillage practices and alternative fallow can be used in response to climate change-related moisture and nutrient deficiencies. This fact offers possibilities for the elaboration of efficient measures for adaptation to the predicted climate change scenarios preventing, or at least moderating their unfavorable consequences [2,5-7]. Climate variability and climate forcing not only affects crop production but also affects the movement of water and nutrients in soils [8]. Carbon sequestration in agricultural soils is also liked to be affected by climate change [9]. Potassium (K^+) is an essential nutrient for growth in plants, crops and trees. As large amounts are absorbed from the root zone and utilized for the production of most of the agronomic crops, it is classified as a macronutrient. Soil commonly contains over 20000 ppm of total K^+. Potassium dissolved in the soil water available for plants are often less than 100 ppm [10] and involved in many plant metabolism reactions, ranging from lignin and cellulose used for formation of cellular structural components and regulation of photosynthesis and production of plant sugars that are used for various plant metabolic needs. It controls water loss from trees and is involved in overall tree health. Soils that have adequate potassium allow trees to develop rapidly and outgrow tree disease, insect damage and protect against winter freeze damage [11]. Most Pakistani soils are mica based; due to continuous weathering, intensive cropping and K^+ release, these soils are generally converted to illite and vermiculite-dominant clay minerals. Pakistan is located in the sub-tropical zone and soils are deficient in a number of plant nutrients especially nitrogen (N) and phosphorus (P). Soil K^+ is bound within minerals which do not release K^+ at the rate required for crop production. On the other hand, some soils with low plant available K^+ maintain levels of solution K^+ that are optimal for plant growth, leading to no response to K^+ fertilization. Nevertheless, K^+ deficiency has been observed in many crops in different areas of the country [12]. The major natural source of soil K^+ is weathering of K^+-containing minerals such as micas and alkali feldspars, which contain 6-9 and 3.5-12% K^+, respectively. The age of soil developed from such minerals determines the extent of weathering as well as the K^+ dynamics [13] and the release of K^+ converts micas to secondary 2:1 clay minerals–illite and then vermiculite [14,15]. The fate of K^+ fertilizer also depends on the age of the soil; application of K^+ fertilizer to soils containing illite and vermiculite clay minerals leads to fixation of some of its fraction by soil particles which are unavailable or slowly available to the plants [16]. The fixed K^+ may become available to plants by its release from soil particles into soil solution when the concentration of K in the soil falls but in most cases this release is too slow to meet the plant-growth requirements [17]. Besides the nature of parent material and weathering process, the soil texture also affects the availability of K^+ to plants. The previous studies has revealed this fact that the fixation of K^+ by expanding type clay minerals has been considered one of the reasons for reduced crop response to K^+ fertilization. Presence of high soil clay content and the type of clay minerals are responsible for fixation of added K^+ and recovery of non-exchangeable K^+ already present in the soil are also reported [18]. The K^+ fixation does not have direct correlation with total clay content but with the types of clay mineral dominant in the soil [19]. Soils differing in clay mineralogy may respond differently to K^+ fertilizer application [20]. Land use systems have significant impact on the properties of soils and runoff water. Forest soil exhibits the highest moisture content, while fallow and pasture lands retains similar soil moisture and agricultural land the lowest soil moisture. Soil water content differs with soil depths with higher values in the sub-soil than the top soil in all land use systems. Percent water holding capacity (WHC) of soil also varies among land use systems. In top soil, the WHC of pasture and forest soils is almost similar. The concentrations of cations varies land uses in the order of Ca>Mg>Na>K. Irrespective of land use, the lower layer of the soil exhibits lesser concentration of K^+. The land use pattern differs for K^+ concentrations as follow: agricultural land>fallow land>forest land>pasture land. As expected the water soluble fraction of the plant nutrients in soils is substantially higher under forest than cultivated or fallow land. This phenomenon can be associated with the constant litter falls and the process of nutrient transformations as influenced by vegetation. Accelerated erosion has resulted to nutrient losses from deforested land [21]. Specifically, the objectives of this study were to (i) assess the effects of climatic regimes on crop yield under different land use systems and (ii) To explore the variations in soil nutrients bioavailability and climate on vegetation. Through this research we explored a piece of scientific information about the physical properties of soil and the concentration of extractable K^+ varying under different land use systems in the two selected climatic regimes i.e. Gilgit Baltistan and Hazara divisions in Pakistan.

