MAPPING OF NUTRIENTS STATUS IN SOILS OF KISHTWAR AND RAMBAN DISTRICTS OF J&K USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

BY

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(J-16-M-442)

Thesis submitted to Faculty of Postgraduate Studies
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE IN AGRICULTURE
SOIL SCIENCE AND AGRICULTURE CHEMISTRY

Division of Soil Science and Agricultural Chemistry
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu,
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2018

CERTIFICATE-I

This is to certify that the thesis entitled **"Mapping of nutrients status in soils of Kishtwar and Ramban districts of J&K using geographic information system (GIS)"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Soil Science and Agriculture Chemistry** to the Faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu is a record of bonafide research carried out by **Mr. Owais Ali Wani,** Registration Number **J-16-M-442,** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that such help and assistance received during the course of investigation have been duly acknowledged.

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We, the members of the Advisory Committee of **Mr. Owais Ali Wani,** Registration Number **J-16-M-442,** a candidate for the degree of **Master of Science in Soil Science and Agriculture Chemistry** have gone through the manuscript of the thesis entitled **"Mapping of nutrients status in soils of Kishtwar and Ramban districts of J&K using geographic information system (GIS)"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the award of degree.

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ABSTRACT

Title of the Thesis	:	**Mapping of nutrients status in soils of Kishtwar and Ramban districts of J&K using geographic information system (GIS).**
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ABSTRACT

A study was carried out to assess nutrient status of Kishtwar and Ramban districts located at 32° 53′ to 34°21′N latitude and 75°1′ to 76° 47′E longitude and 33° 14'N to 75° 17'E longitudes and experiences temperate and Subtropical type of climate respectively. Composite surface soil samples from one hundred sixty seven (167) and one hundred fourteen (114) locations distributed randomly across the whole of the districts were collected at the depth of 0-15cm using global positioning system (GPS).Inverse distance weighting (IDW) technique was adopted to generate prediction maps of the soil properties. The choice of either technique to prepare filled contour maps of soil properties was based upon error analysis. The process of digitization and generation of maps was carried out with ArcGIS 10.3. Sandy loam and clay loam texture were usually dominant textural groups in Kishtwar and Ramban districts, respectively. Sand content in Kishtwar district was mainly less than 20 per cent, also strips of 40 to 60 per cent sand were present across the district. Whole of the tehsil Padder and major area of tehsil Kishtwar of district Kishtwar was having sand content between 20-40 per cent. In Ramban district majority of area had sand between 20 – 40 per cent. Some area in the form of small patches in Banihal tehsil of Ramban district was having sand content less than 20 per cent. Whereas in Ramban tehsil some area had sand content greater than 60 per cent. In case of silt, major area of Kishtwar district had silt content between 30 to 40 per cent on both east and west ends. In the central part of the district silt content varied from 20 to 30 per cent, with some scattered patches having greater than 40 per cent silt. Half of the area of Ramban district spreading over north and south ends had silt content ranging between 30- 40 per- cent, whereas other half of the area located in the central part of the district had silt content between 20-30 per cent. Silt content in some patches of the district was greater than 20 per cent, whereas a very small area in the form of scattered patches had silt content less than 20 per cent. In case of clay content major

area of Kishtwar district had 20-30 per cent clay followed by the area on central and eastern side of the district having 30- 40 per cent clay. In Ramban district clay content varied from 30 -40 per cent in majority of the area present on the northern and southern sides. Whereas it was 20 -30 per cent in rest of the area between the two ends. Soils in few patches scattered over the district had clay content between 40 -50 per cent, whereas few patches with small area towards southern part of the district had clay content less than 20 per cent. Soils of almost entire district of Kishtwar were found to be neutral in reaction. Very small patches of the district were having soils with acidic and basic reactions. Soils of almost half of the Ramban district towards south-west and northern side were neutral in reaction, whereas soils of the area on the eastern and central part of district were basic in reaction. EC was found to be within the safe limits in both the districts, however EC of soils of both districts had great variation. Western side of Kishtwar was having EC ranging from 0.5 to 1.0 dS m-1 and on eastern side it varied between 1.0 and 1.5 dS m-1. Some strips across north and southern side of Kishtwar district had EC between 1.5 and 3.0 dS m-1. In Ramban district soils on northern and southern side had EC mainly in between 0.5 to 1.0 dS m-1 and on eastern and western side it was mainly in the range of 1.5- 3.0 dS m-1. Soil organic carbon (OC) of both the districts was in high range (>12.5 g/kg) especially in forest blocks. In Kishtwar district, Marwah tehsil had higher content of OC ranging from 12.5 to 20.0 g/kg. In rest of the district it ranged between 7.5-12.5 g/kg. Major part of Ramban district had OC ranging from 7.5-12.5 g/kg, whereas central part of the district covering Banihal tehsil had lower OC (0.5-7.5 g/kg) as compared to Ramban tehsil. While comparing two districts higher content of OC was recorded in Kishtwar district. Available nitrogen (N) was not limiting in the entire Kishtwar district. In Marwah and Padder tehsils of Kishtwar district majority area was having N in medium range (420-560 kg/ha). In Central part of the district stretching from north-east to southern side had N in the medium range (280-420 kg/ha). In Ramban N varied from 280-560 kg/ha with some patches greater than 560 kg/ha, northern part of District covering Banihal tehsil and part of Ramban tehsil had N in Medium to High range (480-560 kg/ha), area lying on eastern and western part of Ramban tehsil of the district had N in medium range (280-420 kg/ha). Available Phosphorus (P) in whole of the Kishtwar district was sufficient. Major part of the district had available P in high range (25.0 to 50.0 kg/ha), whereas some central part of district lying in Chatro tehsil was having P in medium range (12.5-25.0 kg/ha). In Ramban district also major part was having available P in the high range (25.0-50.0kg/ha), whereas some areas on the northern side of the district covering Banihal tehsil had P in medium range (12.5-25.0 kg/ha). Available potassium (K) in whole of the Kishtwar district was mainly in high range from 500 to 750 kg/ha. North, northwest and south east area of the district covering part of Marwah, Chathro and Padder tehsil was having high content of K ranging from 500-750kg/ha. Whereas central part of the district stretching from north-east to southern side had available K in high range (280- 500 kg/ha). Major part of Ramban district had available K in the high range (280-500 kg/ha). Other area of the district lying on eastern and northern side was having K in medium range (110- 280 kg/ha). Secondary nutrients Calcium, Magnesium and Sulphur were in medium to high range in almost entire areas of both of the districts, except in some areas of Ramban district where they were on lower side. Almost whole of the Kishtwar district had secondary nutrients in high range, except some strips in the district having nutrients in medium range. In Ramban district some area on the northern tip had very high content of secondary nutrients. Western part of Ramban district covering part of Ramban tehsil had secondary nutrients in low range,

whereas in middle part of the district they were in medium range. Rest of the district had nutrients in high range. Calcium in majority area of Kishtwar was in the range of 15-20 m.eq/100g, whereas in case of district Ramban on western side of tehsil Ramban it was less than 10 m.eq/100g. Exchangeable Magnesium also followed the same trend. All the micronutrients except zinc (Zn) in soils of both the districts were sufficient and well above the critical limit (0.6 ppm). As such their was no problem of their deficiency. Soils of south-eastern part of Kishtwar district covering Padder tehsil and centrally located elongated strip stretching from north east to south were deficient in DTPA zinc content. Available copper was mainly sufficient in both the districts except some negligible patches in Chattro tehsil of Kishtwar district where it was found deficient. In Kishtwar district, Chattro tehsil recorded higher iron content as compared to other tehsils of the district. In Ramban district Ramban Tehsil had higher iron than that in Banihal tehsil.

Key words: GIS, GPS, Inverse distance weighting, Nitrogen, Phosphorus, Calcium, DTPA.

Owais

Signature of Major Advisor **Signature of the Student**

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INTRODUCTION

Soil is one of the most vital and precious natural resources of nature. The socio-economic development of people depends on soil (Kanwar, 2004) that sustains life on earth. Soil is the most valuable natural resource, but is finite and non-renewable. It is considered as an integral part of landscape and its characteristics are largely governed by landforms on which it develops. The information on characteristic, classification, location and distribution of soils, is required for any developmental planning in particular area. Systematic study of chemical properties and taxonomy of soil provides information on its nature, type and constraints. Soil fertility plays a pivotal role in maintaining productivity of agricultural systems, as it is the inherent ability of soil to supply nutrients for crop growth and maintenance of its physical conditions to optimize crop yields.

Soil spatial variability is a naturally occurring feature that is important in the identification of soil properties related to soil productivity (Ball and Williams, 1968; Cline, 1944). Since, soil properties gradually change across the landscape, the investigation of the variability of chemical properties of soil with distance have become more important over the past few years. When an observation gives some information to the value or magnitude of its neighbour, such data are spatially dependent. When variables are spatially dependent, classical statistics analysis is no longer valid. One method of handling spatially dependent variables is using the theory of regionalized variables (Matheron, 1963). The successful application of this theory in mining, geology, and hydrology related problems led to the genesis of new branch of statistics vis-à-vis geostatistics, of which kriging is a main branch (Krige, 1966; Delhoumme, 1978).

GIS is a computerized spatial information system for supplying data or information for planning and policymaking. It is defined as a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modelling and displaying of spatially referenced data for solving complex planning and management problems (Bernhard Sen, 1999; Clarke, 2001).Soil test-based fertility management is an effective tool for increasing the productivity of agricultural soils that have a high degree of spatial variability. However, major constraints such as the prevalence of small holding systems of farming as well as lack of infrastructural facilities for extensive soil testing, impede the wide-scale adoption of soil testing in most of the developing countries (Iftikar *et al*., 2010). Under this context, a Geographical Information System (GIS)-based soil fertility mapping has appeared as a promising alternative compared to developed countries where precision nutrient management addresses in-field nutrient variability. The present approach of study addresses spatial variability of soil parameters between the fields. GPS-GIS can be efficiently used for monitoring soil fertility status of respective districts and is also useful for ensuring balanced crop production. The basic technological principle of precision fertilization is to adjust the fertilizer input according to the specific circumstances or properties of soils in each location for the least waste and the highest profit by fully understanding the variation of soil nutrients. Therefore, understanding the spatial variability of soil nutrient is the first step and the pre-condition for precision fertilization. The spatial distribution map of soil nutrients, developed by using the geostatistics as a principle and the software GIS as a tool, can reflect the spatial variability of nutrients and also make the balanced fertilization possible.

The Geostatistics has been proven to be one of the most effective ways to analyse the characteristics of the soil nutrient spatial distribution and the law of variation (Sun Hongquan, 1990). Soil characterization in relation to evaluation of fertility status of the soils of an area or region is an important aspect in context of sustainable agriculture production. Soil test-based fertility management is an effective tool for increasing productivity of agricultural soils that have high degree of spatial variability resulting from the combined effects of physical, chemical or biological processes (Goovaerts, 1998). Use of GIS map as a decision support tool for nutrient management will not only be helpful for adopting a rational approach compared to farmer’s practices or blanket use of state recommended fertilization but will also reduce the necessity to elaborate plot-by-plot soil testing activities. However, information pertaining to such use of GIS-based fertility maps are meagre in India (Sen and Majumdar, 2006; Sen *et al*., 2008).

Availability of reliable soil fertility map is the bottleneck for providing spatial fertilizer recommendation. If such maps are made available, then it is possible to transform the fertilizer equations into spatial fertilizer recommendation maps. The use of remote sensing, GIS, GPS, and simulation modelling are very effective in this direction. A suitable soil sampling strategy is the most important part of fertility mapping. The method of using these techniques for devising suitable soil sampling plan has been described (Oliver and Frogbrook, 1998; Polive and Aubert, 1998). The advantage of using global positioning system is that if we want to update the fertility maps after certain period of time, one can always reach to the same spot from where previous sample was obtained. Soil testing program is beneficial to formulate specific fertilizer recommendations. Soil fertility maps are meant for highlighting the nutrient needs, based on fertility status of soils to realize good crop yields. Soil fertility map for a particular area can be proven highly beneficial in guiding the farmers, manufacturers and planners (associated with fertilizer marketing and distribution) in ascertaining the requirement of various fertilizers in a season/year and making projections for increased requirement based on cropping pattern and intensity. The soil tests were calibrated into different fertility categories such as low, medium and high (Welch et al., 1987; Rashid and Memon, 1996).

Recent Government initiatives like Soil Health Card Scheme, National Sustainable Agriculture Scheme and Pramparagati Krishi Vikas Yojna, mainly aim at resource conservation especially natural resources**.** At present information on soils of Ramban and Kishtwar with respect to chemical properties based on GPS-GIS is not available, therefore present study was planned which would be helpful for better land use planning and to realise the above discussed benefits of soil fertility mapping .

The study is carried under following objectives:

1. To assess the spatial distribution of macro and micro nutrients and basic properties of the soils present in respective districts.
2. To identify soil fertility constraints in the district.
3. To generate soil fertility maps of districts of Kishtwar & Ramban using Geographic Information System (GIS).

REVIEW OF LITERATURE

The work pertaining to the objectives of the study has been discussed in this chapter under the following sub-headings.

2.1 Spatial variability in soils.

2.2 Georeferencing.

2.3 Interpolation techniques and application of mapping.

2.4 Case studies.

2.1 Spatial variability in soils.

Spatial variability occurs when a parameter that is measured at different spatial locations exhibits values that differ across the space. Spatial variation can be looked at as the way that something fluctuates over an area on the earth's surface, in the atmosphere, or the sea. Soil characteristics, after facing successive changes caused by agricultural practices and, consequently, by erosion, behave quite differently across the landscape (Izidorio *et al*., 2005; Souza *et al.,* 2005; Souza *et al.,* 2006). Soils subjected to the same management system in places with small terrain variation manifest different spatial variability in intrinsic soil characteristics. This variability is a function of the spatial variation of soils in the landscape (Barbieri *et al*., 2008) or in slopes, even when the terrain has little expression (Sanchez *et al*., 2005; Souza *et al* .,2006). Several studies have documented that soil properties vary across farm fields, causing spatial variability in crop yields (Rockstro¨m *et al.,* 1999; Gaston *et al* 2001). Precision farming or site-specific management is aimed at managing soil spatial variability by applying inputs in accordance with the site-specific requirements of a specific soil and crop (Fraisse *et al.*,1999). Such management practices require quantification of soil spatial variability across the field. One of the recent approaches to quantify soil spatial variability for site specific management is to divide fields into productivity level management zones (Khosla *et al* .,2002; Fleming *et al* .,2000). Healthy and productive soils are the foundations for food production on earth. Soil fertility is the status of a soil with respect to its ability to supply elements essential for plant growth without toxic concentration of any element. A sufficient and balanced supply of liable and available elements is needed to guarantee suitable plant nutrition. Soil productivity is defined as “the capacity of a soil to produce a certain yield of agronomic crops or other plants with optimum management”. The soil productivity is dependent on soil fertility as well as management practices and the factors affecting plant growth. Productive soils are always fertile but soils can be unproductive because of limiting growth factors like drought and unsuitable management practices. Soil fertility status is determined by chemical, physical and biological factors. The range of acidity (soil pH) influences soil nutrient availability. Thus soil quality is the sum total of the capacity of a soil to function, within its ecosystem and land-use boundaries, with the ability to sustain biological activity, maintain environmental quality, and promote plant, animal, and human health (Doran and Parkin,1994; Doran *et al*., 1996a). It reflects the biological, chemical, and physical properties and processes and their interactions within each soil resource (Karlen *et al*., 2001). It also relates to the dynamic nature of soil as influenced by human use and management (Mausbach and Seybold, 1998., Carter *et al*, 1997) stressed that the concept of soil quality is relative to a specific soil function or use. The physical, chemical and biological properties of soils are highly variable over time and space (Robertson and Gross, 1994; Ryel *et al.*,1996). This variability may be attributed to the variations in soil parent material that is inherent in nature. Spatial variability of soil properties is somewhat inherent in nature because of variations in soil parent materials and microclimate. (Zhao *et al*., 2007). Farming activities across fields should then be related to this for efficient application of farm inputs, thus necessitating the estimation and mapping of spatial variability of soil properties. The maps so generated shall be helpful to farmers and soil management experts to design land management practices. This knowledge of soil spatial variability and the relationship among soil properties is important for evaluating agricultural land use.

A study was undertaken by Ravikumar *et al*. (2007) to map major nutrients status of 48A distributary of Malaprabha Right Bank Command of Karnataka for site specific recommendations. The mapping of available nutrient status by GIS technique indicated that majority of the area was low to medium with respect to available nitrogen N (154 to 333 kg/ha), low to high with respect to phosphorus (5.09 to 28.60 kg/ha) and sulphur (17.30 to 53.80 kg /ha). The entire study area was reported to be high in potassium (375 to 887 kg/ha). Low available nitrogen status demands replenishment of soil nitrogen through organics and /or in organics to avoid soil mining for nitrogen.

Akhter *et al*. (2010) in district Hyderabad of Pakistan prepared map of the soil fertility using GIS software under cotton, wheat and sugarcane crops. The soil samples were taken from 80 spatially distributed locations from a depth of 0-60 cm. The data regarding fertilizer application, cropping pattern, crop rotation and irrigation practices were also collected from the farmers. The interpolated maps for the status of micro and macro nutrients show a clear deficiency of nutrients across the district. Nitrogen is deficient in 96 %, potassium and phosphorus are below the critical levels in 95 and 76 % of the soils of the irrigated area, respectively. Organic matter is below recommended levels in 95 % of the cropping area. More than 50 % of the area has sandy loam to sandy clay loam soil texture.

A study conducted by Pulakeshi *et al.* (2012) concluded that, soils of Mantagani village in northern transition zone of Karnataka were low in Soil organic matter content. Available nitrogen and phosphorus were low to medium and available potassium and sulphur were low to high. Regarding DTPA micronutrients status zinc and iron were deficient whereas, copper and manganese were deficient to sufficient in these soils. One hundred fifteen samples (0-30 cm) drawn from the farmers' fields were analysed for their fertility status and mapped by (GIS) technique. The pH of soil samples was slightly acidic to alkaline. Soil organic matter content was low. Available nitrogen (low; 93% area), phosphorus (low; 24% area, Medium; 76% area) was generally low to medium and available potassium and sulphur were low to high. Regarding DTPA micronutrients, zinc and iron were deficient (88% and 72 % area, respectively) whereas, copper and manganese were deficient 54% and 51% area, respectively.

Vijaya Kumar *et al*. (2015) conducted study on global positioning system (GPS) based soil survey in the sugarcane dominant tracts of Theni district of Tamil Nadu to map the soil fertility status using GIS software. The soil samples were taken from 400 spatially distributed locations from a depth of 0 to 30 cm and analysed for texture, pH, EC, organic carbon, available nitrogen, phosphorus, potassium and micronutrients viz., Fe, Mn, Zn and Cu. The interpolated maps for the status of macro and micronutrients show a clear deficiency of available Nitrogen in 96% of the soil samples of the cane growing areas and DTPA – extractable Zn deficiency in almost 60% of the regions surveyed. However, the available phosphorus and potassium contents were reported to be moderate to high in 90% of the samples. Majority of the soils were sandy loam to sandy clay loam in texture and reported to have low organic carbon context (<0.5%).

A study was carried out by Sharma *et al.* (2009) to assess the fertility status of erosion prone soils of Jammu Shiwaliks. Soil reaction of kandi belt was found neutral ranging from 6.76 and 7.67. The electrical conductivity of the soils ranged from 0.27 to 1.18 dS m-1, Major portion of soils were found to be low in organic carbon ranging from 0.31 to 0.55 per cent.