MATERIALS AND METHODS

The soil samples were collected from three land use systems i.e. cultivated land, forest land and rangeland in the eleven districts i.e. five districts of hazara division (i.e. Mansehra, Abbottabad, Haripur, Batagram and Kohistan) and six districts of Gilgit Baltistan division (Ghanchi, Hunza Nagar, Skardoo, Gilgit, Diamer and Astore in Pakistan). Soil samples were collected by digging up to 15 cm depth. The samples were then air dried, cleaned from stones and plant litter etc, crushed, and sieved (2 mm) to ensure homogeneity. After that soil samples were weighed in porcelain crucibles and oven dried in the muffle furnace at 105°C for 24 h and stored in air tight plastic envelops for further analysis. A small proportion of each sample was separated for determination of EC, pH and soil texture. Additionally three replicates of undisturbed soil samples of known volume were taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination at three sites from each of the land use types.

Soil pH and Electrical Conductivity (EC)

Soil pH and EC was determined using an electrode pH and EC meter in a 1:5 soil: water suspension. 20 g of soil sample was mixed with 50 ml distilled water in a beaker and shaked the mixture in shaker for 30 minutes. The sample was left undisturbed for 20 minutes and then recorded reading using an electrode pH meter [22] and EC meter [23].

Soil Texture

Soil texture was determined through mechanical analysis method. Using the sieve shaker, the air and oven dried soil samples were sieved through a 2 mm sieve. Soil texture was determined by dispersion in Sodium Hexa Metaphosphate ($Na (PO_3)_6$) and density of suspension was recorded by inserting hydrometer into the suspension at specific time intervals 40 seconds after the cylinder was set down record the hydrometer reading. Similarly the second reading was recorded after 2 h [24].

Extractable form of K^+

Ammonium acetate soluble cation K^+ was extracted with 1 M NH_4OAc, adjusted to pH 7. The soil samples were placed in a 100 ml centrifuge tube. 25 ml NH_4OAc solution was added and was shaken mechanically for 1 h. The supernatant was separated from the soil by centrifuge at 2400 rpm for 30 min. Supernatant was filtered into a 100 mL volumetric flask. The extract was made up of volume with deionized water and used for the determination of the ammonium acetate soluble cation K^+. The content was determined using an atomic absorption flame photometer [25].

Acid Digestion

For identification of total form samples were digested with 5 ml concentrated $HClO_4$ by gradual heating and after drying, 20% HNO_3 was added to the samples. The filtered solution was then stored for further analysis of total form of K^+ through an atomic absorption spectrophotometer [26].

Statistical Analysis

The data (with three replications for each experiment) was then transferred to the ANOVA software and analyzed statistically through two way analysis. The mean values were compared with least significant difference test (LSD) at 5% level of significance by using appropriate software [27].