The dominant textural group was sandy loam followed by loam soils. The cation exchange capacity of the soils varied from 7.2 to 12.4 Cmol (p.) kg. The soils were low in available N (169 to 265 kg ha-1), low to medium in available P content (9.0 to 14.3 kg ha-1) and available K (77to 144 kg ha-1).

Patil *et al*. (2016) studied soil samples from Dindur sub-watershed in northern dry zone of Karnataka drawn at 250 m grid interval and assessed for their fertility parameters. Soil fertility maps were prepared for each parameter under GIS environment using Arc GIS v 10.4. Soils were neutral to very strongly alkaline with non-saline to slight salinity. Soil organic carbon content was low to medium. Available nitrogen (N) was low, available phosphorus (P) was low to medium, available potassium (K) was medium to high and sulphur (S) was low to medium. Regarding available micronutrients, zinc (Zn) and iron (Fe) were deficient in about half of the sub-watershed area whereas, copper (Cu) and manganese (Mn) were sufficient in the soils.

A study was conducted by Bhuyan *et al*. (2014) with an aim to analyse the spatial and temporal variability of soil C, N, P under four prominent land use pattern viz., Jhum, Agro-forestry, forest garden and vegetable agro-ecosystem of East Siang district, Arunachal Pradesh. Soil samples were collected on monthly basis from 8-10 places of every selected system from two depths (0-15 cm and 15-30 cm) in replicates. Minimum SOC was recorded during the rainy season in all the systems while maximum in winter (Agro-forestry and Vegetable AES) and spring season (Jhum and Forest garden).Surface soil layer had significantly greater SOC concentration than the subsurface soil depth. However, available phosphorus resulted reverse trend during spring season in agro-forestry and vegetable The C/N ratio ranges from 1.8 to10 among the systems.

In a study carried out by Nazia *et al.* (2016) revealed physico- chemical characterization of an agriculturally important soil and its fertility mapping was conducted by collecting 72 soil samples at two depths (0-15 and 15-30 cm) from the Research Farm, The University of Agriculture, Peshawar-Pakistan. These samples were collected at grid pattern with 100 m distances. The results indicated that in all samples collected from the area total nitrogen content ranged from marginal to adequate level in some samples, ranges from deficient in 9.72 %, marginal in 33.33 % and 56.95 % sufficient nitrogen in the surface while in subsurface it was deficient 54.17 %, marginal in 30.83 % and in 15 % sufficient. The AB-DTPA extractable phosphorus was deficient in 97 % surface and 100 % sub-surface soils while potassium was marginal to adequate levels in all samples with mean value of 150 mg kg-1. The surface soil sample was in adequate to the level of 58.33 % and subsurface it ranges from 86.11 %, respectively.

A study was undertaken by Azlan *et al.* (2012) in which total of four sites distributed in different soils of Kelantan State, Malaysia was identified for the study. Soils were collected by depth interval of 0-10cm, 10-20cm and 20-30cm. The results showed that, SOM concentration was lower ($P < 0.05$) at Pengkalan Chepa area (1.96%) compared to Kota Bharu (2.06%), Banggu (2.77%) and Jeli (7.39%). At the same time, the TOC level also showed that Banggu area recorded the lowest concentration (0.42%) followed by Kota Bharu (0.71%), PengkalanChepa (0.76%) and Jeli (3.73%). The temporal factor ($p < 0.05$) showed that TOC content higher during dry season (1.76%) and lower during pre-monsoon (0.48%) and lowest in monsoon season (0.25%). Similar results were obtained for SOM content, higher during dry season (4.00%) followed by pre monsoon (2.12%) and lowest in monsoon season (1.67%).

A study conducted by Ramzan *et al*. (2017) addressed the spatial distribution characteristics of organic matter (OM), pH, available nitrogen (AvN), available phosphorus (AvP), available potassium (AvK) and available sulphur (AvS) in Research farm of SKUAST-K, Shalimar, Srinagar. A total of seventy-seven (77) soil samples were collected in a systematic grid design using geographical positioning system (GPS). Each grid was specified at a fixed distance of 50×50 m^2. The results showed that soil organic matter and S was distributed normally while as the three soil macronutrients (AvN, AvP and AvK) and soil pH followed log normal distribution. Soil available phosphorus had a highest coefficient of variation (56.87%) and the soil pH (7.06%) the lowest. All the soil macronutrients were found in medium range except sulphur which was found deficient in whole of the research farm. The experimental semivariogram of the log-transformed data of soil available phosphorus, potassium, sulphur, soil pH and normally distributed soil organic matter was fitted to exponential model. Gaussian model was found to be the best fit for experimental semivariogram of soil available nitrogen. Experimental semivariogram results indicated a moderate degree of spatial dependence for soil organic matter, available potassium and sulphur, soil pH and weak degree of spatial dependence for soil available nitrogen and phosphorus. Using such analyses, it is possible to plan appropriate soil management practices, including fertilization for agricultural production and environmental protection.

2.2 Georeferencing,

Georeferencing means that the internal coordinate system of a map or aerial photo image can be related to a ground system of geographic coordinates. The relevant coordinate transforms are typically stored within the image file, though there are many possible mechanisms for implementing georeferencing. The most visible effect of georeferencing is that display software can show ground coordinates (such as latitude/longitude or UTM coordinates) and also measure ground distances and areas. In other words, georeferencing means to associate something with locations in physical space. The term is commonly used in the geographic information systems field to describe the process of associating a physical map or raster image of a map with spatial locations. Georeferencing may be applied to any kind of object or structure that can be related to a geographical location, such as points of interest, roads, places, bridges, or buildings.

Characteristics of georeferencing. (Hackeloer *et al,* 2014)

- Georeferencing is crucial to making aerial and satellite imagery, usually raster images, useful for mapping as it explains how other data, such as the above GPS points, relate to the imagery.
- Very essential information may be contained in data or images that were produced at a different point of time. It may be desired either to combine or compare this data with that currently available. The latter can be used to analyse the changes in the features under study over a period of time.
- Different maps may use different projection systems. Georeferencing tools contain methods to combine and overlay these maps with minimum distortion.
- Using georeferencing methods, data obtained from surveying tools like total stations may be given a point of reference from topographic maps already available.
- It may be required to establish the relationship between social survey results which have been coded with postal codes or street addresses and other geographic areas such as census zones or other areas used in public administration or service planning.

Historical Development of Soil mapping

Soil mapping is indispensable components of soil science, because soils are inherently spatial (Arnold, 1994; Campbell and Edmonds, 1984; Fridland, 1974; Goryachkin, 2005) The processes for creating soil maps, with uses ranging from scientific study of soil pattern to applied use and management decisions, are firmly rooted in the concepts and methodologies of geography (Bushnell, 1929, Helms *et al* 2002). Therefore, it can be beneficial to review the historical development of soil mapping, as it relates to evolving concepts in geography. The on-line Dictionary of Cartography (2014) defines a base map as a “map on which information may be placed for purposes of comparison or geographical correlation.” From the beginning of accurate surveying techniques (17th century), until the widespread completion of topographic maps, base maps were often limited to outline maps, which provide only positional reference. Although positional reference is a key function of all maps, recent developments in global positioning systems (GPS) and geographic information systems (GIS) have nearly replaced the need for separate maps to provide positional reference. Because of the heavy reliance on base maps for positional reference in the past, these new geographic technologies may lead some to consider the term ‘base map’ as outdated. However, base maps still have use in “geographic correlation. “In the modern definition of base maps, geography is recognizing the continuing role of base maps for spatial association. Indeed, GPS data do not actually replace base maps, because GPS only provides information on location. In contrast, base maps provide more information than location alone; they include spatially associated attributes and context (Abler, 1993).

Early soil geography

Ever since early peoples began sowing crops, and perhaps before, humans have had a vested interest in the geography of soil. Dating generally produced for individual cities and for more practical purposes. For example, the Romans surveyed grid systems of “centuries” as a base map for city planning and levying of taxes (Dilke, 1987). The earliest known spatial representations, i.e., maps, of soil properties were tied to the assessment of land valuation at the analysis scale of parcels or fields. In general, the valuation of land - from which the levying of taxes was based - was assessed by an index of soil productivity (Kain and Baigent, 1992). From approximately 300 to 1951 AD, China compiled data on land quality by crop fields, as well as with other physiographic properties, into special geographic descriptions called difanchzhi (Lee, 1921; Zaichikov, 1955). Although cadastral maps advanced the geographic collection of soil data, they lacked a fundamental theory of prediction. Also, geographic information was limited, because soil boundaries often were simply field boundaries.

The emergence of topographic maps

Before thematic maps (i.e. geologic and soil maps) would be considered viable endeavours, mappers needed more reliable base maps of the landscape thematic maps used for scientific study still tended to use small cartographic scales, up to and through the 19th century. Although the principles for determining position were mostly worked out by the ancients, it would take inventions of the 17th century to produce instruments accurate enough to determine position within few meters (Bennett, 1987). In 1668, France became the first country in Europe to sponsor a systematic survey of islands using accurate methods. Its motivation was to improve infrastructure for the purpose of increasing trade and tax revenue (Brown, 1979). From their inception, thematic maps have relied on base maps for positional reference, because of the special equipment and time-consuming work of accurately determining location on the Earth's surface Base maps were purchased by publishing companies, who printed compilations of themas atlases. These atlases were widely popular, because they presented new views of the world and reported the discoveries of European explorers. By the 1600s, hand-colouring of these maps was a fashionable activity for the recreational study of geography (Brown, 1979). The reliance of thematic maps on base maps focused the production of thematic maps at the cartographic scale of the available base maps. The primary sponsors of base map production were national governments interested in outlining the borders of their country (Harley, 1988).

Use of topographic maps for soil mapping

When agro geologists met the newly available, accurate, topographic maps, a new synergy was found. For the first time, a resource existed that allowed them to record and visualize spatial information with a reasonable amount of efficiency and accuracy. Scientists could simply plot their observations on the base map. The linking of soil and geology attributes was based on the mapper's experience of soil characteristics corresponding to the spatial distribution of geology as mapped at that cartographic scale (Boud, 1975; Brevik and Hartemink, 2010). When the U.S. Soil Survey began in 1899, its primary goal was to create maps specific enough to provide guidance for crop selection (Whitney, 1900, 1909). However, the base maps available prevented the use of larger cartographic scales and limited the amount of detail that could be shown (Simonson, 1952).

Introduction of aerial photography

The ability to locate features in soil surveys accurately and with greater detail was markedly enhanced by the use of aerial photography in the 1930s (Soil Survey Staff, 1951). Aerial photography for soil survey work in the U.S. had been proposed as early as 1923 (Cobb, 1923), but the U.S. Bureau of Chemistry and Soils showed little interest in taking on the expense (Simonson, 1989). Bushnell (1929) compared soil mapping with and without aerial photography, and made four main points on the advantages of using aerial photography. Aerial photographs made soil mapping (1) more efficient, (2) of higher quality, (3) with improved consistency, and (4) with reduced cartographic demands for the determination of location. The paradigm shifts caused by the implementation of aerial photography have yielded lessons about the use of base maps. For example, Brown (2006) By the late 1900s, even though aerial photography had greatly increased the level of detail that could be included in a soil map, limits still existed. The minimum delineation size on paper maps is relative to the legibility of identifying symbols and colors, as well as levels of spatial accuracy (Arnold, 2006;Base maps in the age of geographic information systems The recent introduction of geographic information technologies, such as GPS and GIS, has instigated another revolution in soil geography. Similar to aerial photographs, and topographic maps before them, these new technologies have created opportunities in soil mapping by providing critical spatial information and new methods to analyse that data. In short, modern geospatial technologies are resetting the soil mapping paradigm yet again. New technologies beckon the revaluation of current procedures and the development of new techniques for the advancement science. For this reason, the current geospatial revolution has caused soil science to spawn a new sub-discipline, digital soil mapping (Scull *et al*., 2003). New geospatial technologies are shifting the soil mapping paradigm in three primary ways:

(1) By increasing the types of spatial information available as base maps,

(2) By replacing base maps with GPS as the primary source of positional referencing, and

(3) By decoupling the relationships between different aspects of map scale

More spatial data

Remote sensing technologies, beginning in the 20th century and continuing today, have greatly improved the quality and variety of information that can be used as base maps (Lillesand *et al* ., 2008). New remote sensing technologies range from proximal to aerial to satellite based sensors, each with unique capabilities for measuring soil properties directly, or for providing indirect evidence of soil properties by spatial association (Doolittle, 1987; Doolittle and Brevik, 2014 Base maps, such as aerial photographs, have also provided important contextual information for the soil mapper. From an aerial photograph, interpretations can be made about geomorphology, landscape position, vegetation, soil wetness, erosion status, land use, among other parameters useful for predicting soil properties (Goosen, 1968; Soil Survey Staff, 1993) Spatial analysis methods in GIS can quantify context much more efficiently than traditional methods, but also offer new methods of analysis. For example, multiple remote sensing bands can be analysed together to produce indicators such as the normalized difference vegetation index (Kriegler *et al.,* 1969) Although the list of spatial analysis methods available today is large, one of the most commonly used categories of analysis to produce base maps for soil mapping is land-surface derivatives (Florinsky *et al.,* 2002)

GPS becomes primary source of spatial referencing

GPS provides an efficient means for accurately determining location by triangulating for the distance between a GPS receiver and the known locations of satellites in orbit around the Earth. The distance between the receiver and the satellites is calculated using the time it takes radio signal to travel from the respective satellites to the receiver (Hofmann-Wellenhof *et al* 2001) By this method, the location of the surface-based receiver can be determined rapidly, accurately, and at relatively low cost. Thus, the preferred method for spatial referencing field observations is now with a GPS receiver (Schaetzl *et al*., 2002). Despite the efficiency of GPS, the need for base maps for positional reference has not been completely replaced. Data collected without GPS available need to be geo referenced before they can be used in a GIS. The majority of data requiring georeferencing are legacy data, created before the availability of GPS and GIS technologies (e.g. Pásztor *et al*.,2010).

Challenging definitions of scale

A common problem for disciplines studying spatial phenomena is the wide range of interpretations and definitions of scale (Dungan *et al.,* 2002). One of the most fundamental differences between traditional soil mapping and digital soil mapping is that the cartographic scale -often referred to as map scale- of base maps no longer constrains the cartographic scale of the resulting soil map. For practical reasons, such as legibility, the amount of information that can be placed on a paper map is limited by a finite space, i.e. the piece of paper. To illustrate this difference between resolution and analysis scale, consider a cell in a digital elevation model (DEM). The DEM resolution is the cell size. For the original grid of elevation values, the analysis scale is equivalent to resolution. If the mean elevation within soil delineations is calculated from that elevation grid, the analysis scale is changed to a level equivalent to the soil delineations, even though the information is based on data collected at the original DEM's resolution. The DEM also can be analysed for slope, but must use a neighbourhood of cells in order to determine a change in elevation over a distance. The size of that neighbourhood is the analysis scale Soil maps have always relied on base maps for information needed to predict the spatial distribution of soil properties. Over time, the spatial information garnered from base maps has shifted in emphasis between positional references in early maps, to attributes that are more reliably associated with soil properties. The only possible exceptions to the reliance on base maps are spatial interpolation techniques that solely rely on spatial autocorrelation. However, recent spatial interpolation methods, such as co-kriging, reiterate the utility of base maps for making accurate soil maps. Even before paper maps, it seems likely that a mental map of above ground observations informed the creation of a mental soil map.

2.3 Interpolation techniques and application of mapping.

The First Law of Geography, according to (Waldo Tobler 1970)is "everything is related to everything else, but near things are more related than distant things This first law is the foundation of the fundamental concepts of spatial dependence and spatial autocorrelation and is utilized specifically for the inverse distance weighting method for spatial interpolation and to support the regionalized variable theory for kriging (Kemp *et al*.,2008).Interpolation is a process of creating a surface based on values at isolated sample points. Sample points are locations where we collect data on some phenomenon and record the spatial coordinates. We use mathematical estimation to "guess at" what the values are "in between" those points. We can create either a raster or vector interpolated surface. Interpolation is used because field data are expensive to collect, and can't be collected everywhere. In another words, interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data elevation, rainfall, temperature, chemical dispersion, noise level or other spatially-based phenomena. Interpolation is the estimation of a value or set of values based on their context. Linear interpolation, a very simple form of interpolation, is basically the rendering of a straight line between two or more points. Interpolation is useful for filling in missing data, such as in up scaling images or creating statistical models. In the mathematical field of numerical analysis, interpolation is a method of constructing new data points within the range of a discrete set of known data points.

Types of interpolation.

(ESRI) Geographic information System Company**.**

1. Inverse distance weighted **(**IDW)
2. Kriging
3. Natural neighbour
4. Spline
5. Spline with Barriers
6. Topo to Raster
7. Trend

From agricultural point of view two are important Kriging and IDW and kriging more specifically

1. KRIGING

Kriging is a Geostatistical interpolation technique that considers both the distance and the degree of variation between known data points when estimating values in unknown areas. A kriged estimate is a weighted linear combination of the known sample values around the point to be estimated.

Kriging procedure that generates an estimated surface from a scattered set of points with z-values. Kriging assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. The Kriging tool fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogram modelling, creating the surface, and (optionally) exploring a variance surface. Kriging is most appropriate when you know there is a spatially correlated distance or directional bias in the data. It is often used in soil science and geology.

The predicted values are derived from the measure of relationship in samples using sophisticated weighted average technique. It uses a search radius that can be fixed or variable. The generated cell values can exceed value range of samples, and the surface does not pass through samples.

THE KRIGING FORMULA

Kriging is similar to IDW in that it weights the surrounding measured values to derive a prediction for an unmeasured location. The general formula for both interpolators is formed as a weighted sum of the data:

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

where:

$Z(s_i)$ = the measured value at the *i*th location

λ_i = an unknown weight for the measured value at the *i*th location

s_0 = the prediction location

N = the number of measured values

In IDW, the weight, λ_i, depends solely on the distance to the prediction location. However, with the kriging method, the weights are based not only on the distance between the measured points and the prediction location but also on the overall spatial arrangement of the measured points. To use the spatial arrangement in the weights, the spatial autocorrelation must be quantified. Thus, in ordinary kriging, the weight, λ_i, depends on a fitted model to the measured points, the distance to the prediction location, and the spatial relationships among the measured values around the prediction location. The following sections discuss how the general kriging formula is used to create a map of the prediction surface and a map of the accuracy of the predictions.

Kriging interpolation is frequently used for mapping soil properties in the analysis and interpretation of spatial variation of soil. Mapping quality could affect the performance of site-specific management. Soil map–delineation in existing soil maps showing abrupt changes at the boundaries between different soil types can provide valuable categorical information for interpreting variation in soil properties (Liu et al 2006) Kriging interpolation is frequently used for mapping soil properties for the analysis and interpretation of spatial variation. The quality of the mapping soil properties affects the performance of soil site-specific management. Insufficiently intensive sampling wastes time and money because it cannot provide the level of accuracy and precision needed for successful site-specific management (Mueller et al., 2004). However, the cost of intensive soil sample collection and analysis quickly exceeds any benefits from site-specific management (Kravchenko, 2003).

TYPES OF KRIGING

ORDINARY KRIGING

Ordinary kriging assumes the model

$Z(\mathbf{s}) = \mu + \varepsilon(\mathbf{s})$,

Where μ is an unknown constant, one of the main issues concerning ordinary kriging is whether the assumption of a constant mean is reasonable. Sometimes there are good scientific reasons to reject this assumption. However, as a simple prediction method, it has remarkable flexibility.

Ordinary kriging can use either semivariograms or covariances, use transformations and remove trends, and allow for measurement error.

SIMPLE KRIGING

Simple kriging assumes the model

$Z(\mathbf{s}) = \mu + \varepsilon(\mathbf{s})$,

where μ is a known constant.

Simple kriging can use either semivariograms or covariances, use transformations, and allow for measurement error.

UNIVERSAL KRIGING

Universal kriging assumes the model

Z(**s**) = μ(**s**) + ε(**s**),

where μ(**s**) is some deterministic function.

Universal kriging can use either semivariograms or covariances, use transformations, and allow for measurement error.

INDICATOR KRIGING

Indicator kriging assumes the model

I(**s**) = μ + ε(**s**),

where μ is an unknown constant and *I*(**s**) is a binary variable. The creation of binary data may be through the use of a threshold for continuous data, or it may be that the observed data is 0 or 1. For example, you might have a sample that consists of information on whether or not a point is forest or non-forest habitat, where the binary variable indicates class membership. Using binary variables, indicator kriging proceeds the same as ordinary kriging. Indicator kriging can use either semivariograms or covariances.

Spatial variability of soil fertility parameters were mapped by kriging interpolation method. Circular, Spherical, Exponential, and Gaussian models were tested. Root Mean Square Error (RMSE) technique was used to select the best kriging model (Li *et al* 2011). The RMSE was calculated using the following formula:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left\{z\left(x_{1,i}\right) - z\left(x_{2,i}\right)\right\}^2}$$

Kriging is optimal interpolation method if it meets certain conditions (ESRI)

1) Normally distributed.

2) Stationary.

3) No trends.

These conditions are checked by Expolatory Spatial Data Analysis (ESDA)

Exploratory Spatial Data Analysis

1. Where is the data located?

2. What are the values of the data points?

3. How does the location of a point relate to its value?

Characteristics of optimal interpolator

- Estimates the true value, on average
- Lowest expected prediction error
- Able to use extra information, such as covariates
- Filters measurement error
- Can be generalized to polygons (Areal interpolation, Geostatistical simulations)
- Estimates probability of exceeding a critical threshold.

Methods to check whether data follows normal distribution or not.

1. Histogram - Check for bell-shaped distribution - Look for outliers

2. Normal QQPlot - Check if data follows 1:1 line

   If data is not normally then we apply a transformation

   Log, Box Cox, Arcsin, Normal Score Transformation

Characteristics of normal distribution

Bell-shaped

No outliers

Mean ≈ Median

Skewness ≈ 0

Kurtosis ≈ 3

Stationarity

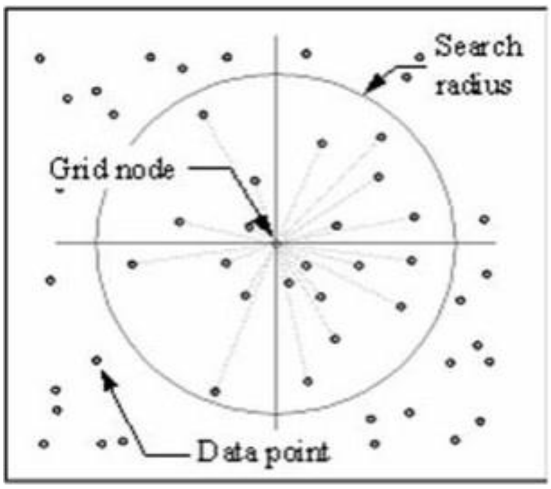
The statistical relationship between two points depends only on the distance between them. - The variance of the data is constant (after trends have been removed) Stationarity can be checked by (Voronoi Map) symbolized by Entropy or Standard Deviation. If data is non-stationary transformations can stabilize variances - Empirical Bayesian Kriging.

Trends

Trends are systematic changes in the values of the data across the study area. trends can be checked by Trend Analysis ESDA tool. If my data has trends we can use trend removal options. Potential problem is that trends are often indistinguishable from autocorrelation and anisotropy.

2. INVERSE DISTANCE WEIGHTED (IDW)

The Inverse Distance Weighting interpolator assumes that each input point has a local influence that diminishes with distance. It weights the points closer to the processing cell greater than those further away. A specified number of points, or all points within a specified radius can be used to determine the output value of each location. Use of this method assumes the variable being mapped decreases in influence with distance from its sampled location. The Inverse Distance Weighting (IDW) algorithm effectively is a moving average interpolator that is usually applied to highly variable data.



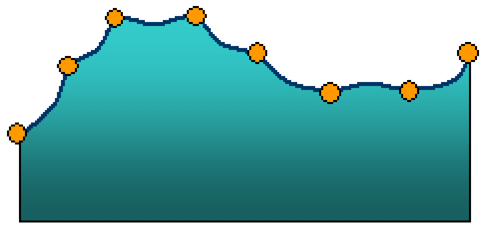
A radius is generated around each grid node from which data points are selected to be used in the calculation. Options to control the use of IDW include power, search radius, fixed search radius, variable search radius and barrier.

$$z_p = \frac{\sum_{i=1}^{n}\left(\frac{z_i}{d_i^p}\right)}{\sum_{i=1}^{n}\left(\frac{1}{d_i^p}\right)}$$

The sigma notation simply means that you are adding whatever number of points that will be interpolated. Here we are are simply summing the elevation values at each point with respect to distance.

Conditions when to use IDW.

A surface calculated using IDW depends on the selection of the power value (*p*) and the search neighborhood strategy. IDW is an exact interpolator, where the maximum and minimum values (see diagram below) in the interpolated surface can only occur at sample points.



Inverse Distance Weighted profile example

The output surface is sensitive to clustering and the presence of outliers. IDW assumes that the phenomenon being modeled is driven by local variation, which can be captured (modeled) by defining an adequate search neighborhood. Since IDW does not provide prediction standard errors, justifying the use of this model may be problematic.

Geostatistical workflow

1. Explore the data
2. Choose an interpolation method
3. Fit the interpolation model
4. Validate the results
5. Repeat steps 2-4 as necessary
6. Map the data for decision-making

Gotway *et al.* (1994) found that the IDW method generated more accurate results than Kriging for mapping soil organic matter and soil NO3 levels.

Wollenhaupt *et al.* (1994) compared these two interpolation techniques and concluded that IDW was more accurate for mapping P and K levels of soil, too. Mueller et al. (2004) observed that for the optimal parameters of the method, the accuracy of IDW interpolation generally equalled or exceeded the accuracy of Kriging at all scales of measurement (2,3). On the other hand, other researchers observed that Kriging was more accurate for the interpolation of several soil attributes.

Leenaers *et al*. (1990) assessed the Kriging interpolation method as more accurate compared to IDW, for mapping soil Zn content.

Kravchenko *et al* (2003) evaluated the effect of data variability and the strength of spatial correlation in the data on the performance of the grid soil sampling of different sampling density and two interpolation procedures, ordinary point Kriging and optimal Inverse Distance Weighting (IDW). Kriging with known variogram parameters performed significantly better than the IDW for most of the studied cases (4,5). Many other studies also compared Kriging, IDW, and RBF in soil science.

Schloeder *et al.* (2001) observed that Ordinary Kriging (OK) and IDW were similarly accurate and effective methods, while thin-plate smoothing spline with tensions was not.

Weller *et al.* (2002) concluded that even in cases where the assumptions for Kriging were not fulfilled the Kriging approach was as good as any other radial base function interpolation. Summarising the above, the accuracy of each method depends on the assumptions and subjective judgments that are made, such as the application of smoothness of the results or not and linearity of interpolation functions or not Apart from research studies to judge the quality of a technique's performance, validation or accuracy assessment of a method is rarely done in operational applications because of its high cost.

Many Indian scientists prepared Digital maps of sand content of arid western India using four different approaches of DSM methodology were applied to prepare sand content map of arid western India and these are ordinary kriging (OK), universal kriging (UK)/kriging with eternal drift (KED), random forest regression and regression kriging (RK). Apart from legacy soil data, information on auxiliary and environmental variables e.g. soil map, terrain attributes and bioclimatic variables were used in the DSM methodology.

Application of mapping

S.No	Application	Reference
1	Assessment of Soil Erosion Using Remote Sensing and GIS	Srinivas *et al* .,2002.
2	Soil Resource Assessment and Mapping using Remote Sensing and GIS	Velmurugan *et al* .,2009.
3.	Soil Informatics for Evaluating and Mapping Soil Productivity Index	Raj Setia *et al.*, 2012.
4.	Land use change mapping and analysis using GIS	Butt *et al* .,2015. .
5.	Use of satellite data and GIS for soil mapping and monitoring soil productivity of the cultivated land	Kawy *et al*, 2013.
6.	Mapping soil erosion susceptibility	Bahadur *et al* ,2008.
7.	3D mapping of soil texture	Adhikari *et al.*, 2009.

2.4 Case studies

Sharma *et al.* (2016) conducted a research In which geo-referenced soil samples from Indian Punjab were analysed map fertility status using a Geographical Information System (GIS). Soil texture, which affects soil hydraulic properties and soil strength, varied from sandy to clayey loam, with majority (47.3%) of the cultivated area being sandy loam. About 95% of the total area of the state shows pH between 6.5 and 8.5(40% of the area between pH

6.5 and 7.5 and 54% between 7.5 and 8.5) and electrical conductivity (EC) <0.8 dS m−1. Calcium carbonate ($CaCO_3$) with <5%values represents 97% area of the state. The GIS-based maps indicate that irrespective of the agro climatic variations, more than 90% of the soils showed low to medium soil organic carbon (OC) content and 50% low to medium (<22.4 kg P ha−1) available phosphorus (P) content with a marginal (7%) deficiency of potassium (K). The dominance of low to medium status of available P in these soils could be due to the mining of soil P by the rice–wheat cropping system practiced in the region. The intensively cultivated soils of Indian Punjab showed 11% of soil samples were low in zinc (Zn), 15% low in manganese (Mn), 2% low in copper (Cu), and 12% low in iron (Fe). Availability of micronutrients increased with increase in OC content and decreased with increase in sand content, pH, and $CaCO_3$.

Bogunovic *et al.* (2014) conducted a research to assess spatial variability of plant available phosphorus, plant available potassium, soil pH and soil organic matter content in central Croatia was investigated using Geostatistical tools and geographical information system to create nutrient maps and provide useful information for the application of inputs that will also be used for the design of an adequate soil sampling scheme. In a regular grid (50 m×50 m), 330 samples were collected on sandy loam (Stagnic Luvisol). Soil available phosphorus and plant available potassium showed relatively high spatial heterogeneity, ranging from 105 mg kg_1 to 310 mg kg-1, and from 115 mg kg_1 to 462 mg kg_1, respectively. Content of soil organic matter and pH had lower variability ranging from 1.26% to 2.66% and from 3.75 to 7.13, respectively. Investigated soil properties did not follow normal distribution. Logarithm and Box–Cox transformation were applied to achieve normality. Directional exponential model for soil available phosphorus, potassium and pH and spherical model for soil organic matter was used to describe spatial autocorrelation. Fourteen different interpolation models for mapping soil properties were tested to compare the prediction accuracy. All models gave similar root mean square error values. Available phosphorus, potassium and pH evaluated by radial basis function models (CRS, IMTQ and CRS, respectively) provide a more realistic picture of the structures of analysed spatial variables in contrast to kriging and inverse distance weighting models. For soil organic matter datasets, the most favourable model was LP1. According to the best model soil nutrient maps were created to provide guidance for site-specific fertilization and liming. Soil fertility maps showed sufficient concentrations of soil available phosphorus and available potassium. Acidity map showed that the largest part of the investigated area is very acid and acid. For future management it is necessary to provide more liming materials while fertilization rate should be lower.

Guan *et al*. (2017) concluded that Soil nitrogen (N), phosphorus (P) and potassium (K) are important micronutrients for plant growth and productivity. Because of the high spatial and temporal variability of soil, information on the spatial distribution of N, P and K contents in Moso bamboo forests is very limited, although this information is important for improving soil nutrient management. Therefore, in this study, soil samples at 0–20, 20–40 and 40–60 cm were taken from138 locations in Moso bamboo forests across the study area. The N, P and K contents of different soil layers ranged from 1.01 to 4.11 g kg^{-1}, from 0.025 to 0.131 g kg^{-1} and from 0.42 to5.40 g kg^{-1}, respectively. The coefficient of variation of N, P and K contents ranged from 26% to 43%, suggesting moderate variability. Ordinary kriging (OK) and inverse distance weighting (IDW) approaches were applied to analyse the spatial patterns of N, P and K contents. Geostatistical analysis showed a moderate spatial dependence of N, P and K contents, indicating that N, P and K contents were controlled by both intrinsic and extrinsic factors. Cross-validation illustrated that OK performed better than IDW. OK and ID showed a similar spatial pattern of N, P and K contents over the whole study area, demonstrating the suitability of OK and IDW in spatial interpolation. However, OK produced a smaller range of predicted, N P and K contents than IDW, highlighting the necessity of using different approaches when studying the spatial distribution of soil properties.

MATERIALS AND METHOD

With an aim to achieve the objectives mentioned in the preceding pages, investigations were carried out in Kishtwar and Ramban Districts to assess the spatial variability of the soil properties. The details of various materials used and methods employed for achieving the objectives of the current investigation have been given in this chapter under following sub-heads:

3.1 Study area

3.2 Collection and preparation of samples

3.3 Soil properties

3.4 Conventional Statistical analysis

3.5 Geo-statistical analysis

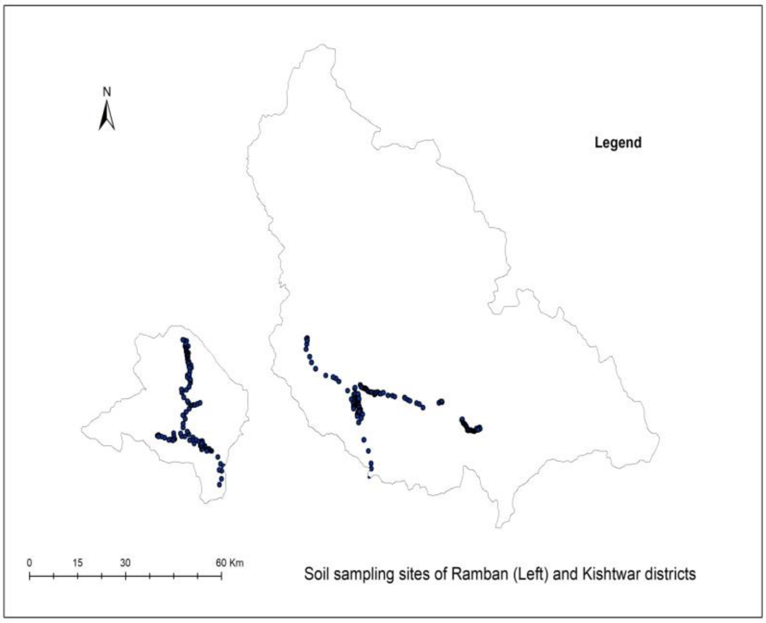
3.6 Soil mapping

3.1 Study area

Study area District Kishtwar lies at 32° 53´ to 34°21´N latitude and 75°1´ to 76° 47´E longitude, with an average elevation of 1107 meters (3361 feet) from mean sea level. Ramban district located at 33^{o} 14' N and 75^{o} 17'E longitudes with an average elevation of 1,156 metres (3792 feet) from sea level. The climate of the Districts varies according to altitude. District Kishtwar experiences cold winters, even sub-zero temperature in some areas. The temperature in case of District Ramban rises as high as 42 °C in the low-lying areas, located in between steep Mountains on the banks of river Chenab and drops to sub-zero in the high altitude areas. Area of District Kishtwar according to village papers is 113787 hac. The area of Ramban district according to village papers is about (113787 hac).

3.2 Collection and preparation of soil samples

Composite surface soil samples from one hundred sixty seven (167) and one hundred fourteen (114) sites of Kishtwar and Ramban Districts, were taken respectively. Samples were taken from different locations distributed randomly across the whole of the districts at the depth of 0-15 cm using global positioning system (GPS). The exact sample locations were recorded using a handheld GPS receiver and then were analysed as per the standard procedure for laboratory analysis. ArcGIS 10.3 was used to digitize the nutrient map of the district.



3.3 Soil properties

The basic soil properties and available nutrients were analysed in laboratory as per the procedures outlined below.

3.3.1 pH

Reaction of the soil samples was determined in 1:2.5, soils: water ratio (w/v) with the help of glass electrode pH meter.

3.3.2 Electrical Conductivity

Electrical Conductivity was estimated in 1:2.5 soil water suspension with EC meter.

3.3.3 Particle size analysis

Mechanical analysis of soil was done by Hydrometric method.

3.3.4 Organic Carbon

Organic carbon was estimated according to the Chromic Acid Digestion method (Walkley & Black, 1934).

3.3.5 Available Nitrogen

It was determined using alkaline permagnate as per the modified Kjeldahl method (Subbiah & Asija, 1956).

3.3.6 Available Phosphorus

The available phosphorus was determined by the method mentioned by (Jackson, 1973).

3.3.7 Available Potassium

1 N NH_4OAc was used as extractant and the available potassium content was determined by feeding the extract to flame photometer (Jackson, 1973).

3.3.8 Exchangeable Calcium and Magnesium

These were estimated by Versenate method. (Black, 1965).

3.3.9 Available Sulphur

Available sulphur was estimated by Turbidimetric method (Black, 1965).

3.3.10 Available Boron

It was estimated by Azomethine- H method.

3.3.11 Cation Exchange Capacity

CEC was done by 1 N NH_4OAc by method mentioned by (Piper,1966).

3.3.12 Calcium carbonate

Calcium carbonate was done by Puri method.

3.3.13 Available Micronutrients (Zn, Cu, Mn, Fe)

Available micronutrients were analysed through DTPA extractable method.

3.4 Conventional Statistical Analysis

Descriptive Statistical analysis which included mean values, Coefficient of variation, Minimum and Maximum Values, Standard deviation, Standard error of mean, Skewness and Kurtosis were carried out using SPSS.

3.5 Geo-Statistical Analysis

A semi variance analysis was conducted to estimate nugget, sill and range for quantifying the spatial dependence. Semivariogram were calculated based on equation (Vieira et al., 1983):

$$\gamma(h) = \frac{1}{2N_h} \sum_{i=1}^{N_h} \left[\left(Z_i - Z_{(i+h)} \right)^2 \right]$$

Where, z(xi) is the value of the variable Z at location xi, h is the lag, and N(h) is the number of pairs of sample points [values $Z(x_i)$, $Z(x_{xi+h})$] separated by a vector h. These Semivariograms were generated in ArcGIS 10.3 for different soil properties.

3.6 Soil Mapping

Inverse distance weighting (IDW) technique was adopted to generate prediction maps of the soil properties. The choice of either technique to prepare filled contour maps of soil properties was based upon error analysis (Robinson & Metternicht, 2006). The process of digitization and generation of maps was carried out with ArcGIS 10.3.

RESULTS

RESULTS

The results of present study are documented in this chapter

4.1 Descriptive Statistics

The data obtained from soil samples of District Kishtwar while analysing for various soil properties in the laboratory has been described here for a greater understanding of its nature under different landuse systems with following sub-heads.

4.1.1 Basic soil properties

4.1.1.1 Particles Size Analysis

4.1.1.2 Soil chemical properties

4.1.1.3 Soil Available nutrients

Table 4.1: Descriptive statistics of Sand, Silt and Clay percentage in soils under different landuse system in District Kishtwar.