RESULTS AND DISCUSSION

The altitude data obtained from Google reveals that the highest altitude in Climatic regime-I is of district Astore i.e. 2546 m and in Climatic regime-II is of Abbottabad i.e. 1250 m **(Table 1)**. Soil pH and EC are important to understand soil chemistry. Soil pH is vital soil property because it has significant influence on solubility and bio-availability of nutrients. The solubility and bioavailability of nutrients remain optimum over pH range slightly acidic to alkaline. The preliminary physico-chemical analysis of different land use systems of the two climatic regimes of Gilgit Baltistan and Hazara division, as shown in **(Tables 2 and 3)**, almost all the soils in the three land use systems were found neutral to alkaline in nature, except few forest and rangeland soils that were slightly acidic in nature. The EC values are less than 1 dS m^{-1} means that all the soils are free from salinity problem. The pH and EC values in the two climatic regimes were like Cultivated land>rangeland>forestland. Of the two regimes, the highest pH and EC values were found for Ghanche cultivated land (i.e. pH 8 and EC 0.9 dS m^{-1}) in Gilgit Baltistan found lowest pH and EC values were for Astore forest land soil (i.e. pH 5.7) and Skardoo forest land soil (i.e. 0.024 dSm^{-1}) respectively. Similarly in climatic regime 2; Hazara division the highest pH and EC values were of haripur cultivated land soil (i.e. 7.8 and 0.56 dSm^{-1}) and lowest value was for Abbottabad forest (i.e. 6.5 and 0.21 dSm^{-1}). Moreover, it was also revealed that the cultivated land soils of Hazara division were with relatively higher EC values than that of Gilgit Baltistan division [28] revealed the same in his study conducted in Gilgit showing that the pH of soils varied from 7.34 to 8.03 with an average value of 7.72 showing most of the soils neutral to alkaline in reaction. EC ranged from (0.06 to 0.5 dSm^{-1}) with a mean value of (0.19 dSm^{-1}) suggesting that soils in study area are free from salinity problem. Contrarily Whiteman reported the lime content ranged from 0.25 to 12.4 percent with a mean value of 5.5 percent showing slightly to moderately calcareous nature of the parent materials [29]. The crop land (with no trees) has been reported with poorer quality soils because the agricultural machinery destroys the soil organisms and soil structure. It is generally recognized that plant canopy and surface litter protect the soil surface from the energy of raindrop impact and surface detachment so here the pH of the soils range from slightly to moderately alkaline, while the forest soil shows slightly lower pH regardless of depth **(Table 4)**. Through the soil texture it was found that forest soils in the two regimes were with more silt and clay particles so it showed a bit resistance for water leaching and can retain more water than any other soils [28]. The Astore valley's certain edaphic factors; altitudinal variation, soil texture and amount of organic matter were responsible for variation in vegetation. Soil was fine to coarse in texture ranging from clay loam to sand and acidic to slightly alkaline in nature, containing considerable amount of calcium carbonate (up to 16 %) and appreciable amount of organic matter(up to 33.094%), maximum water holding

Table 1. Altitude variability among the districts of Climatic Regime I and II.

S.No.	Climatic Regime I-Gilgit Baltistan		Climatic Regime II-Hazara Division		
	District name	**Altitude**	**S.No.**	**District name**	**Altitude**
1.	Astore	2546 m	**1.**	Abbottabad	1250 m
2.	Hunza Nagar	2500 m	**2.**	Mansehra	1088 m
3.	Skardoo	2500 m	**3.**	Batagram	1038 m
4.	Gilgit	1500 m	**4.**	Kohistan	1090 m
5.	Diamer	1265 m	**5.**	Haripur	1706 m
6.	Ghanche	1100 m			

Table 2. Chemical properties of soils of Climatic Regime-I under different land use systems.

S. No.	Sampling sites	pH	EC (dSm^{-1})
1	Ghanche Cultivated land	8	0.9
	Ghanche Rangeland	7.7	0.77
	Ghanche Forest	7.6	0.55
2	Hunza Nagar Cultivated land	7.8	0.03
	Hunza Nagar Rangeland	7.2	0.06
	Hunza Nagar Forest	7.4	0.054
3	Skardoo Cultivated land	7.5	0.039
	Skardoo Rangeland	7.3	0.04
	Skardoo Forest	7.4	0.024
4	Gilgit Cultivated land	7.55	0.47
	Gilgit Rangeland	7.4	0.44
	Gilgit Forest	7.32	0.34
5	Astore Cultivated land	7.1	0.43
	Astore Rangeland	6.5	0.54
	Astore Forest	5.7	0.032
6	Diamer Cultivated land	7.9	0.83

Table 3. Chemical properties of soils of Climatic Regime-II under different land use systems.