	Descriptive Statistics	Type of Landuse System				
		Agriculture	Horticulture	Forest	Pasture	Wasteland
Sand percentage (%)	Min.	4.96	6.96	6.96	8.96	12.96
	Max.	76.96	64.96	54.96	58.96	88.96
	Mean	36.07	37.01	38.85	34.78	49.51
	Median	28.96	35.96	44.96	38.96	52.96
	S.E.	2.46	2.87	3.30	6.08	7.15
	C.V.	0.64	0.48	0.37	0.58	0.48
	Skewness	0.45	-0.05	-0.92	-0.30	0.43
	Kurtosis	-1.20	-1.19	-0.28	-1.82	-0.36
Silt percentage (%)	Min.	4.00	18.00	16.00	0.00	2.00
	Max.	64.00	58.00	46.00	52.00	58.00
	Mean	33.02	35.79	35.16	38.73	35.64
	Median	34.00	34.00	36.00	44.00	34.00
	S.E.	1.52	1.73	2.01	4.33	6.02
	C.V.	0.43	0.30	0.25	0.37	0.56
	Skewness	0.00	0.40	-0.78	-2.25	-0.68
	Kurtosis	-0.99	-0.77	0.26	5.78	-0.44
Clay percentage (%)	Min.	9.04	7.04	11.04	9.04	9.04
	Max.	65.04	55.04	47.04	49.04	47.04
	Mean	30.90	27.20	25.99	26.49	14.86
	Median	37.04	27.04	23.04	15.04	11.04
	S.E.	1.60	2.59	2.73	5.18	3.26
	C.V.	0.49	0.59	0.46	0.65	0.73
	Skewness	-0.17	0.24	0.51	0.24	3.15
	Kurtosis	-1.21	-1.54	-0.94	-2.28	10.20

4.1.1.1.1 Sand percentage

The sand per cent in the surface layer (0-15 cm) of the soils of Kishtwar district varied from 4.96 to 76.96, 6.96 to 64.96, 6.96 to 54.96, 8.96 to 58.96 and 12.96 to 88.96 under agriculture, horticulture, forest, pasture and wasteland, respectively.(Table 4.1) The mean value, standard error, coefficient of variance, skewness and kurtosis was 36.07, 2.46, 0.64, 0.45 and -1.20 under agriculture, 37.01, 2.87, 0.48, -0.05 and -1.19 under horticulture, 38.85, 3.30, 0.37.-0.92 and -0.28 under forest, 34.78, 6.08, 0.58, -0.30, and -1.82 under pasture and 49.51, 7.15, 0.48, 0.43 and -0.36 under wasteland, respectively. The highest CV (64%) was observed in case of agricultural landuse indicating more widespread distribution of sand content in agriculture landuse as compared to other landuses. The least variability in sand content was observed under forest landuse (CV 37%).The highest mean sand content (49.51%) was found in waste landuse followed by forest (38.85%), horticulture (37.01%), agriculture (36.07%), and pasture (34.78%). Out of total 167 samples, 26 % of soil samples were found to have sand content less than 20 % whereas in 57 % and 16% samples it was between 20 – 60 % and above 60 %, respectively. Further analysis of data by F-Statistics revealed that mean sand content of all the landuses did not differ significantly among themselves at p value (0.371). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. The sand content data in case of all landuses except agriculture and wasteland was negatively skewed indicating longer left tail and concentration of mass of distribution on right side of figure. Negative skewness of data also implied that few observations were on lower side of the mean. Whereas positive skewness of data in case of agriculture and wasteland indicated longer right tail and concentration of mass of distribution on left side of figure. It also suggested that there existed a few observations where sand percentage exceeded mean levels. In all landuses kurtosis was less than 3 indicating it as platykurtic (Broad).

4.1.1.1.2 Silt percentage

The silt per cent in the surface layer (0-15 cm) of the soils of Kishtwar district varied from 4.00 to 64.00, 18.00 to 58.00, 16.00 to 46.00, 0.00 to 52.00 and 2.00 to 58.00 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.1). The mean value, standard error, coefficient of variance, skewness and kurtosis was 33.02, 1.52, 0.43, 0.00 and -0.99 under agriculture, 35.79, 1.73, 0.30, 0.40 and -0.77 under horticulture, 35.16, 2.01, 0.25, -0.78 and 0.26 under forest, 38.73, 4.33, 0.37, -2.25 and 5.78 under pasture and 35.64, 6.02, 0.56, -0.68 and -0.44 under wasteland use system, respectively. Spatial variability of silt content in wasteland was most widespread (CV 56%) as compared to other landuses. However silt content in soils under forest showed least variability (CV 25 %). The highest mean silt content (38.73%) was found in pasture landuse followed by horticulture (35.79%), wasteland (35.64%), forest (35.16%) and agriculture (33.02%).Out of total 167 samples 15 % soil samples were found to have silt less than 20 %, whereas in 41% and 37 % samples it was between 20-40 % and greater than 40 %, respectively. Further analysis of data by F-Statistics revealed that mean silt content of all the landuses did not differ significantly among themselves at p value (0.624). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Silt content data in case of all landuses except horticulture was negatively skewed indicating longer left tail and concentration of mass of distribution on right side of figure. It also indicated the location of few observations on lower side of the mean. Positively skewed data in case of horticulture indicated that a few observations were located on higher side of the mean. The data under agriculture exhibited zero skewness indicating its symmetry. In all landuses kurtosis was less than 3 indicating it as platykurtic (Broad). The mean value for Agriculture soils was least as compare to other landuse systems.

4.1.1.1.3 Clay percentage

The clay per cent in the surface layer (0-15 cm) of the soils of Kishtwar district varied from 9.04 to 65.04, 7.04 to 55.04, 11.04 to 47.04, 9.04 to 9.04 and 49.04 to 47.04 under agriculture, horticulture, forest, pasture and wasteland, respectively**.**(Table-4.1)The mean value, standard error, coefficient of variance, skewness and kurtosis was 30.90, 1.60, 0.49, -0.17 and -1.21 under agriculture, 27.20, 2.59, 0.59, 0.24 and -1.54 under horticulture, 25.99, 2.73, 0.46, 0.51 and -0.94 under forest, 26.49, 5.18, 0.65, 0.24, and -2.28 under pasture and 14.86, 3.26, 0.73, 3.15 and 10.20 under wasteland use system respectively. Distribution of clay per cent in wasteland was most widespread (CV 73 %) as compared to that in other landuses. However it was least in case of forest (CV 46 %).The highest mean clay content (30.90 %) was found in agriculture landuse followed by horticulture (27.20%), pasture (26.49%), forest (25.99%), and wasteland (14.86%). Clay content less than 40 % was present in 66 % of total soil samples and greater than 40 % was present in 33 % of overall samples. Further analysis of data by F-Statistics revealed that mean silt content of all the landuses significantly differed among themselves at p value of (0.016). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Clay content data in all landuses except agriculture was positively skewed thereby suggesting that there existed few observations where clay percentage exceeded mean values. It also depicted longer right tail and concentration of mass of distribution on left side of figure. Whereas negative skewness in case of agriculture landuse indicated longer left tail and concentration of mass of distribution on right side of figure. It also suggested that a few observations were on lower side. In all landuses kurtosis was less than 3 which indicated it as platykurtic (Broad) while in wasteland it was greater than 3 indicating it as leptokurtic.

Soil Textural Class

Table 4.2: Soil textural classes in District Kishtwar.

Textural class	**No. of samples**
Clay	18
Clay loam	33
Loam	7
Sandy clay	2
Sandy clay loam	2
Sandy loam	**51**
Sandy soil	2
Silt loam	17
Silt clay	35

The data revealed that the dominant soil texture class was sandy loam followed by silty clay in all landuse systems. (Table-4.2).

4.1.1.2 Soil chemical properties

Table 4.3: Descriptive statistics of soils pH, EC and $CaCO_3$ under different landuse systems in District Kishtwar.

	Descriptive Statistics	Type of Landuse System				
		Agriculture	Horticulture	Forest	Pasture	Wasteland
pH	Min.	4.80	5.30	5.80	5.70	5.30
	Max.	8.00	7.50	6.90	7.40	7.50
	Mean	6.91	6.66	6.29	6.65	6.43
	Median	7.00	6.70	6.30	6.67	6.30
	S.E.	0.06	0.08	0.08	0.18	0.23
	C.V.	0.08	0.07	0.06	0.09	0.12
	Skewness	-0.66	-0.43	0.33	-0.47	-0.04
	Kurtosis	1.15	0.49	-1.07	-1.17	-1.41
EC (dSm^{-1})	Min.	0.03	0.05	0.21	0.21	0.34
	Max.	9.80	9.10	5.96	5.30	4.40
	Mean	1.23	1.72	1.29	2.44	2.30
	Median	0.79	1.19	0.56	1.67	2.23
	S.E.	0.17	0.32	0.35	0.53	0.45
	C.V.	1.31	1.16	1.18	0.72	0.66
	Skewness	3.48	2.22	2.04	0.62	0.22
	Kurtosis	14.72	4.94	4.08	-1.07	-1.61
Calcium carbonate (%)	Min.	0.00	0.00	0.00	0.00	0.34
	Max.	3.60	1.89	3.20	2.10	3.20
	Mean	0.70	0.81	0.54	1.05	1.46
	Median	0.56	0.56	0.44	0.87	1.50
	S.E.	0.07	0.11	0.16	0.24	0.27
	C.V.	0.92	0.88	1.28	0.75	0.62
	Skewness	1.72	0.33	3.35	0.07	0.67
	Kurtosis	4.25	-1.61	13.07	-1.89	-0.41

4.1.1.2.1 Soil pH

The pH ranged in the surface layer (0-15 cm) of the soils of Kishtwar district varied from 4.80 to 8.00, 5.30 to 7.50, 5.80 to 6.90, 5.70 to 7.40 and 5.30 to 7.50 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.3). The mean value, standard error, coefficient of variance, skewness and kurtosis was6.91, 0.06, 0.08, -0.66 and 1.15 under agriculture, 6.66, 0.08, 0.07, -0.43 and 0.49 under horticulture, 6.29, 0.08, 0.06, 0.33 and -1.07 under forest, 6.65, 0.18, 0.09, -0.47 and -1.17 under pasture and 6.43, 0.23, 0.12, -0.04 and -1.41 wasteland use system, respectively. The highest spatial variability (CV 12%) of data was explored in wasteland indicating widespread distribution of pH, whereas least variability was recorded in forest (CV 6%).The highest mean pH (6.91) was found in Agriculture, followed by horticulture(6.66), pasture (6.65), wasteland (6.43), and forest (6.29). Out of 167 soil samples 33 per cent samples were found to be acidic whereas 61 per cent were neutral in reaction and very minute percentage of samples that is 4.8 per cent were basic in reaction. Further analysis of data by F-Statistics revealed that mean pH content of all the landuses significantly differed among themselves at p value of (0.000). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Soil pH content data in case of all landuses except forest was negatively skewed, negative skewness indicated that left tail is longer and mass of distribution is located on right of the figure it also suggested that few numbers of values/observations were on lower side of mean. While positive skewness in case of forest indicated longer right tail and concentration of mass of distribution on left side of figure it also indicated that a few number of observations were located on higher side of mean. In all landuses kurtosis was less than 3 which indicated it as platykurtic (Broad).

4.1.1.2.2 Electrical Conductivity (EC):

The range of EC (dSm^{-1}) in the surface layer (0-15 cm) of the soils of Kishtwar district varied from 0.03 to 9.80, 0.05 to 9.10, 0.21 to 5.96, 0.21 to 5.30 and 0.34 to 4.40 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.3). The mean value, standard error, coefficient of variance, skewness and kurtosis was1.23, 0.17, 1.31, 3.48 and 14.72 under agriculture, 1.72, 0.32, 1.16, 2.22 and 4.94 under horticulture, 1.29, 0.35, 1.18, 2.04 and 4.08 under forest, 2.44, 0.53, 0.72, 0.62 and -1.07 under pasture and 2.30, 0.45, 0.66, 0.22 and -1.61 under wasteland use system, respectively. Highest spatial variability (CV 131%) in EC was found in agriculture landuse indicating its widespread distribution. Whereas in wasteland lowest variability was recorded (CV 66 %). The highest mean EC (2.44 dSm^{-1}) was observed in pasture, followed by wasteland (2.30), horticulture (1.72), forest (1.29) and agriculture (1.23). Out of total number of samples analysed 76 per cent were in safe range and 13 per cent were moderately saline and 9.6 per cent were saline. Further analysis of data by F-Statistics revealed that mean EC content of all the landuses did not differ significantly among themselves at p value (0.073). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. EC data in case of all landuses was positively skewed pointing longer right tail and concentration of mass of distribution on left side of figure. It also stipulated that few observations exceeded the mean. In all landuses kurtosis was less than 3 which indicated it as platykurtic (Broad) and in case of agriculture, horticulture and forest it was greater than 3 specifying it as leptokurtic.

4.1.1.2.3 Calcium carbonate.

Range of $CaCO_3$ per cent in the surface layer (0-15 cm) of the soils of Kishtwar district varied from 0.00 to 3.60, 0.00 to 1.89, 0.00 to 3.20, 0.00 to 2.10 and 0.34 to 3.20 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.3). The mean value, standard error, coefficient of variance, skewness and kurtosis was 0.70, 0.07, 0.92, 1.72 and 4.25 under agriculture, 0.81, 0.11, 0.88, 0.33 and -1.61 under horticulture, 0.54, 0.16, 1.28, 3.35 and 13.07 forest1.05, 0.24, 0.75, 0.07 and -1.89 under pasture and 1.46, 0.27, 0.62, 0.67 and -0.41 under wasteland use system, respectively. Highest spatial variability in $CaCO_3$ content was found in forest landuse (CV 128%) showing its wider distribution and lowest variability was recorded in wasteland (62 %). The highest mean per cent $CaCO_3$ content (1.46) was found in wasteland, followed by pasture (1.05), horticulture (0.81), agriculture (0.70), and forest (0.54). Almost all soil samples have calcium carbonate content present within safe limits while in 25 per cent of sample calcium carbonate was not found. Further analysis of data by F-Statistics revealed that mean $CaCO_3$ content of all the landuses significantly differed among themselves at p value (0.004). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Calcium carbonate content data in case of all landuses was positively skewed implying longer right tail and concentration of mass of distribution on left side of figure. It also imported that a few observations exceeded mean level. In all landuses kurtosis was less than 3 which indicated it as platykurtic (Broad) and in case of agriculture and forest it was greater than 3 registering it as leptokurtic.

Table 4.4: Descriptive Statistics of organic carbon (%) in soils under different landuse systems in District Kishtwar.

Descriptive Statistics	Organic Carbon OC (%)				
	Type of Landuse System				
	Agriculture	Horticulture	Forest	Pasture	Wasteland
Min.	0.30	0.27	0.72	0.35	0.13
Max.	2.68	2.77	2.63	1.20	1.30
Mean	1.11	1.32	1.64	0.82	0.70
Median	1.11	1.20	1.53	0.90	0.72
S.E.	0.06	0.11	0.13	0.09	0.12
C.V.	0.47	0.52	0.33	0.38	0.58
Skewness	0.76	0.43	0.20	-0.50	-0.02
Kurtosis	0.81	-0.61	-0.84	-1.51	-1.09

4.1.1.2.4 Organic Carbon Percentage

Distribution of organic carbon percent (OC) in the surface layer (0-15 cm) of the soils of Kishtwar district varied from 0.30 to 2.68, 0.27 to 2.77, 0.72 to 2.63, 0.35 to 1.20 and 0.13 to 1.30 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.4). The mean value, standard error, coefficient of variance, skewness and kurtosis was1.11, 0.06, 0.47, 0.76 and 0.81 under agriculture, 1.32, 0.11, 0.52, 0.43, and –0.61 under horticulture1.64, 0.13, 0.33, 0.20 and -0.84 under forest, 0.82, 0.09, 0.38, -0.50 and -1.51 under pasture and 0.70, 0.12, 0.58, -0.02 and -1.09 under wasteland use system, respectively. Highest spatial variability (CV 58%) was found in wasteland whereas lowest was recorded in forest landuse (CV 33%).The highest mean OC (1.64%) was found in forest followed by horticulture (1.32%), agriculture (1.11%), pasture (0.82%) and wasteland (0.70%). Out of total soil samples taken 12 per cent were found in low range 16 % in medium range and majority of samples (71 %) were found in high range. Further analysis of data by F-Statistics revealed that mean OC content of all the landuses differed significantly among themselves with p value (0.000). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Organic carbon content data in case of all landuses except pasture and wasteland was positively skewed demonstrating longer right tail and concentration of mass of distribution on left side of figure. It also specified that there existed few observations that exceeded mean. Negatively skewed data in case of pasture and wasteland indicated longer left tail and location of mass of distribution on right of the figure It also implied that few observations were on lower side of mean level. In all landuses kurtosis was less than 3 which indicated it as platykurtic (Broad).

Table 4.5: Descriptive Statistics of Cation Exchange Capacity (cmol p+/kg) in soils under different landuse systems in District Kishtwar.

Descriptive Statistics	Cation Exchange Capacity (CEC) cmol p+/kg				
	Type of Landuse System				
	Agriculture	Horticulture	Forest	Pasture	Wasteland
Min.	11.43	12.27	14.42	15.13	11.69
Max.	41.52	39.12	40.28	39.71	34.68
Mean	24.44	24.14	27.09	26.53	23.13
Median	23.47	23.14	25.77	28.84	20.39
S.E.	0.79	1.06	1.77	2.45	2.57
C.V.	0.31	0.27	0.28	0.31	0.37
Skewness	0.34	0.28	0.08	-0.09	0.16
Kurtosis	-0.61	-0.55	-1.12	-1.10	-1.50

4.1.1.2.5 Cation exchange Capacity

Range of Cation exchange Capacity (CEC) in the surface layer (0-15 cm) of the soils of Kishtwar district varied from 11.43 to 41.52, 12.27 to 39.12, 14.42 to 40.28, 15.13 to 39.71 and 11.69 to 34.68 **(**cmol p+/kg) under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.5). The mean value, standard error, coefficient of variance, skewness and kurtosis was 24.44, 0.79, 0.31, 0.34 and -0.61 under agriculture, 24.14, 1.06, 0.27, 0.28 and -0.55 under horticulture, 27.09, 1.77, 0.28, 0.08 and -1.12 under forest, 26.53, 2.45, 0.31, -0.09 and -1.10 under pasture and 23.13, 2.57, 0.37, 0.16 and -1.50 under wasteland use system, respectively. Highest spatial variability (CV 37%) was found in wasteland whereas lowest variability was recorded in horticulture (CV 27%) The highest mean CEC (27.09) was found in forest followed by pasture (26.53), agriculture (24.44), horticulture (24.14) and wasteland (23.13).Out of total samples taken 55 per cent were having moderate CEC and 45 per cent were having high CEC. Further analysis of data by F-Statistics revealed that mean CEC of all the landuses did not differ significantly among themselves at p value (0.485). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. CEC data in case of all landuses except pasture was positively skewed specifying longer right tail and concentration of mass of distribution on left side of figure, also suggested that few observations exceeded mean. Negative skewness in case of pasture indicated that left tail is longer and mass of distribution is located on right of the figure. It also stipulated that few observations were on lower side of mean. In all landuses kurtosis was less than 3 which indicated it as platykurtic (Broad).

4.1.1.3 Soils nutrient status

Table 4.6: Descriptive statistics of available Nitrogen in (kg ha^{-1}), Phosphorus (kg ha^{-1}), and Potassium (kg ha^{-1}), in soils under different landuse systems in District Kishtwar.

	Descriptive Statistics	Type of Landuse System				
		Agriculture	Horticulture	Forest	Pasture	Wasteland
Nitrogen (kg ha^{-1})	Min.	37.72	44.00	238.87	113.15	56.57
	Max.	785.75	817.18	804.61	993.19	434.88
	Mean	428.22	450.85	495.36	493.17	240.43
	Median	445.73	478.31	496.59	490.31	238.87
	S.E.	20.68	30.20	36.04	67.10	37.33
	C.V.	0.45	0.41	0.32	0.45	0.51
	Skewness	-0.21	-0.19	0.16	0.77	0.06
	Kurtosis	-0.82	-0.07	-0.42	2.30	-1.35
Phosphorus (kg ha^{-1})	Min.	3.00	4.00	3.00	9.00	4.00
	Max.	96.00	112.00	153.00	78.00	77.00
	Mean	25.15	35.21	44.68	34.64	24.27
	Median	18.50	32.50	34.00	33.00	18.00
	S.E.	1.98	3.81	8.38	5.70	6.64
	C.V.	0.74	0.67	0.82	0.55	0.91
	Skewness	1.31	0.89	1.95	1.23	1.55
	Kurtosis	1.79	1.47	4.21	2.08	2.47
Potassium (kg ha^{-1})	Min.	124.88	129.15	264.38	189.25	129.38
	Max.	1103.40	1110.71	1040.63	1039.50	927.00
	Mean	511.88	503.40	684.30	547.04	399.27
	Median	510.18	449.61	625.12	483.08	239.63
	S.E.	26.69	43.05	56.14	81.45	89.80
	C.V.	0.49	0.53	0.36	0.49	0.75
	Skewness	0.46	0.81	0.04	0.95	1.06
	Kurtosis	-0.48	-0.05	-1.16	0.26	-0.64

4.1.1.3.1 Available nitrogen

The values of available Nitrogen (N) content (kg ha^{-1}) in surface soils (0-15 cm) of Kishtwar district varied from 37.72 to 785.75, 44.00 to 817.18, 238.87 to 804.61, 113.15 to 993.19 and 56.57 to 434.88 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.6). The mean value, standard error, coefficient of variance, skewness and kurtosis was 428.22, 20.68, 0.45, -0.21 and -0.82 under agriculture, 450.85, 30.20, 0.41, -0.19, and -0.07under horticulture, 495.36, 36.04, 0.32, 0.16 and -0.42 under forest, 493.17, 67.10, 0.45, 0.77 and 2.30 under pasture and 240.43, 37.33, 0.51, 0.06 and -1.35under wasteland use system respectively. Available N in soil of wasteland showed highest spatial variability (CV 51%) indicating its widespread distribution whereas lowest variability was found in forest (CV 32%).The highest mean in kg ha^{-1} N content (495.36) was observed in forest followed by pasture (493.17), horticulture (450.85), wasteland (240.43) and agriculture (428.22). Lower nitrogen content among all landuses was observed in wasteland. Out of total samples analysed 24 per cent were low in range 51 per cent in medium range 24 per cent in high range. Further analysis of data by F-Statistics revealed that mean nitrogen content of all the landuses significantly differed among themselves at p value (0.05). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. The data in case of all landuses except agriculture and horticulture was positively skewed, pinpointing longer right tail and concentration of mass of distribution on left side of figure. It also suggested that a few observations exceeded the mean. Negative skewness in case of agriculture and horticulture plotted that left tail is longer and mass of distribution is located on right of the figure It also specified that few observations were on lower side of mean. In all except agriculture kurtosis was less than 3 which indicated it as platykurtic (Broad).The maximum coefficient of variance was found under wasteland landuse system

4.1.1.3.2 Available phosphorus

The values of available Phosphorus (P) content (kg ha^{-1}) in surface soils of Kishtwar district (0-15 cm) varied from 3.00 to 96.00, 4.00 to 112.00, 3.00 to 153.00, 9.00 to 78.00 and 4.00 to 77.00 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.6). The mean value, standard error, coefficient of variance, skewness and kurtosis was 25.15, 1.98, 0.74, 1.31 and 1.79 under agriculture, 35.21, 3.81, 0.67, 0.89, and 1.47 under horticulture, 44.68, 8.38, 0.82, 1.95 and 4.21 under forest, 34.64, 5.70, 0.55, 1.23 and 2.08 under pasture and 24.27, 6.64, 0.91, 1.55 and 2.47 under wasteland use system respectively. Highest spatial variability (CV 91%) was found in wasteland suggesting widespread distribution of phosphorus whereas lowest variability was recorded in case of pasture (CV 55%).The highest mean P in (kg ha^{-1}) content (44.68) was observed in forest followed by horticulture (35.21), pasture (34.64), agriculture (25.15) and wasteland (24.27). Out of total samples, 21 per cent were found in low in range 29 per cent in medium and 49 per cent high in range. Further analysis of data by F-Statistics revealed that mean phosphorus content of all the landuses significantly differed among themselves at p value (0.006).Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Phosphorus content data in case of all landuses was positively skewed demonstrating longer right tail and concentration of mass of distribution on left side of figure It also revealed the location of few observations on higher side of the mean. In all except forest kurtosis was less than 3 which indicated it as platykurtic (Broad) while in case of forest it was greater than 3 marking it as leptokurtic means (thin).

4.1.1.3.3 Available potassium

The values of available Potassium (K) content (kg ha^{-1}) in surface soils (0-15 cm) of Kishtwar district varied from 124.88 to 1103.40, 129.15 to 1110.71, 264.38 to 1040.63, 189.25 to 1039.50 and 129.38 to 927.00 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.6). The mean value, standard error, coefficient of variance, skewness and kurtosis was511.88, 26.69, 0.49, 0.46 and -0.48 under agriculture, 503.40, 43.05, 0.53, 0.81 and -0.05 under horticulture, 684.30, 56.14, 0.36, 0.04 and -1.16 forest, 547.04, 81.45, 0.49, 0.95 and 0.26 pasture and 399.27, 89.80, 0.75, 1.06 and -0.64 under wasteland use system respectively. Available potassium in soil of wasteland showed highest spatial variability (CV 71%) indicating its widespread distribution. While lowest variability was recorded in forest (CV 36%).The highest mean K in kg ha^{-1} (684.3) was observed in forest followed by pasture (547.04), agriculture (511.88), horticulture (503.40) and wasteland (399.27).Out of total samples analysed, 55 per cent samples were observed to be in medium range and 44 per cent in high range. Further analysis of data by F-Statistics revealed that mean potassium content of all the landuses significantly differed among themselves at p value (0.037).Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Potassium content data in case of all landuses was positively skewed displaying longer right tail and concentration of mass of distribution on left side of figure. It also exhibited a few observations located on higher side of mean. In all landuses kurtosis was less than 3 which indicated it as platykurtic (Broad).The maximum coefficient of variance was found under wasteland landuse system.

Table 4.7: Descriptive statistics of Exchangeable Calcium, Magnesium (m.eq/100g), and Sulphur (mg kg^{-1}) under different landuse systems in District Kishtwar.

	Descriptive Statistics	Type of Landuse System				
		Agriculture	**Horticulture**	**Forest**	**Pasture**	**Wasteland**
Exchangeable Calcium (m.eq/100g)	Min.	7.40	8.90	7.75	10.16	10.93
	Max.	29.40	26.40	24.50	26.42	25.07
	Mean	16.49	16.84	15.36	16.79	17.05
	Median	15.59	16.30	14.30	15.32	16.40
	S.E.	0.56	0.73	1.13	1.69	1.43
	C.V.	0.32	0.27	0.32	0.33	0.28
	Skewness	0.47	0.24	0.22	0.36	0.38
	Kurtosis	-0.59	-0.77	-0.91	-1.24	-1.22
Exchangeable Magnesium (m.eq/100g)	Min.	2.30	2.40	4.60	4.30	6.07
	Max.	12.86	11.40	21.50	12.58	11.79
	Mean	7.11	6.67	10.93	7.32	8.46
	Median	7.18	6.52	10.27	6.13	7.86
	S.E.	0.27	0.34	1.02	0.90	0.61
	C.V.	0.36	0.32	0.41	0.41	0.24
	Skewness	0.17	0.29	0.76	0.74	0.42
	Kurtosis	-0.47	-0.32	0.26	-1.12	-1.41
Available Sulphur (mg kg^{-1})	Min.	3.50	6.30	11.00	10.80	4.50
	Max.	18.40	18.00	18.90	17.20	17.60
	Mean	12.31	12.51	15.01	13.79	12.87
	Median	12.55	13.30	14.20	13.50	14.20
	S.E.	0.27	0.41	0.57	0.67	1.08
	C.V.	0.21	0.20	0.17	0.16	0.28
	Skewness	-0.73	-0.58	0.04	0.30	-1.26
	Kurtosis	0.93	-0.06	-1.12	-1.15	2.05

4.1.1.3.4 Calcium

Exchangeable Calcium (Ca) in m.eq/100g in the surface layer (0-15 cm) of soils Kishtwar district varied from 7.40 to 29.40, 8.90 to 26.40, 7.75 to 24.50, 10.16 to 26.42 and 10.93 to 25.07 (m.eq/100g) under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.7). The mean value, standard error, coefficient of variance, skewness and kurtosis was16.49, 0.56, 0.32, 0.47 and -0.59 under agriculture, 16.84, 0.73, 0.27, 0.24 and -0.77 under horticulture, 15.36, 1.13, 0.32, 0.22 and -0.91 under forest 16.79, 1.69, 0.33, 0.36 and -1.24 under pasture and 17.05, 1.43, 0.28, 0.38 and -1.22 under wasteland use system respectively. Highest spatial variability (CV 33%) observed in pasture suggesting wider distribution of calcium whereas lowest variability was recorded in horticulture (CV 27%).The highest Ca in m.eq/100g (17.05) was observed in wasteland followed by horticulture (16.84), pasture (16.79), agriculture (16.49) and forest (15.36).Out of total samples taken 8 per cent sample were having low calcium and 91 per cent samples were having calcium medium in range. Further analysis of data by F-Statistics revealed that mean Calcium content of all the landuses did not differ significantly among themselves at p value (0.858). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Calcium content data in case of all landuses was positively skewed; positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure. From positive skewness of data it was inferred that a few observations were located on higher side of the mean. In all landuses kurtosis are was less than 3 indicated it as platykurtic (Broad).The maximum coefficient of variance was found under pasture landuse system.

4.1.1.3.5 Magnesium

The values of Exchangeable Magnesium (Mg) in m.eq/100g surface soils (0-15 cm) of Kishtwar district varied from 2.30 to 12.86, 2.40 to 11.40, 4.60 to 21.50, 4.30 to 12.58 and 6.07 to 11.79 (m.eq/100g) under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.7). The mean value, standard error, coefficient of variance skewness and kurtosis was7.11, 0.27, 0.36, 0.17 and -0.47 under agriculture, 6.67, 0.34, 0.32, 0.29 and -0.32 under horticulture, 10.93, 1.02, 0.41, 0.76 and 0.26 under forest, 7.32, 0.90, 0.41, 0.74 and -1.12 under pasture and 8.46, 0.61, 0.24, 0.42 and -1.41 under wasteland use system respectively. Spatial variability of exchangeable magnesium was most widespread in forest and pasture (CV 41%) suggesting whereas lowest variability was observed in horticulture (CV 32%).The highest mean Mg in m.eq/100g (10.93) was observed in forest followed by wasteland (8.46), pasture (7.32), agriculture (7.11) and horticulture (6.67).Out of total samples analysed in the district, 19 per cent were found in low range 64 per cent in medium range and 16 per cent in high range. Further analysis of data by F-Statistics revealed that mean Magnesium content of all the landuses significantly differed among themselves at p value (0.000). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Magnesium content data in case of all landuses showed positive skewness, demonstrating longer right tail and concentration of mass of distribution on left side of figure. It also indicated that a few observations were located on higher side of mean. In all kurtosis were less than 3 indicated it as platykurtic (Broad). The maximum coefficient of variance was found maximum under pasture landuse system.

4.1.1.3.6 Sulphur

The values of Available Sulphur (S) in mg/kg surface soils (0-15 cm) of Kishtwar district varied from 3.50 to 18.40, 6.30 to 18.00, 11.00 to 18.90, 10.80 to 17.20 and 4.50 to 17.60 (mg kg^{-1}) under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.7). The mean value, standard error, coefficient of variance, skewness and kurtosis was 12.31, 0.27, 0.21, -0.73 and 0.93 under agriculture, 12.51, 0.41, 0.20, -0.58 and -0.06 under horticulture, 15.01, 0.57, 0.17, 0.04 and -1.12 under forest, 13.79, 0.67, 0.16, 0.30 and -1.15 under pasture and 12.87, 1.08, 0.28, -1.26 and 2.05 under wasteland use system, respectively. Available Sulphur showed highest spatial variability (CV 28%) in wasteland indicating its widespread distribution whereas it recorded lowest variability in pasture landuse (CV 16%).The highest mean S in ppm was observed in forest (15.51) followed by pasture (13.79), wasteland (12.87), and horticulture (12.51) and agriculture (12.31). Out of total samples obtained, 14 per cent were found to be low in range and 74 per cent in medium range and 10 per cent in high range. Further analysis of data by F-Statistics revealed that mean Sulphur content of all the landuses significantly differed among themselves at p value (0.001). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Sulphur content data in case of all landuses except forest and pasture was negatively skewed expressing that left tail was longer and mass of distribution was located on right of the figure .It also suggested that few observations were located on lower side of mean. While positive skewness in case of forest and pasture demonstrated longer right tail and concentration of mass of distribution on left side of figure. Along with this it also exhibited that a few observations existed on higher side of mean. In all landuses kurtosis was less than 3 indicated it as platykurtic (Broad).

Table 4.8: Descriptive statistics of Available Boron (mg kg^{-1}) under different landuse systems in District Kishtwar.

Descriptive statistics	Boron (B) ppm				
	Type of Landuse System				
	Agriculture	Horticulture	Forest	Pasture	Wasteland
Min.	0.05	0.17	0.14	0.14	0.13
Max.	3.60	1.55	1.42	0.63	1.30
Mean	0.80	0.64	0.71	0.32	0.55
Median	0.67	0.56	0.63	0.28	0.45
S.E.	0.07	0.07	0.09	0.05	0.13
C.V.	0.86	0.66	0.58	0.52	0.77
Skewness	1.81	0.80	0.36	0.93	0.47
Kurtosis	4.61	-0.51	-1.14	-0.26	-1.27

4.1.1.3.7 Boron

The values of Available Boron (B) in ppm surface soils (0-15 cm) varied in Kishtwar district varied from 0.05 to 3.60, 0.17 to 1.55, 0.14 to 1.42, 0.14 to 0.63 and 0.13 to 1.30 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.8). The mean value, standard error, coefficient of variance, Skewness and kurtosis was 0.80, 0.07, 0.86, 1.81 and 4.61 under agriculture, 0.64, 0.07, 0.66, 0.80 and -0.51 under horticulture, 0.71, 0.09, 0.58, 0.36 and -1.14 under forest, 0.32, 0.05, 0.52, 0.93, and -0.26 under pasture and 0.55, 0.13, 0.77, 0.47 and -1.27 under wasteland use system, respectively. Spatial variability was found to be highest in agriculture landuse (CV 86%) suggesting widespread distribution of boron whereas it was lowest in pasture (CV 52%). The highest mean in (mg kg^{-1}) B (0.80) was observed in Agriculture followed by forest (0.71), horticulture (0.64), wasteland (0.55) and pasture (0.32). Out of total samples analysed, 46 per cent samples were in low range 31 per cent in medium range and 21 per cent in high range. Further analysis of data by F-Statistics revealed that mean Boron content of all the landuses did not differ significantly among themselves at p value (0.073). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Boron content data in case of all landuses was positively skewed; positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure. It also suggested that few observations were located on higher side of mean. In all landuses kurtosis was less than 3 showing it as platykurtic (Broad) in agriculture kurtosis was greater than 3 marking it as leptokurtic. The maximum coefficient of variance was found under agriculture landuse system.

Table 4.9: Descriptive statistics of DTPA extractable Zn (mg kg^{-1}), Cu, Fe and Mn in soils under different landuse system in District Kishtwar.

	Descriptive statistics	Type of Landuse System				
		Agriculture	Horticulture	Forest	Pasture	Wasteland
Zinc (mg kg^{-1})	Min.	0.13	0.21	0.14	0.32	0.22
	Max.	1.43	1.60	0.99	1.30	0.93
	Mean	0.63	0.66	0.69	0.70	0.57
	Median	0.64	0.66	0.74	0.69	0.62
	S.E.	0.03	0.05	0.04	0.08	0.08
	C.V.	0.40	0.47	0.25	0.38	0.44
	Skewness	0.65	1.36	-1.73	1.08	0.06
	Kurtosis	1.14	2.69	5.11	1.92	-1.74
Copper (mg kg^{-1})	Min.	0.11	0.11	0.62	0.15	0.11
	Max.	2.30	1.67	1.91	1.34	0.90
	Mean	0.80	0.73	0.87	0.72	0.54
	Median	0.80	0.73	0.83	0.72	0.62
	S.E.	0.04	0.06	0.07	0.10	0.09
	C.V.	0.52	0.55	0.34	0.48	0.55
	Skewness	1.13	0.63	2.65	0.44	-0.34
	Kurtosis	2.68	0.67	8.40	0.11	-1.59
Iron (mg kg^{-1})	Min.	5.40	6.40	18.70	11.20	12.30
	Max.	35.30	37.45	41.30	42.40	39.40
	Mean	21.31	20.66	25.10	24.91	24.63
	Median	21.57	21.91	23.40	26.20	22.20
	S.E.	0.70	1.06	1.19	2.52	2.35
	C.V.	0.31	0.32	0.21	0.34	0.32
	Skewness	-0.23	-0.05	1.95	0.48	0.30
	Kurtosis	-0.52	0.39	4.74	1.02	0.00
Manganese (mg kg^{-1})	Min.	8.90	11.20	7.40	8.40	8.30
	Max.	36.20	27.30	31.20	31.40	26.50
	Mean	18.07	18.62	20.40	19.92	18.19
	Median	18.74	18.73	19.32	19.07	18.15
	S.E.	0.57	0.57	1.24	2.26	1.79
	C.V.	0.29	0.19	0.27	0.38	0.33
	Skewness	0.53	-0.02	0.23	0.11	-0.28
	Kurtosis	0.99	0.65	1.84	-0.82	-0.66

4.1.1.3.8 DTPA extractable zinc

The values of DTPA extractable Zinc (Zn) in (mg kg^{-1}) content in surface soils (0-15 cm) of Kishtwar district varied from 0.13 to 1.43, 0.21 to 1.60, 0.14 to 0.99, 0.32 to 1.30 and 0.22 to 0.93 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.9). The mean value, standard error, coefficient of variance, skewness and kurtosis was 0.63, 0.03, 0.40, 0.65 and 1.14 under agriculture, 0.66, 0.05, 0.47, 1.36 and 2.69 under horticulture 0.69, 0.04, 0.25, -1.73 and 5.11 under forest, 0.70, 0.08, 0.38, 1.08 and 1.92 under pasture and 0.57, 0.08, 0.44, 0.06 and -1.74 under wasteland use system, respectively. Available zinc in soils of horticulture landuse depicted highest spatial variability (CV 47%) indicating its widespread distribution whereas forest soils showed lowest variability (CV 25%). The highest mean Zn in mg kg^{-1}content (0.70) was observed in pasture followed by forest (0.69), horticulture (0.66), agriculture (0.63) and wasteland (0.57).Out of total samples taken 39 per cent were low in range, 41 per cent were in medium range and 18 per cent were in high range. Further analysis of data by F-Statistics revealed that mean Zinc content of all the landuse significantly differed among themselves at p value (0.666). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Zinc content data in case of all landuses except forest was positively skewed reflecting longer right tail and concentration of mass of distribution on left side of figure. It also hinted the location of few observations on lower side of mean. Whereas negative skewness case of forest predicted longer left tail and mass of distribution on right of the figure. It also signalled that a few observations were located on higher side of mean. In all the land-uses kurtosis were less than 3 indicated it as platykurtic (Broad) and leptokurtic in forest. The maximum coefficient of variance was found under horticulture landuse system.