S. No.	Sampling sites	pH	EC (dSm^{-1})
1	Abbottabad Cultivated land	7.4	0.35
	Abbottabad Rangeland	7.5	0.31
	Abbottabad Forest	6.5	0.21
2	Mansehra Cultivated land	7.4	0.32
	Mansehra Rangeland	7.3	0.27
	Mansehra Forest	6.9	0.22
3	Haripur Cultivated land	7.8	0.56
	Haripur Rangeland	7.7	0.54
	Haripur Forest	7.3	0.31
4	Kohistan Cultivated land	7.1	0.29
	Kohistan Rangeland	7.3	0.23
	Kohistan Forest	6.8	0.22
5	Batagram Cultivated land	7.6	0.31
	Batagram Rangeland	6.9	0.29
	Batagram Forest	6.8	0.29

capacity (21.415-63.179) and pH values (5.35-7.20) [30]. Soil texture was analyzed through mechanical analysis method. The soil texture data **(Tables 5 and 6)** revealed that soils in the two regimes was with more silt and clay particles so showed a bit resistance for erosion and leaching retaining maximum possible nutrients. Soil texture in the climatic regime-I were loam, silt clay loam>clay loam>silt loam>sandy loam and loam. According to a study conducted on soil texture classes of Gilgit varied from silt loam to silt clay, showing the most diverse nature of parent material, rocks of different types and compositions. Most common textural

Table 4. Textural variability of soils of Climatic Regime-I under different land use systems.

Sampling sites	%Clay	%Silt	%Sand	Soil Type
Hunza Cultivated	31.44	41.28	27.28	Clay Loam
Hunza Rangeland	26.72	38.28	35	Loam
Hunza Forest	31.52	33.48	35	Clay Loam
Chilas Cultivated	26.96	63.76	9.28	Silt Loam
Chilas Rangeland	23.2	68.96	7.84	Silt Loam
Chilas Forest	32.64	54.08	13.28	Silty Clay Loam
Skardu Cultivated	33.36	50.64	16	Silty Clay Loam
Skardu Raneland	32.96	60.32	6.72	Silty Clay Loam
Skardu Forest	34.96	50	15	Silty Clay Loam
Gilgit Cultivated	31.84	53.04	15	Silty Clay Loam
Gilgit Rangeland	29.68	57.6	13	Silty Clay Loam
Gilgit Forest	28.4	66.88	5	Silty Clay Loam
Astore Cultivated	14.48	26	60	Sandy Loam
Astore Ranegland	36.8	33	30	Clay Loam
Astore Forest	28.96	27	44	Clay Loam
Ghanche Cultivated	38.08	54.8	7.12	Silty Clay Loam
Ghnache Rangeland	34.64	55.68	9.68	Silty Clay Loam
Ghanche Forest	38.64	47.12	14.24	Silty Clay Loam

Table 5. Textural variability of soils of Climatic Regime-II under different land use systems.

Sampling Sites	%Clay	%Silt	%Sand	Soil Type
Abbottabad Cultivated	30.24	43	27	Clay Loam
Abbottabad Rangeland	26.8	41	32	Loam
Abbottabad Forest	30.96	44	25	Silty Clay Loam
Haripur cultivated	46.24	47.76	6	silt clay
Haripur Rangeland	42.08	51.92	6	silt clay
Haripur Forest	47.36	49.2	3.44	silt clay
Kohistan Forest	34.64	62.8	2.56	Silty Clay Loam
Kohistan Rangeland	34.08	60.8	5.12	Silty Clay Loam
Kohistan cultivated	30.24	61.76	8	Silty Clay Loam
Mansehra Cultivated	31.68	61.92	6.4	Silty Clay Loam
Mansehra Rangeland	36.96	60.24	2.8	Silty Clay Loam
Mansehra Forest	38.96	54.8	6.24	Silty Clay Loam
Batagram Cultivated	37.68	50.48	11.84	Silty Clay Loam
Batagram Rangeland	34.96	60.64	4.4	Silty Clay Loam
Batagram Forest	38.24	59.2	2.56	Silty Clay Loam

Table 6. Soluble K^+ ($mg.Kg^{-1}$) concentrations in soils of Climatic Regime-I under different land use systems.