4.1.1.3.9 DTPA extractable copper

The values of DTPA extractable Copper (Cu) in (mg kg^{-1}) content in surface soils of Kishtwar district (0-15 cm) varied from 0.11 to 2.30, 0.11 to 1.67, 0.62 to 1.91, 0.15 to 1.34 and 0.11 to 0.90 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.9). The mean value, standard error, coefficient of variance, skewness and kurtosis was 0.80, 0.04, 0.52, 1.13 and 2.68 under agriculture, 0.73, 0.06, 0.55, 0.63 and 0.67 under horticulture, 0.87, 0.07, 0.34, 2.65 and 8.40 under forest, 0.72, 0.10, 0.48, 0.44 and 0.11 under pasture and 0.54, 0.09, 0.55, -0.34 and – 1.59 under wasteland use system, respectively. Spatial variability was found to be highest in horticulture and wasteland (CV 55%) indicating its widespread distribution whereas it was lowest in forest (CV 34 %). The highest mean Cu in mg kg^{-1} content (0.87) was observed in forest followed by agriculture (0.80), horticulture (0.73), pasture (0.72) and wasteland (0.54).Out of total samples taken 9 per cent were low in range 6 per cent in medium range 85 per cent were in high range. Further analysis of data by F-Statistics revealed that mean Copper content of all the landuses did not differ significantly among themselves at p value (0.180).Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Copper content data in case of all landuses except wasteland exhibited positive skewness indicating longer right tail and concentration of mass of distribution on left side of figure. It also suggested that few observations were located on higher side of mean. Negative skewness in wasteland implied that left tail is longer and mass of distribution is located on right of the figure. It also marked the location of a few observations on lower side of mean. In all landuses kurtosis was less than 3 indicating it as platykurtic (Broad) and in case of forests it is leptokurtic. The maximum coefficient of variance was found under horticulture landuse system.

4.1.1.3.10 DTPA extractable iron

The values of DTPA extractable Iron (Fe) in (mg kg^{-1}) content in surface soils (0-15 cm) Kishtwar district varied from 5.40 to 35.30, 6.40 to 37.45, 18.70 to 41.30, 11.20 to 42.40 and 12.30 to 39.40 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.9) The mean value, standard error, coefficient of variance, skewness and kurtosis was21.31, 0.70, 0.31, -0.23 and -0.52 under agriculture, 20.66, 1.06, 0.32, -0.05 and 0.39 under horticulture, 25.10, 1.19, 0.21, 1.95 and 4.74 under forest, 24.91, 2.52, 0.34, 0.48 and 1.02 under pasture and 24.63, 2.35, 0.32,0.30 and 0.00 under wasteland use system, respectively. Available zinc showed highest spatial variability in pasture (CV 34%) indicating its widespread variability whereas lowest variability was recorded in forest (CV 21%).The highest mean Fe in mg kg^{-1} content (25.10) was observed in forest followed by pasture (24.91), wasteland (24.63), horticulture (21.31), and horticulture (20.66). Out of total soil samples taken 2 per cent were in medium range and 98 per cent were in high range. Further analysis of data by F-Statistics revealed that mean iron content of all the landuses differed significantly among themselves at p value (0.037).Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Iron content data in case of all landuses except agriculture and horticulture was positively skewed demonstrating longer right tail and concentration of mass of distribution on left side of figure. It also suggested that a few observations were located on higher side of mean. Negative skewness in case of agriculture and horticulture indicated that left tail is longer and mass of distribution is located on right of the figure. It also marked the location of few observations on lower side of mean. In all landuses kurtosis were less than 3 indicated it as platykurtic (Broad).The maximum coefficient of variance was found under pasture landuse system.

4.1.1.3.11 DTPA extractable manganese

The range of DPTA Extractable Magnesium (Mn) in (mg kg^{-1}) content in soils (0-15 cm) of Kishtwar district 8.90 to 36.20, 11.20 to 27.30, 7.40 to 31.20, 8.40 to 31.40 and 8.30 to 26.50 under agriculture, horticulture, forest, pasture and wasteland, respectively.(Table-4.9) The mean value, standard error, coefficient of variance, skewness and kurtosis was18.07, 0.57, 0.29, 0.53 and 0.99 under agriculture, 18.62, 0.57, 0.19, -0.02 and 0.65 under horticulture, 20.40, 1.24, 0.27, 0.23 and 1.84 under forest, 19.92, 2.26, 0.38, 0.11 and -0.82 under pasture and 18.19, 1.79, 0.33, -0.28 and -0.66 under wasteland use system, respectively. Highest spatial variability (CV38%) was observed in pasture indicating its widespread variability whereas lowest variability was found in horticulture (CV 19%).The highest mean value of available Mn in mg kg^{-1} (20.40) was observed in Forest followed by pasture (19.92), horticulture (18.62), wasteland (18.19) and agriculture(18.07). Out of total soil samples taken 66 per cent were medium in range and 14 per cent were in high range. Further analysis of data by F-Statistics revealed that mean Mn content of all the landuses did not differ significantly among themselves at p value (0.409). Standard error of data observed under wasteland was highest among all the landuses which might be due to small sample size. Manganese content data in case of all landuses except horticulture and wasteland was positively skewed demonstrating longer right tail and concentration of mass of distribution on left side of figure. It also exhibited the location of a few observations on higher side of mean. Negative Skewness in case of horticulture and wasteland indicated that left tail is longer and mass of distribution is located on right of the figure showing the existence of a few observations on lower side of mean. In all kurtosis were less than 3 indicated it as platykurtic (Broad) The maximum coefficient of variance was found under pasture landuse system.

Ramban

4.2.1 Descriptive Statistics

The data obtained from the various soil properties of samples taken from District Ramban analysed in the laboratory has been described here for a greater understanding of its nature under different land use systems with sub-heads.

4.2.1.1 Basic soil properties

4.2.1.1.1 Particles Size Analysis

4.2.1.1.2 Soil chemical properties

4.2.1.1.3 Soil Available nutrients

4.2.1.1.4 Maps of Soil Properties

Table 4.2.1: Descriptive statistics of sand, Silt and Clay percentage in soils under different land use system in District Ramban.

	Descriptive Statistics	Type of Land use System				
		Agriculture	Horticulture	Forest	Pasture	Wasteland
Sand percentage (%)	Min.	2.96	8.96	8.96	12.96	8.96
	Max.	58.96	54.96	64.96	62.96	86.96
	Mean	28.73	24.59	33.88	38.67	45.46
	Median	28.96	18.96	32.96	38.96	44.96
	S.E.	2.17	4.05	3.09	5.55	11.95
	C.V.	0.57	0.66	0.47	0.38	0.74
	Skewness	0.02	0.98	0.35	-0.20	0.12
	Kurtosis	-1.29	-0.57	-0.60	2.51	-2.28
Silt percentage (%)	Min.	10.00	14.00	8.00	20.00	4.00
	Max.	90.00	72.00	62.00	42.00	50.00
	Mean	34.42	36.38	32.85	28.00	29.50
	Median	30.00	35.00	28.00	28.00	33.00
	S.E.	2.08	4.58	3.19	2.93	6.88
	C.V.	0.46	0.50	0.50	0.28	0.66
	Skewness	0.86	0.68	0.59	0.87	-0.21
	Kurtosis	1.20	-0.40	-0.67	0.71	-2.25
Clay percentage (%)	Min.	7.04	15.04	7.04	17.04	7.04
	Max.	53.04	67.04	63.04	45.04	45.04
	Mean	36.86	39.04	33.27	33.33	25.04
	Median	37.04	35.04	35.04	35.04	23.04
	S.E.	1.42	3.96	2.79	3.19	5.52
	C.V.	0.29	0.41	0.43	0.25	0.62
	Skewness	-0.69	0.25	-0.18	-1.03	0.17
	Kurtosis	0.13	-1.00	-0.49	2.82	-2.01

4.2.1.1.1.1 Sand percentage

The sand per cent in the surface layer (0-15 cm) of the soils of Ramban district varied from 2.96 to 58.96, 8.96 to 54.96, 8.96 to 64.96, 12.96 to 62.96 and 8.96 to 86.96 under agriculture, horticulture, forest, pasture and wasteland, respectively. (Table 4.2.1). The mean value, standard error, coefficient of variance, skewness and kurtosis was 28.73, 2.17, 0.57, 0.02 and -1.29 under agriculture, 24.59, 4.05, 0.66, 0.98 and -0.57 under horticulture, 33.88, 3.09, 0.47, 0.35 and -0.60 under forest, 38.67, 5.55, 0.38, -0.20 and 2.51 under pasture and 45.46, 11.95, 0.74, 0.12 and -2.28 under wasteland, respectively. Highest spatial variability (CV 74%) was found in wasteland suggesting widespread variability whereas lowest variability was recorded in pasture (CV 38%).The highest mean sand content (45.46 %) was found in wasteland followed by pastures (38.67%), followed by forest (33.88%), and followed by agriculture (28.73%) and horticulture (24.59%). Higher sand Percentage in wasteland may be due to fact that wasteland are subjected to harsh condition like runoff and erosion which leads to removal of finer particles Out of total 114 samples taken 35 % of soil samples were found to have sand content less than 20 %, 57 % and 8% samples were having sand content between 20–60 % and above 60 % respectively. Further analysis of data by F-Statistics revealed that mean sand content of all the land uses significantly differed among themselves at p value (0.042). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Sand content data in case of all land uses except pasture was positively skewed, positive skewness in case of all land uses except pasture indicated longer right tail and concentration of mass of distribution on left side of figure suggesting that a few observations were located on higher side of mean whereas negative skewness in case of pasture indicating that left tail is longer and mass of distribution is located on right of the figure indicated that a few observations were on lower side of mean. In all land uses kurtosis was less than 3 which indicated it as platykurtic (Broad).

4.2.1.1.1.2 Silt percentage

The silt per cent in the surface layer (0-15 cm) of the soils of Ramban district varied from 10.00 to 90.00, 14.00 to 72.00, 8.00 to 62.00, 20.00 to 42.00 and 4.00 to 50.00 under agriculture, horticulture, forest, pasture and wasteland, respectively.

(Table-4.2.1). The mean value, standard error, coefficient of variance, skewness and kurtosis was 34.42, 2.08, 0.46, 0.86 and 1.20 under agriculture, 36.38, 4.58, 0.50, 0.68 and -0.40 under horticulture, 32.85, 3.19, 0.50, 0.59 and -0.67 under forest, 28, 2.93, 0.28, 0.87 and 0.71 under pasture and 29.50, 6.88, 0.66, -0.21 and -2.25 under wasteland use system, respectively. Highest spatial variability (CV 66%) was found in wasteland indicating widespread variability while as lowest variability was found in pasture (CV 28%).The highest mean silt content (36.38 %) was found in Horticulture followed by agriculture (34.42%) followed by forest (32.85%) followed by wasteland (29.50%) and pasture (28%). Out of total 114 samples 15 % samples were found to have silt content less than 20 %, 37% samples were found to have silt content between 20 -40 % and 48 % having silt content greater than 40 %. Further analysis of data by F-Statistics revealed that mean silt content of all the land uses did not differ significantly among themselves with p value (0.730). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Silt content data in case of all land uses except wasteland exhibited positive skewness, positive skewness in case of all land uses except wasteland indicated longer right tail and concentration of mass of distribution on left side of figure also suggested that a few observations were located on higher side of mean whereas negative skewness in case of wasteland indicating that left tail is longer and mass of distribution is located on right of the figure also suggested that a few observations were on lower side of mean. In all land uses kurtosis was less than 3 which indicated it as platykurtic (Broad). The maximum coefficient of variance was found under wasteland land use system. The mean value for wasteland and pasture soils was least as compare to other land use systems.

4.2.1.1.1.3 Clay percentage

The clay per cent in the surface layer (0-15 cm) of the soils of Ramban district varied from 7.04 to 53.04, 15.04 to 67.04, 7.04 to 63.04, 17.04 to 45.04 and 7.04 to 45.04 under agriculture, horticulture, forest, pasture and wasteland, respectively. (Table-4.2.1). The mean value, standard error, coefficient of variance, skewness and kurtosis was 36.86, 1.42, 0.29, -0.69 and 0.13 under agriculture, 39.04, 3.96, 0.41, 0.25 and -1.00 under horticulture, 33.27, 2.79,0.43, -0.18 and -0.49 under forest, 33.33, 3.19, 0.25, -1.03, and 2.82 under pasture and 25.04, 5.52, 0.62, 0.17 and -2.01 under wasteland use system, respectively. Highest spatial variability (CV 62%) was found in wasteland indicating widespread variability whereas in case of pasture least variability (CV 25%) was recorded. The highest mean clay content (39.04 %) was found in Horticulture, followed by agriculture (36.86%), followed by pasture (33.33%) followed by forest (33.27%) and wasteland (25.04%). Clay content less than 40 % was present in 60 % and greater than 40 % was present in 40 % samples. Further analysis of data by F-Statistics revealed that mean clay content of all the land uses were not significantly different among themselves at p value (0.086). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Clay content data in case of all land uses except agriculture and pasture was negatively skewed. Negative skewness indicated that left tail is longer and mass of distribution is located on right of the figure also suggesting that few observations were on lower side of mean whereas positive skewness in case of agriculture and pasture indicated longer right tail and concentration of mass of distribution on left side of figure suggesting that a few observations were located on higher side of mean. In all land uses kurtosis was less than 3 which indicate it as platykurtic (Broad). The maximum coefficient of variance was found under wasteland land use system.

Soil Textural Class

Table 4.2.2: Soil textural classes in District Ramban.

Textural class	No. of samples
Clay	24
Clay loam	**29**
Sandy clay	4
Sandy clay loam	7
Sandy loam	7
Sandy soil	2
Silt loam	13
Silt clay	20
Silty clay loam	8
Silt	1

The data revealed that the dominant soil texture lass was sandy loam followed by silty clay in all land use systems. (Table-4.2.2).

4.2.1.1.2 Soil chemical properties

Table 4.2.3: Descriptive statistics of soils pH, EC and $CaCO_3$ under different land use systems in District Ramban.

	Descriptive Statistics	Type of Land use System				
		Agriculture	Horticulture	Forest	Pasture	Wasteland
pH	Min.	6.40	6.20	6.20	6.30	6.70
	Max.	7.60	7.40	7.22	7.40	8.40
	Mean	7.06	6.84	6.68	6.96	7.72
	Median	7.10	6.79	6.60	6.90	7.83
	S.E.	0.04	0.09	0.06	0.15	0.20
	C.V.	0.05	0.05	0.05	0.06	0.07
	Skewness	-0.16	-0.01	0.26	-0.50	-0.70
	Kurtosis	-1.14	-0.95	-0.74	-0.68	0.44
EC (dSm^{-1})	Min.	0.16	0.22	0.16	0.22	0.22
	Max.	2.50	6.90	5.60	6.10	5.30
	Mean	0.91	0.97	0.90	1.72	1.58
	Median	0.78	0.43	0.54	0.97	0.45
	S.E.	0.07	0.41	0.23	0.76	0.71
	C.V.	0.60	1.69	1.27	1.18	1.27
	Skewness	0.87	3.58	3.09	2.20	1.42
	Kurtosis	-0.04	13.49	11.18	5.10	0.37
Calcium carbonate (%)	Min.	0.00	0.00	0.00	0.00	0.00
	Max.	2.20	1.34	1.87	0.67	1.60
	Mean	0.24	0.28	0.42	0.16	0.48
	Median	0.00	0.00	0.33	0.00	0.24
	S.E.	0.05	0.10	0.09	0.11	0.21
	C.V.	1.70	1.50	1.15	1.75	1.23
	Skewness	2.76	1.52	1.31	1.44	1.09
	Kurtosis	9.84	1.63	1.87	0.48	0.26

4.2.1.1.2.1 Soil pH

The pH ranged in the surface layer (0-15 cm) of the soils of Ramban district varied from 6.40 to 7.60, 6.20 to 7.40, 6.20 to 7.22 6.30 to 7.40 and 6.70 to 8.40 under agriculture, horticulture, forest, pasture and wasteland, respectively. (Table-4.2.3) The mean value, standard error, coefficient of variance, skewness and kurtosis was 7.06, 0.04, 0.05, -0.16 and -1.14 under agriculture, 6.84, 0.09, 0.05,-0.01 and -0.95 under horticulture, 6.68, 0.06, 0.05, 0.26 and -0.74 under forest, 6.96, 0.15, 0.06, -0.50 and -0.68 under pasture and 7.72, 0.20, 0.07, -0.70 and 0.44 under wasteland use system, respectively. Highest spatial variability (CV 7%) was found in wasteland indicated widespread variability of pH whereas less variability was found in agriculture and horticulture (CV 5%).The highest mean pH (7.72) was found in Wasteland, followed by agriculture (7.06), followed by pasture (6.96), followed by horticulture (6.84), and forest (6.68). Out of total samples taken 9.6 per cent soil samples were acidic 84 per cent neutral in reaction and 6 per cent sample are alkaline in reaction .Further analysis of data by F-Statistics revealed that mean clay content of all the land uses were significantly different among themselves with p value (0.000). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. pH data in case of all land uses except forest was negatively skewed Negative skewness indicating that left tail is longer and mass of distribution is located on right of the figure also indicated that a few observations were on lower side of mean whereas positive skewness in case of forest indicated longer right tail and concentration of mass of distribution on left side of figure also indicated that a few observations were located on higher side of mean. In all land uses kurtosis was less than 3 which indicated it as platykurtic (Broad). The maximum coefficient of variance was found under wasteland land use system. The mean value for forest soils was least as compare to other land use systems.

4.2.1.1.2.2 Electrical Conductivity:

The range of Electrical Conductivity (EC) in (dSm^{-1}) content in the surface layer (0-15 cm) of the soils of Ramban district varied from 0.16 to 2.50, 0.22 to 6.90, 0.16 to 5.60, 0.22 to 6.10 and 0.22 to 5.30 under agriculture, horticulture, forest, pasture and wasteland, respectively. (Table-4.2.3). The mean value, standard error, coefficient of variance, Skewness and kurtosis was 0.91, 0.07, 0.60, 0.87 and -0.04

under agriculture, 0.97, 0.41, 1.69, 3.58 and 13.49 under horticulture, 0.90, 0.23, 1.27, 3.09 and 11.18 under forest, 1.72, 0.76, 1.18, 2.20 and 5.10 under pasture and 1.58, 0.71, 1.27, 1.42 and 0.37 under wasteland use system, respectively. Highest spatial variability (CV 169 %) was found in horticulture suggesting widespread variability whereas lowest variability was recorded in agriculture (CV 60%).The highest mean EC in dSm^{-1} (1.72) was found in pasture, followed by wasteland (1.58), followed by horticulture (0.97), followed by agriculture (0.91), and forest (0.90) .Further analysis of data by F-Statistics revealed that mean clay content of all the land uses were not significantly different among themselves at p value (0.258). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. EC content data in case of all land uses was positively skewed, positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure also suggesting that few observations were located on higher side of mean. In agriculture and wasteland kurtosis was less than 3 which indicated it as platykurtic (Broad) while in case of other land uses kurtosis was greater than 3 which are leptokurtic means (thin).