Soil Samples	Cultivated	Rangeland	Forest
Ghnache	19.0	9.0	13.0
Hunza Nagar	31.0	11.0	22.0
Skardoo	23.0	8.0	14.0
Gilgit	24.0	9.0	12.0
Astore	28.0	8.5	13.0
Diamer	11.0	6.0	8.0

classes were silt loam 35% followed by sandy loam 30%, loam 20%, loamy sand 7.5%, silt clay loam 5% and silt clay 2.5% [28]. Climatic regime-II soils were mostly silt clay loam>silt clay>clay loam and loam. Abbottabad district soil is mainly loamy and clayey, mainly non-calcareous, or alluvial or loess plains/terraces, steep, shallow soils or some rock outcrops of humid and sub humid mountain regions [31]. The concentration of ammonium acetate extracted cation K^+ showed the highest contents of extractable potassium in cultivated land soil than the other two land use systems. All the three forms soluble K^+, extractable K^+ and total K^+ were found highest in Hunza Nagar in the range of cultivated>forest>rangeland in climatic regime I and Abbottabad in the range of cultivated>forest>rangeland in climatic regime II. Extractable K^+ was as high as 27.19 to 129.48 $mgkg^{-1}$ with an average value of 82.58 mg in Gilgit soil [28]. Results of the previous study revealed the significant variation in the overall concentration of exchangeable K^+ with land use types and soil depth, being higher under farmland followed by the protected forest land than in the grazing and open grasslands and in the upper than in the lower soil depths [32]. Exchangeable K^+ was higher in soil under the farmlands as compared to the adjacent natural forest. Nitric acid-extractable K^+ or the acid-extractable K^+ represents exchangeable K plus some K extracted from within phyllosilicates and tektosilicate mineral structures are the function of the amount and type of dominant K^+ mineral present in a soil and governs plant uptake of K^+ at low exchangeable levels. Soils that are high in kaolinite, quartz, and other siliceous minerals contain little or no exchangeable and acid-extractable K^+, whereas soils containing vermiculite, feldspars, and micas can have large amounts of acid-extractable K^+. Most Pakistani soils are mica based; due to continuous weathering, intensive cropping and K^+ release, these soils generally convert to illite and vermiculite-dominant clay minerals [12]. In terms of soil K^+ fertility status, the exchangeable K^+ is suggested to be readily available for plant uptake and, thus, represents an intensity factor. In contrast, acid-extractable K^+ measures both readily available K^+ and the capacity of a soil to supply K^+ under continuous intensive cropping and, thus, represents primarily a capacity factor. The exchangeable K^+ content of a soil sample may be increased by prior heating at 450°C, due to exfoliation of the micaceous soil minerals exposing K^+ in formerly contracted inter layers and to removal of organic coatings. As such, changes in the exchangeable K^+ content of a soil sample due to heating may be used as an index of the extent to which micaceous soil components have been altered during weathering (e.g., cropping and cultivation). Non-NH_4-exchangeable K^+ (subsequently referred to as non-exchangeable K^+) including fixed K and K-bearing minerals (e.g., biotite, muscovite, orthoclase, and microcline) can constitute over 94% of total soil K and can become plant-available only very slowly through weathering. Most of the acid soils had more of the problems including low base saturation percentage and low concentrations of exchangeable Ca^{2+}, Mg^{2+} and K^+ **(Tables 7 and 8)**. Detrimental effects of soil acidity on plant growth are related to Al^{3+} (which causes stunted root development) and the availability of soil nutrients, which may increase with decrease in pH (Fe, Mn, Cu, Zn and Co), decrease with increase in pH (Ca^{2+}, Mg^{2+} and K^+) or be restricted to pH intervals (P, B and N) because of different processes. Soil pH and OC content were positively and significantly correlated with exchangeable Ca^{2+}, Mg^{2+} and K^+ content. Soil OC content was positively and significantly correlated with EC and exchangeable Ca^{2+}, Mg^{2+} and K^{++} in all soil series. This indicated that higher OC content in acid soils led to higher EC and higher content of exchangeable K^+, Ca^{2+} and Mg^{2+} in soil. Soil OC is important constituent of SOM. The SOM is considered as key factor driving most of the soil properties which subsequently influence nutrient storage and availability to plants. Soil EC content was also positively and significantly correlated with exchangeable K^+ in all soil series. Exchangeable cations like K^+, Ca^{2+}, Mg^{2+} were positively and significantly correlated with each other. In the present study Haripur in Climatic Regime II showed pH 7.8 and EC 0.56 dSm^{-1} with K^+ soluble, extractable and total form in the range of cultivated>forestland>rangeland soils. The values are lower than those of Abbottabad soils and the possible reason for this could be the soil parent material of that area and slightly saline water due to industrial wastes in the haripur soils. Moreover the haripur soils were with more clay content that helped in resisting soil and nutrient erosion and leaching. Study on soil texture and bulk density within the different LULC types, clay content in the surface layers (0–5 and 5-15 cm) varied from 59 to 65%, whereas silt fractions ranged from 27 to 37%. Clay contents were higher in the cultivated land and the fallow land as compared with that of the woodland at the layer 0–5 cm; however, there was no significant difference between the three LULC types at the depth of 5–15 cm. The study also revealed that sand and silt fractions differed significantly across the LULC types. The high amount of clay fractions in the first layer of the cultivated land may be attributed to the removal of silt and sand fractions by runoff,