4.2.1.1.2.3 Calcium carbonate.

Range of Calcium carbonate ($CaCO_3$) per cent in the surface layer (0-15 cm) of the soils of Ramban district varied from 0.00 to 2.20, 0.00 to 1.34, 0.00 to 1.87, 0.00 to 0.67 and 0.00 to 1.60 under agriculture, horticulture, forest, pasture and wasteland, respectively. (Table-4.2.3). The mean value, standard error, coefficient of variance, skewness and kurtosis was 0.24, 0.05, 1.70, 2.76 and 9.84 under agriculture, 0.28, 0.10, 1.50, 1.52 and 1.63 under horticulture, 0.42, 0.09, 1.15, 1.31 and 1.87 under forest 0.16, 0.11, 1.75, 1.44 and 0.48 under pasture and 0.48, 0.21, 1.23, 1.09 and 0.26 under wasteland use system, respectively. Highest spatial variability (CV 175%) was found in pasture indicating widespread variability whereas lowest variability was found in forest (CV 115%).The highest mean $CaCO_3$ (0.48) was found in wasteland, followed by forest (0.42), followed by horticulture (0.28), followed by agriculture (0.24) and pasture (0.16). Further analysis of data by F-Statistics revealed that mean $CaCO_3$ content of all the land uses were not significantly different among themselves with p value (0.260). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Calcium carbonate content in case of all land uses was positively skewed; positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure also suggesting that a few observations were located on higher side of mean. In all except agriculture kurtosis was less than 3 which indicated it as platykurtic (Broad) while in case of agriculture land uses kurtosis was greater than 3 which are leptokurtic means (thin). The lowest $CaCO_3$ was observed under pasture whereas it was highest under wasteland soils.

Table 4.2.4: Descriptive Statistics of organic carbon (%) in soils under different landuse systems in District Ramban.

Descriptive Statistics	Organic carbon (OC) Type of Land use System				
	Agriculture	Horticulture	Forest	Pasture	Wasteland
Min.	0.11	0.15	0.16	0.47	0.17
Max.	1.74	1.28	1.74	1.42	1.01
Mean	0.86	0.74	1.05	0.87	0.58
Median	0.85	0.66	1.06	0.79	0.48
S.E.	0.05	0.09	0.09	0.12	0.11
C.V.	0.47	0.46	0.43	0.37	0.53
Skewness	0.21	0.02	-0.29	0.67	0.36
Kurtosis	-0.53	-0.95	-1.00	0.19	-1.34

4.2.1.1.2.4 Organic Carbon Percentage

Distribution of Organic Carbon (OC) per cent in the surface layer (0-15 cm) of the soils of Ramban district varied from 0.11 to 1.74, 0.15 to 1.28, 0.16 to 1.74, 0.47 to 1.42 and 0.17 to 1.01 under agriculture, horticulture, forest, pasture and wasteland, respectively.(Table-4.2.4). The mean value, standard error, coefficient of variance, skewness and kurtosis was 0.86, 0.05, 0.47, 0.21 and -0.53 under agriculture, 0.74, 0.09, 0.46, 0.02 and -0.95 under horticulture, 1.05, 0.09, 0.43, -0.29 and -1.00 under forest, 0.87, 0.12, 0.37, 0.67 and 0.19 under pasture and 0.58, 0.11, 0.53, 0.36 and -1.34 under wasteland use system, respectively. Highest spatial variability (CV 53%) was found in wasteland whereas as lowest variability was recorded in pasture (CV 37%). The highest mean OC in % (1.05) was observed in forest, followed by pasture (0.87%), agriculture (0.86%), horticulture (0.74%) and wasteland (0.58%). Further analysis of data by F-Statistics revealed that mean OC content of all the land uses significantly differed among themselves at p value (0.03). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. OC content data in case of all land uses was positively skewed except forest. Positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure. Positive skewness in case of all other land uses indicated that a few observations were located on higher side of mean. Negative skewness indicating that left tail is longer and mass of distribution is located on right of the figure also suggesting that a few observations were on lower side. In all except agriculture kurtosis was less than 3 which indicated it as platykurtic (Broad).The lowest per cent of organic carbon was observed under wasteland whereas it was highest under forest soils.

Table 4.2.5: Descriptive Statistics of Cation Exchange Capacity (cmol p+/kg) in soils under different land use systems in District Ramban.

Descriptive Statistics	Cation Exchange Capacity (CEC) cmol p+/kg				
	Type of Land use System				
	Agriculture	Horticulture	Forest	Pasture	Wasteland
Min.	6.78	7.17	6.36	19.32	10.66
Max.	39.43	42.27	36.27	33.81	36.87
Mean	22.40	22.46	20.58	27.54	17.66
Median	22.85	20.26	18.71	28.27	14.71
S.E.	1.07	2.86	1.57	2.10	3.19
C.V.	0.36	0.51	0.39	0.20	0.51
Skewness	0.13	0.31	0.36	-0.32	1.58
Kurtosis	-0.55	-1.11	-0.36	-1.56	2.56

4.2.1.1.2.5 Cation exchange Capacity

Cation exchange Capacity (CEC) in cmol p+/kg in the surface layer (0-15 cm) of the soils of Ramban district varied from 6.78 to 39.43, 7.17 to 42.27, 6.36 to 36.27, 19.32 to 33.81 and 10.66 to 36.87 cmol p+/kg under agriculture, horticulture, forest, pasture and wasteland, respectively. (Table-4.2.5) The mean value, standard error, coefficient of variance, skewness and kurtosis was 22.40, 1.07, 0.36, 0.13 and -0.55

under agriculture 22.46, 2.86, 0.51, 0.31 and -1.11 under horticulture, 20.58, 1.57, 0.39, 0.36 and -0.36 under forest, 27.54, 2.10, 0.20, -0.32 and -1.56 under pasture and 17.66, 3.19, 0.51, 1.58 and 2.56 under wasteland use system, respectively. Highest spatial variability (CV 51 %) was found in horticulture indicating widespread variability whereas lowest variability was found in pasture (CV 20%). The highest mean CEC (27.54) was found in pasture, followed by horticulture (22.46), followed by agriculture (22.40) followed by forest (20.58) and wasteland (17.66). Further analysis of data by F-Statistics revealed that mean CEC of all the land uses significantly differed among themselves with p value (0.216). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. CEC data in case of all land uses was positively skewed except pasture, positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure also suggesting that a few observations were located on higher side of mean whereas negative skewness in case of pasture indicating that left tail is longer and mass of distribution is concentrated on right side of figure also suggesting that a few observations were on lower side of mean. In all except agriculture kurtosis was less than 3 which indicated it as platykurtic (Broad). The lowest CEC was observed under wasteland whereas it was highest under pasture soils.

4.2.1.1.3 Soils nutrient status

Table 4.2.6: Descriptive statistics of available Nitrogen (kg ha^{-1}), Phosphorus (kg ha^{-1}) and Potassium (kg ha^{-1}) in soils under different land use systems in District Ramban.

	Descriptive Statistics	Type of Land use System				
		Agriculture	Horticulture	Forest	Pasture	Wasteland
Available (kg ha^{-1}) Nitrogen	Min.	213.72	144.58	201.15	314.30	94.29
	Max.	735.46	710.32	741.75	641.17	402.30
	Mean	464.72	503.27	512.42	470.55	275.44
	Median	458.88	537.45	502.59	490.31	306.02
	S.E.	16.88	43.23	25.25	40.21	41.51
	C.V.	0.27	0.34	0.25	0.23	0.43
	Skewness	0.25	-0.60	-0.21	0.10	-0.72
	Kurtosis	-0.73	-0.41	-0.13	0.18	-0.82
Available (kg ha^{-1}) Phosphorus	Min.	2.00	4.00	5.00	6.00	5.00
	Max.	132.00	146.00	90.00	61.00	42.00
	Mean	26.21	32.13	32.42	28.00	24.13
	Median	21.00	21.00	31.50	21.00	23.50
	S.E.	3.13	9.79	4.28	8.30	5.56
	C.V.	0.90	1.22	0.67	0.78	0.65
	Skewness	2.20	2.20	0.77	0.70	-4.10
	Kurtosis	7.03	4.59	0.16	-1.19	-2.42
Available (kg ha^{-1}) Potassium	Min.	67.50	99.00	114.08	138.38	104.63
	Max.	982.13	1133.21	1121.29	667.13	382.50
	Mean	272.96	432.49	382.44	420.19	210.81
	Median	172.13	297.96	298.63	384.75	183.15
	S.E.	28.97	85.36	49.42	80.76	39.84
	C.V.	0.77	0.79	0.66	0.51	0.53
	Skewness	1.52	0.84	1.21	-0.19	0.95
	Kurtosis	1.27	-0.49	1.39	-1.61	-0.64

4.2.1.1.3.1 Available nitrogen

The values of available nitrogen (N) in (kg ha^{-1}) content in surface soils (0-15 cm) of Ramban district varied from 213.72 to 735.46, 144.58 to 710.32, 201.15 to 741.75, 314.30 to 641.17 and 94.29 to 402.30 under agriculture, horticulture, forest, pasture and wasteland, respectively. (Table-4.2.6) The mean value, standard error, coefficient of variance, skewness and kurtosis was 464.72, 16.88, 0.27, 0.25 and -0.73 under agriculture, 503.27, 43.23, 0.34, -0.60 and -0.41 under horticulture, 512.42, 25.25, 0.25, -0.21 and -0.13 under forest 470.55, 40.21, 0.23, 0.10 and 0.18 under pasture and 275.44, 41.51, 0.43, -0.72 and -0.82 under wasteland use system, respectively. The highest mean N in kg ha^{-1} (512.42) was found in forest, followed by horticulture (503.27), followed by pasture (470.55), and followed by agriculture (464.72) and wasteland (275.44). Highest spatial variability (CV 43 %) was found in wasteland suggesting widespread variability whereas lowest variability was recorded under pasture (CV 23%) Lower nitrogen content among all land uses was observed in wasteland. Further analysis of data by F-Statistics revealed that mean nitrogen content of all the land uses significantly differed among themselves at p value (0.001). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Nitrogen content data in case of all land uses was positively skewed except horticulture and forest. whereas positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure positive skewness in case of all other land uses indicated that a few observations were located on higher side whereas in case of negative skewness indicating that left tail is longer and mass of distribution is located on right of the figure also suggesting that a few observations were on lower side of mean. Positive kurtosis indicates that distribution has heavier tails and a sharper peak than normal distribution. In all except agriculture kurtosis was less than 3 which indicated it as platykurtic (Broad).The mean value available N for wasteland soils was least as compare to other land use systems

4.2.1.1.3.2 Available phosphorus

The values of available phosphorus (P) in (kg ha^{-1}) content in surface soils (0-15 cm) of Ramban district varied from 2.00 to 132.00, 4.00 to 146.00, 5.00 to 90.00, 6.00 to 61.00 and 5.00 to 42.00 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.2.6) The mean value, standard error, coefficient of variance, skewness and kurtosis was 26.21, 3.13, 0.90, 2.20 and 7.03 under agriculture, 32.13, 9.79, 1.22, 2.20 and 4.59 under horticulture, 32.42, 4.28, 0.67,0.77 and 0.16 under forest, 28.00, 8.30, 0.78, 0.70 and -1.19 under pasture and 24.13, 5.56, 0.65, -4.10 and -2.42 under wasteland use system, respectively. Highest spatial variability (CV 122%) was found in horticulture suggesting widespread variability whereas lowest variability was recorded in wasteland (CV 65%). The highest mean P in kg ha^{-1} (32.42) was observed in forest, followed by horticulture (32.13), followed by pasture (28) followed by (26.21), and wasteland (24.13). Further analysis of data by F-Statistics revealed that mean phosphorus content of all the land uses significantly differed among themselves at p value (0.802). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Phosphorus content data in case of all land uses was positively skewed except wasteland; positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure also suggesting that a few observations were located on higher side of mean. Negative skewness indicating that left tail is longer and mass of distribution is located on right of the figure also suggesting that a few observations were on lower side of mean. In all except agriculture kurtosis was less than 3 which indicated it as platykurtic (Broad) while in case of agriculture and horticulture land uses kurtosis was greater than 3 which are leptokurtic means (thin). The available P (kg ha^{-1}) content in wasteland soils is lowest and highest in forest land use system.

4.2.1.1.3.3 Available potassium

The values of available potassium (K) in (kg ha^{-1}) content in surface soils (0-15 cm) of Ramban district varied from 67.50 to 982.13, 99.00 to 1133.21, 114.08 to 1121.29, 138.38 to 667.13 and 104.63 to 382.50 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.2.6) The mean value, standard error, coefficient of variance, skewness and kurtosis was 272.96, 28.97, 71.25, 1.52 and 1.27 under agriculture, 432.49, 85.36, 0.79, 0.84 and -0.49 under horticulture, 382.44, 49.42, 0.66, 1.21 and 1.39 under forest, 420.19, 80.76, 0.51, -0.19 and -1.61 under pasture and 210.81, 39.84, 0.53, 0.95 and -0.64 under wasteland use system, respectively. The highest spatial variability (CV 79%) was found in horticulture suggesting its widespread variability whereas lowest variability was found in pasture (CV 51%). The highest mean K in kg ha^{-1} (432.49) was found in horticulture, followed by pasture (420.19), followed by forest (382.44), and followed by agriculture (272.96) and wasteland (210.81). Further analysis of data by F-Statistics revealed that mean potassium content of all the land uses significantly differed among each other at p value (0.04). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Potassium content data in case of all land uses was positively skewed except pasture, positive skewness wasteland indicated longer right tail and concentration of mass of distribution on left side of figure also suggesting that a few observations were located on higher side of mean whereas Negative skewness indicating that left tail is longer and mass of distribution is located on right of the figure also suggesting that a few observations were on lower side of mean. Positive kurtosis indicates that distribution has heavier tails and a sharper peak than normal distribution. In all kurtosis was less than 3 which indicated it as platykurtic (Broad). Highest average potassium and in horticulture and lowest in wasteland land use systems.

Table 4.2.7: Descriptive statistics of Exchangeable Calcium (m.eq/100g), Magnesium and Sulphur (mg kg^{-1}) under different land use systems in District Ramban.

	Descriptive statistics	Type of Land use System				
		Agriculture	Horticulture	Forest	Pasture	Wasteland
Exchangeable Calcium (m eq 100 g^{-1})	Min.	3.90	3.35	3.36	10.40	6.28
	Max.	28.70	27.40	27.60	23.80	22.52
	Mean	15.45	13.64	13.76	15.80	13.39
	Median	16.50	11.37	11.44	15.60	12.86
	S.E.	0.85	2.16	1.28	1.73	1.86
	C.V.	0.42	0.63	0.48	0.29	0.39
	Skewness	0.06	0.55	0.66	0.78	0.44
	Kurtosis	-0.93	-1.29	-0.44	0.26	-0.20
Exchangeable Magnesium (m eq 100 g^{-1})	Min.	2.30	3.05	2.24	5.20	2.30
	Max.	12.70	14.57	11.44	8.90	14.08
	Mean	6.59	8.23	6.27	6.93	7.69
	Median	6.70	8.25	6.72	6.33	8.04
	S.E.	0.28	0.81	0.44	0.58	1.28
	C.V.	0.32	0.39	0.36	0.22	0.47
	Skewness	0.34	0.04	-0.13	0.28	0.24
	Kurtosis	0.07	-0.46	-0.04	-1.95	0.58
Available Sulphur (mg kg^{-1})	Min.	6.50	6.30	3.40	7.20	6.30
	Max.	28.90	23.30	28.20	22.20	19.20
	Mean	16.75	14.84	18.84	14.87	11.38
	Median	16.80	15.80	18.20	14.50	11.20
	S.E.	0.68	1.24	1.05	2.08	1.47
	C.V.	0.31	0.33	0.28	0.37	0.37
	Skewness	0.33	-0.15	-0.57	-0.04	0.79
	Kurtosis	-0.09	-0.58	1.60	-1.56	0.44

4.2.1.1.3.4 Calcium

The range of Exchangeable Calcium (Ca) in m eq 100 g^{-1} content in the surface layer (0-15 cm) of the soils of Ramban district varied from 3.90 to 28.70, 3.35 to 27.40, 3.36 to 27.60, 10.40 to 23.80 and 6.28 to 22.52 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.2.7). The mean value, standard error, coefficient of variance, skewness and kurtosis was 15.45, 0.85, 0.42, 0.06 and -0.93 under agriculture, 13.64, 2.16, 0.63, 0.55 and -1.29 under horticulture, 13.76, 1.28, 0.48, 0.66, and -0.44 under forest, 15.80, 1.73, 0.29, 0.78, and 0.26 under pasture and 13.39, 1.86, 0.39, 0.44 and -0.20 under wasteland use system, respectively. The highest spatial variability (CV 63%) was found in horticulture suggesting its widespread variability while as lowest variability was found in pasture (CV 29%). The highest mean Ca in m.eq/100g (15.80) was observed in pasture, followed by agriculture (15.45), followed by forest (13.76), and followed by horticulture (13.64) and wasteland (13.39). Further analysis of data by F-Statistics revealed that mean Calcium content of all the land uses were not significantly different among themselves with p value (0.710). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Calcium content data in case of all land uses was positively skewed positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure. Positive skewness indicated that a few number of values/observations were located on higher side. Positive kurtosis indicates that distribution has heavier tails and a sharper peak than normal distribution. In all kurtosis was less than 3 which indicated it as platykurtic (Broad). Highest content in pasture and lowest in wasteland.

4.2.1.1.3.5 Magnesium

The values of Exchangeable Magnesium (Mg) in m eq 100 g^{-1} content in surface soils (0-15 cm) of Ramban district was varied from 2.30 to 12.70, 3.05 to 14.57, 2.24 to 11.44, 5.20 to 8.90 and 2.30 to 14.08 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.2.7). The mean value, standard error, coefficient of variance skewness and kurtosis was 6.59, 0.28, 0.32, 0.34 and 0.07 under agriculture, 8.23, 0.81, 0.39, 0.04 and -0.46 under horticulture, 6.27, 0.44, 0.36, -0.13 and -0.04 under forest, 6.93, 0.58, 0.22, 0.28, and -1.95 under pasture and

7.69, 1.28, 0.47, 0.24 and 0.58 under horticulture use system, respectively. Highest spatial variability (CV 47%) was found in wasteland suggesting its widespread variability while as lowest variability was found in pasture (CV 22%) The highest mean Mg in m.eq/100g (8.23) was observed in horticulture followed by wasteland (7.69), pasture (6.93, agriculture (6.59) and forest (6.27). Further analysis of data by F-Statistics revealed that mean Magnesium content of all the land uses were not significantly different among themselves with p value (0.090). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Magnesium content data in case of all land uses exhibited positive Skewness except forest positive skewness in case of all other land uses indicated longer right tail and concentration of mass of distribution on left side of figure also suggesting that a few observations were located on higher side of mean whereas negative skewness indicating that left tail is longer and mass of distribution is located on right of the figure also suggesting that a few observations were on lower side of mean. Positive kurtosis indicates that distribution has heavier tails and a sharper peak than normal distribution. In all kurtosis was less than 3 which indicated it as platykurtic (Broad)

4.2.1.1.3.6 Sulphur

The values of Available Sulphur (S) in mg/kg content in surface soils (0-15 cm) of Ramban district varied from 6.50 to 28.90, 6.30 to 23.30, 3.40 to 28.20, 7.20 to 22.20 and 6.30 to 19.20 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.2.7) The mean value, standard error, coefficient of variance, skewness and kurtosis was 16.75, 0.68, 0.31, 0.33 and -0.09 under agriculture, 14.84, 1.24, 0.33, -0.15 and -0.58 under horticulture, 18.84, 1.05, 0.28 -0.57 and 1.60 under forest, 14.87, 2.08, 0.37, -0.04 and -1.56 under pasture and 11.38, 1.47, 0.37, 0.79 and 0.44 under wasteland use system, respectively. The highest spatial variability (CV 37%) was found in wasteland indicating widespread variability while as lowest variability was found in forest (CV 27%). The highest mean S in (mg kg^{-1}) (18.84) was observed in forest followed by agriculture (16.75), pasture (14.87), horticulture (14.84) and wasteland (11.38). Further analysis of data by F-Statistics revealed that mean Sulphur content of all the land uses significantly differed among themselves at p value (0.05). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Sulphur content data in case of all land uses was negatively skewed except Agriculture and wasteland. Negative skewness indicating that left tail is longer and mass of distribution is located on right of the figure also suggesting that a few observations were on lower side of mean. In case of positive skewness it indicated longer right tail and concentration of mass of distribution on left side of figure and also suggesting that a few observations were located on higher side of mean. Positive kurtosis indicates that distribution has heavier tails and a sharper peak than normal distribution. In all kurtosis was less than 3 which indicated it as platykurtic (Broad).