Table 7. Soluble K^+ ($mg.Kg^{-1}$) concentrations in soils of Climatic Regime-II under different land use systems.

Soil Samples	Cultivated	Rangeland	Forest
Abbottabad	24.0	13.0	20.0
Mansehra	19.0	11.0	17.0
Haripur	22.0	14.0	19.0
Kohistan	16.0	9.0	14.0
Batagram	21.0	12.0	18.0

Table 8. Extractable K^+ ($mg.kg^{-1}$) concentrations in soils of Climatic Regime-I under different land use systems.

Soil Samples	Cultivated	Rangeland	Forest
Ghnache	83	43	67
Hunza Nagar	120	72	99
Skardoo	100	61	75
Gilgit	82	52	73
Astore	110	69	84
Diamer	84	52	76

because the clay particles were very small in size and therefore were very slow to settle out by runoff process. Similarly soil pH was significantly different between the cultivated land and the woodland with slightly higher for the cultivated land as compared with that of the woodland. This is attributed to the reduction of OM and the ploughing processes of cultivated fields. The exchangeable potassium content decreased with the soil depth for all LULC types with higher amount of potassium in the first layer due to the increases of potassium fixation with the increase of the soil pH. Unlike phosphorus, potassium is most often found in the soil in inorganic forms, usually resulting from the mineral weathering of the rocks and parent material in the soil. Irrespective of land use, the lower layer of the soil exhibits lesser concentration of K^+. The land use pattern differs for K^+ concentrations as follow: agricultural land>fallow land>forest land>pasture land. As expected the water soluble fraction of the plant nutrients in soils is substantially higher under forest than cultivated or fallow land. This phenomenon can be associated with the constant litter falls and the process of nutrient transformations as influenced by vegetation. Accelerated erosion has resulted to nutrient losses from deforested land. Potassium losses in the clay soil were more than twice as those in the sand soil because of the development of preferential flow in the clay soil. Natural and reforested soils are significantly more acidic than those of the grass land and cultivated land except for the forest land, all the soils show greater EC values in the top soil than the sub-soil layer **(Tables 9 and 10)**. Overall, the cations in the runoff water varied in the order Ca>Mg>Na>K, being highly consistent with that in the soils and land use. The highest K^+ concentration is in pasture runoff and lowest in fallow runoff. Variations in the chemical composition of soils under different land uses showed higher correlation between soil carbon and soil moisture, water holding capacity and nutrients. The nutrients concentrations were higher in forest soil and lower in the soils of fallow and agricultural lands. Soil acidity is one of the main reasons for nutrient depletion as well as causes of fertility decline that affects crop production. The result soils in the natural forest had significantly ($p<0.05$) higher soil pH and lower exchangeable acidity ($p<0.01$) **(Table 11)**. Similarly, significantly higher ($p<0.01$) exchangeable Ca^{2+}, Mg^{2+}, K^+ and total nitrogen, organic matter, available potassium and phosphorus, cation exchange capacity and soil clay contents in the natural forest were observed as compared to the other land use systems. However, there was no significant difference in silt fraction, sand, bulk density and exchangeable sodium under soils of different land uses. The results obtained from the study indicated that soils of grazing, cultivated land and plantation forest are strongly acidic (pH<5.5). Therefore, appropriate reclamation method should be launched to improve agricultural productivity and sustainability of the study area.

Table 9. Extractable K^+ ($mg.kg^{-1}$) concentrations in soils of Climatic Regime-II under different land use systems.

Soil Samples	Cultivated	Rangeland	Forest
Abbottabad	79	39	55
Mansehra	51	38	22
Haripur	62	41	37
Kohistan	42	22	35
Batagram	59	21	33

Table 10. Total K^+ ($mg.kg^{-1}$) concentrations in soils of Climatic Regime-I under different land use systems.

Soil Samples	Cultivated	Rangeland	Forest
Ghnache	1703	1440	1639
Hunza Nagar	1992	1500	1654
Skardoo	1858	1215	1543
Gilgit	992	914	872
Astore	687	926	754
Diamer	793	772	920

Table 11. Total K^+ ($mg.kg^{-1}$) concentrations in soils of Climatic Regime-II under different land use systems.

Soil Samples	Cultivated	Rangeland	Forest
Abbottabad	1963	1321	1733
Mansehra	1871	1171	1400
Haripur	1893	1184	1439
Kohistan	1779	1254	1374
Batagram	1792	1277	1364

CONCLUSION

The results from the study revealed that the preliminary physic-chemical analysis viz; soil pH, EC, texture and the concentration of K^+ in relation to varying locations and land use systems in two different climatic regimes Gilgit Baltistan and Hazara Division in Pakistan. Soils in the three land use systems were found neutral to alkaline in nature, except few forest and rangeland soils that were slightly acidic in nature. Moreover, cultivated lands of Hazara division showed relatively higher EC values than that of Gilgit Baltistan division. The soil texture in the two regimes showed a bit resistance for erosion and leaching retaining maximum possible nutrients. Soil texture in the climatic regime-I was loam, silt clay loam>clay loam>silt loam>sandy loam and loam while in climatic regime-II soils were mostly silt clay loam>silt clay>clay loam and loam. The contents of extractable potassium were higher in cultivated land use system than the other two land use systems. Soluble K^+, extractable K^+ and total K^+ were found highest in Hunza Nagar in the range of cultivated>forest>rangeland in climatic regime-I and Abbottabad in the range of cultivated>forest>rangeland in climatic regime-II. Pakistani soils are mica based; due to continuous weathering, intensive cropping and K^+ release, these soils generally converted to illite and vermiculite-dominant clay minerals. In terms of soil potassium fertility status, the exchangeable K^+ is suggested to be readily available for plant uptake and, thus, represents an intensity factor. In contrast, acid-extractable K^+ measures both readily available K^+ and the capacity of a soil to supply K^+ under continuous intensive cropping and, thus, represents primarily a capacity factor. Mostly where the soils were slightly acidic or with comparatively lower pH such as forest soils due to higher organic matter content, there was a low concentration of exchangeable K^+. It is concluded that soil pH, EC and potassium are significantly affected by the different climates, altitude, texture and land use systems.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support of 973 national project (517102-N51501/001), Zhejiang University's Special funds for basic scientific research (517102*172210152), Elite undergraduate students training program (188190*170115101/013/002/001) and Jiangsu Collaborative Innovation Center for Modern Crop Production (JCIC-MCP).

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