Table 4.2.8: Descriptive statistics of Available Boron (mg kg^{-1}) under different land use systems in District Ramban.

Descriptive statistics	Boron (B) gm kg^{-1}				
	Type of Land use System				
	Agriculture	**Horticulture**	**Forest**	**Pasture**	**Wasteland**
Min.	0.15	0.26	0.16	0.22	0.11
Max.	3.60	3.20	4.50	1.34	1.23
Mean	1.21	1.15	1.04	0.66	0.49
Median	0.93	0.87	0.82	0.67	0.42
S.E.	0.12	0.21	0.18	0.14	0.14
C.V.	0.73	0.73	0.86	0.58	0.78
Skewness	1.27	1.40	2.54	0.79	0.96
Kurtosis	0.86	1.17	8.57	0.40	0.58

4.2.1.1.3.7 Boron

The values of Boron (B) in ppm content in surface soils (0-15 cm) of Ramban district varied from 0.26 to 3.20, 0.16 to 4.50, 0.22 to 1.34 and 0.11 to 1.23 mg kg^{-1} under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.2.8) The mean value, standard error, coefficient of variance, skewness and kurtosis was 1.21, 0.12, 0.73, 1.27 and 0.86 under agriculture, 1.15, 0.21, 0.73, 1.40 and 1.17 under horticulture, 1.04, 0.18, 0.86, 2.54 and 8.57 under forest, 0.66, 0.14, 0.58, 0.79 and 0.40 under pasture and 0.49, 0.14, 0.78, 0.96, and 0.58 under wasteland use system, respectively. The highest spatial variability was found in (CV 86%) indicating its widespread variability while as lowest variability was found in pasture (CV 58 %).

The highest mean B in mg kg^{-1} (1.21) was observed in Agriculture followed by horticulture (1.15), forest (1.04), pasture (0.66) and wasteland (0.49). Further analysis of data by F-Statistics revealed that mean Boron content of all the land uses were not significantly different among themselves at p value (0.131). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Boron content data in case of all land uses was positively skewed; positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure. Positive skewness indicated that a few observations were located on higher side of mean. In all kurtosis was less than 3 which indicated it as platykurtic (Broad) except forest which showed leptokurtic.

Table 4.2.9: Descriptive statistics of DTPA extractable Zn (mg kg^{-1}), Cu, Fe and Mn in soils under different land use system in District Ramban.

	Descriptive Statistics	Type of Land use System				
		Agriculture	Horticulture	Forest	Pasture	Wasteland
Zinc (mg kg^{-1})	Min.	0.18	0.24	0.39	0.32	0.11
	Max.	1.60	1.42	1.61	1.24	0.79
	Mean	0.78	0.82	0.86	0.75	0.49
	Median	0.77	0.82	0.83	0.73	0.60
	S.E.	0.04	0.10	0.06	0.10	0.09
	C.V.	0.39	0.47	0.35	0.36	0.53
	Skewness	0.67	0.02	0.81	0.43	-0.50
	Kurtosis	0.85	-1.16	0.41	2.62	-1.61
Copper (mg kg^{-1})	Min.	0.18	0.21	0.29	0.62	0.11
	Max.	1.61	1.82	1.33	1.23	1.33
	Mean	0.88	0.74	0.93	0.93	0.64
	Median	0.89	0.84	0.83	0.91	0.56
	S.E.	0.04	0.11	0.06	0.08	0.16
	C.V.	0.35	0.60	0.30	0.24	0.70
	Skewness	0.10	0.63	-0.37	0.14	0.40
	Kurtosis	0.40	0.68	0.01	-0.95	-1.31
Iron (mg kg^{-1})	Min.	6.30	11.30	7.34	12.40	8.40
	Max.	34.50	34.20	32.60	32.40	21.50
	Mean	18.34	22.43	19.48	21.32	15.79
	Median	17.45	22.07	19.35	18.90	17.75
	S.E.	0.97	2.11	1.14	3.03	1.76
	C.V.	0.40	0.38	0.30	0.38	0.32
	Skewness	0.53	0.03	0.47	0.68	-0.70
	Kurtosis	-0.41	-1.52	0.83	-1.20	-1.16
Manganese (mg kg^{-1})	Min.	2.40	12.80	11.40	12.40	8.40
	Max.	31.50	31.20	31.40	31.20	17.50
	Mean	18.40	19.89	17.76	21.15	12.89
	Median	18.30	18.78	17.00	20.40	12.11
	S.E.	0.78	1.36	1.14	2.16	1.01
	C.V.	0.32	0.27	0.33	0.27	0.22
	Skewness	0.13	0.71	1.06	0.47	0.20
	Kurtosis	0.32	-0.26	0.23	1.73	-0.10

4.2.1.1.3.8 DTPA extractable zinc

The values of DTPA extractable Zinc (Zn) in (mg kg^{-1}) content in surface soils (0-15 cm) of Ramban district varied from 0.18 to 1.60, 0.24 to 1.42, 0.39 to 1.61, 0.32 to 1.24 and 0.11 to 0.79 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.2.9) The mean value, standard error, coefficient of variance, skewness and kurtosis was 0.78, 0.04, 0.39, 0.67 and 0.85 under agriculture, 0.82, 0.10, 0.47, 0.02 and -1.16 under horticulture, 0.86, 0.06, 0.35, 0.81 and 0.41 under forest, 0.75, 0.10, 0.36, 0.43 and 2.62 under pasture and 0.49, 0.09, 0.53, -0.50 and -1.61 under wasteland use system, respectively. Highest spatial variability (CV 53 %) was found in wasteland indicating widespread variability while as lowest variability was found in forest (CV 35%). The highest mean Zn in mg kg^{-1} (0.86) was observed in forest followed by horticulture (0.82), agriculture (0.78), pasture (0.75) and wasteland (0.49). Further analysis of data by F-Statistics revealed that mean Zinc content of all the land uses significantly differed among themselves at p value (0.068). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Zinc content data in case of all land uses positively skewed positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure. Positive skewness indicated that a few observations were located on higher side of mean. In all kurtosis was less than 3 which indicated it as platykurtic (Broad).The mean value of Zn (mg kg^{-1}) contents highest under forest followed by horticulture agriculture, pasture, and wasteland soils.

4.2.1.1.3.9 DTPA extractable copper

The values of DTPA extractable Copper (Cu) in (mg kg^{-1}) content in surface soils (0-15 cm) of Ramban district varied from 0.18 to 1.61, 0.21 to 1.82, 0.29 to 1.33, 0.62 to 1.23 and 0.11 to 1.33 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.2.9) The mean value, standard error, coefficient of variance, skewness and kurtosis was 0.88, 0.04, 0.35, 0.10 and 0.40 under agriculture, 0.74, 0.11, 0.60, 0.63 and 0.68 under horticulture, 0.93, 0.06, 0.30, -0.37 and 0.01 under forest, 0.93, 0.08, 0.24, 0.14 and -0.95 under pasture and 0.64, 0.16, 0.70, 0.40 and -1.31 under wasteland use system, respectively. Highest spatial variability (CV 70%) was found in wasteland indicating widespread variability while as lowest variability was found in pasture (CV 24 %). The highest mean Cu in mg kg^{-1} (0.93) was observed in forest followed by pasture (0.93), agriculture (0.88), horticulture (0.74) and wasteland (0.64). Further analysis of data by F-Statistics revealed that mean Copper content of all the land uses were not significantly different among themselves with p value (0.136). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Copper content data in case all land uses was positively skewed except forest positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure also suggested that a few observations were located on higher side while as negative skewness indicating that left tail is longer and mass of distribution is located on right of the figure indicated that a few observations were on lower side. Positive kurtosis indicates that distribution has heavier tails and a sharper peak than normal distribution. In all kurtosis was less than 3 which indicated it as platykurtic (Broad) .The mean value Cu for wasteland soils were least as compare to other land use systems. It was highest under forest followed by pasture, agriculture, horticulture, wasteland use systems.

4.2.1.1.3.10 DTPA extractable iron

The values of DTPA extractable Iron (Fe) in (mg kg^{-1}) content in surface soils (0-15 cm) of Ramban district varied from 6.30 to 34.50, 11.30 to 34.20, 7.34 to 32.60, 12.40 to 32.40 and 8.40 to 21.50 under agriculture, horticulture, forest, pasture and wasteland, respectively**.** (Table-4.2.9) The mean value, standard error, coefficient of variance, skewness and kurtosis was 18.34, 0.97, 0.40, 0.53 and -0.41 under agriculture, 22.43, 2.11, 0.38, 0.03 and -1.52 under horticulture, 19.48, 1.14, 0.30, 0.47 and 0.83 under forest, 21.32, 3.03, 0.38, 0.68 and -1.20 under pasture and 15.79, 1.76, 0.32, -0.70 and -1.16 under wasteland use system, respectively. The highest spatial variability (CV 40%) was found in agriculture indicating widespread variability while as lowest variability was found in forest (CV 30%). The highest mean Fe in mg kg^{-1} (22.43) was found in Horticulture followed by pasture (21.32), forest (19.48), agriculture (18.34), and wasteland (15.79). Further analysis of data by F-Statistics revealed that mean Copper content of all the land uses were not significantly different among themselves with p value (0.163). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Iron content data in case of all land uses was positively skewed except wasteland. In case of positive it indicated longer right tail and concentration of mass of distribution on left side of figure also suggested that a few observations were located on higher side of mean negative skewness indicating that left tail is longer and mass of distribution is located on right of the figure also suggested that a few observations were on lower side of mean. Positive kurtosis indicates that distribution has heavier tails and a sharper peak than normal distribution. In all kurtosis was less than 3 which indicated it as platykurtic (Broad)

4.2.1.1.3.11 DTPA extractable manganese

The range of DPTA Extractable Manganese (Mn) in (mg kg^{-1}) content in soils (0-15 cm) of Ramban district was 2.40 to 31.50, 12.80 to 31.20, 11.40 to 31.40, 12.40 to 31.20 and 8.40 to 17.50 under agriculture, horticulture, forest, pasture and wasteland, respectively.(Table-4.2.9). The mean value, standard error, coefficient of variance, skewness and kurtosis was 18.40, 0.78, 0.32, 0.13 and 0.32 under agriculture, 19.89, 1.36, 0.27, 0.71 and -0.26 under horticulture, 17.76,1.14, 0.33, 1.06 and 0.23 under forest, 21.15, 2.16, 0.27, 0.47 and 1.73 under pasture and 12.89, 1.01, 0.22, 0.20 and -0.10 under wasteland use system, respectively. Highest spatial variability (CV 33%) was found in forest land use while as lowest was recorded in wasteland (CV 22%) The highest mean Mn in mg kg^{-1} (21.15) was observed in Pasture followed horticulture (19.89), agriculture (18.40) and wasteland (12.89). Further analysis of data by F-Statistics revealed that mean Mn content of all the land uses were significantly different among themselves with p value (0.03). Standard error of data observed under wasteland was highest among all the land uses which might be due to small sample size. Manganese content data in case of all land uses was positively skewed; positive skewness indicated longer right tail and concentration of mass of distribution on left side of figure also suggested that a few observations were located on higher side of mean. Positive kurtosis indicates that distribution has heavier tails and a sharper peak than normal distribution. In all kurtosis was less than 3 which indicated it as platykurtic (Broad). Highest content in pasture lowest in wasteland, respectively.

4.2.1.1.4 Maps of soil properties.

Maps of both of the districts indicated wide range of variation in soil physiochemical properties, as both the districts are located under varying terrains and climatic conditions leading to high variability of soil properties. Sandy loam and clay loam texture were usually dominant textural groups in Kishtwar and Ramban districts, respectively. Sand content in Kishtwar district was mainly less than 20 per cent, also strips of 40 to 60 per cent sand were present across the district. Whole of the tehsil Padder and major area of tehsil Kishtwar of district Kishtwar was having sand content between 20-40 per cent. In Ramban district majority of area had sand between 20 – 40 per cent. Some area in the form of small patches in Banihal tehsil of Ramban district was having sand content less than 20 per cent. Whereas in Ramban tehsil some area had sand content greater than 60 per cent. In case of silt, major area of Kishtwar district had silt content between 30 to 40 per cent on both east and west ends. In the central part of the district silt content varied from 20 to 30 per cent, with some scattered patches having greater than 40 per cent silt. Half of the area of Ramban district spreading over north and south ends had silt content ranging between 30- 40 per- cent, whereas other half of the area located in the central part of the district had silt content between 20-30 per cent. Silt content in some patches of the district was greater than 20 per cent, whereas a very small area in the form of scattered patches had silt content less than 20 per cent. In case of clay content major area of Kishtwar district had 20-30 per cent clay followed by the area on central and eastern side of the district having 30- 40 per cent clay. In Ramban district clay content varied from 30 - 40 per cent in majority of the area present on the northern and southern sides. Whereas it was 20 -30 per cent in rest of the area between the two ends. Soils in few patches scattered over the district had clay content between 40 -50 per cent, whereas few patches with small area towards southern part of the district had clay content less than 20 per cent.

Soils of almost entire district of Kishtwar were found to be neutral in reaction. Very small patches of the district were having soils with acidic and basic reactions. Soils of almost half of the Ramban district towards south-west and northern side were neutral in reaction, whereas soils of the area on the eastern and central part of district were basic in reaction. EC was found to be within the safe limits in both the districts, however EC of soils of both districts had great variation. Western side of Kishtwar was having EC ranging from 0.5 to 1.0 dS m-1 and on eastern side it varied between 1.0 and 1.5 dS m-1. Some strips across north and southern side of Kishtwar district had EC between 1.5 and 3.0 dS m-1. In Ramban district soils on northern and southern side had EC mainly in between 0.5 to 1.0 dS m-1 and on eastern and western side it was mainly in the range of 1.5- 3.0 dS m-1.

Soil organic carbon (OC) of both the districts was in high range (>12.5 g/kg) especially in forest blocks. In Kishtwar district, Marwah tehsil had higher content of OC ranging from 12.5 to 20.0 g/kg. In rest of the district it ranged between 7.5-12.5 g/kg. Major part of Ramban district had OC ranging from 7.5-12.5 g/kg, whereas central part of the district covering Banihal tehsil had lower OC (0.5-7.5 g/kg) as compared to Ramban tehsil. While comparing two districts higher content of OC was recorded in Kishtwar district.

Available nitrogen (N) was not limiting in the entire Kishtwar district. In Marwah and Padder tehsils of Kishtwar district majority area was having N in medium range (420-560 kg/ha). In Central part of the district stretching from north-east to southern side had N in the medium range (280-420 kg/ha). In Ramban N varied from 280-560 kg/ha with some patches greater than 560 kg/ha, northern part of District covering Banihal tehsil and part of Ramban tehsil had N in Medium to High range (480-560 kg/ha), area lying on eastern and western part of Ramban tehsil of the district had N in medium range (280-420 kg/ha). Available Phosphorus (P) in whole of the Kishtwar district was sufficient. Major part of the district had available P in high range (25.0 to 50.0 kg/ha), whereas some central part of district lying in Chatro tehsil was having P in medium range (12.5-25.0 kg/ha). In Ramban district also major part was having available P in the high range (25.0-50.0kg/ha), whereas some areas on the northern side of the district covering Banihal tehsil had P in medium range (12.5-25.0 kg/ha). Available potassium (K) in whole of the Kishtwar district was mainly in high range from 500 to 750 kg/ha. North, northwest and south east area of the district covering part of Marwah, Chathro and Padder tehsil was having high content of K ranging from 500-750kg/ha.Whereas central part of the district stretching from north-east to southern side had available K in high range (280- 500 kg/ha). Major part of Ramban district had available K in the high range (280-500 kg/ha). Other area of the district lying on eastern and northern side was having K in medium range (110- 280 kg/ha).

Secondary nutrients Calcium, Magnesium and Sulphur were in medium to high range in almost entire areas of both of the districts, except in some areas of Ramban district where they were on lower side. Almost whole of the Kishtwar district had secondary nutrients in high range, except some strips in the district having nutrients in medium range. In Ramban district some area on the northern tip had very high content of secondary nutrients. Western part of Ramban district covering part of Ramban tehsil had secondary nutrients in low range**,** whereas in middle part of the district they were in medium range. Rest of the district had nutrients in high range. Calcium in majority area of Kishtwar was in the range of 15-20 m.eq/100g, whereas in case of district Ramban on western side of tehsil Ramban it was less than 10 m.eq/100g. Exchangeable Magnesium also followed the same trend.

All the micronutrients except zinc (Zn) in soils of both the districts were sufficient and well above the critical limit (0.6 ppm). As such their was no problem of their deficiency. Soils of south-eastern part of Kishtwar district covering Padder tehsil and centrally located elongated strip stretching from north east to south were deficient in DTPA zinc content. Available copper was mainly sufficient in both the districts except some negligible patches in Chattro tehsil of Kishtwar district where it was found deficient. In Kishtwar district, Chattro tehsil recorded higher iron content as compared to other tehsils of the district. In Ramban district Ramban Tehsil had higher iron than that in Banihal tehsil.

4.2.1.1.5. Correlation coefficient (r) among the different soil properties of Kishtwar District.

It was observed that silt was negatively correlated with sand (-.689**). Clay was negatively correlated with sand (-.771**) positively correlated with silt (.070).pH was negatively correlated with sand (-0.022) and silt (-0.039) and was positively correlated with clay (0.065). EC was positively correlated with sand (0.006) and silt (0.032) and was negatively correlated with clay (-0.037) and pH (-0.243**). OC was negatively correlated with sand (-0.287**) and pH (-0.195*), and was positively correlated with silt (0.140), with clay (0.272**) and with EC (0.006). N was negatively correlated with sand (-0.507**) and with EC (-0.029), and was positively correlated with silt (0.087), with clay (0.622**), with pH (0.005) and with OC (0.314**).P was positively correlated with sand (0.089), with silt (0.001), with OC (0.085) and was negatively correlated with clay (-0.124), with pH (-0.130), with EC (-0.029) and with N (-0.030). K was negatively correlated with sand (-0.089) and positively correlated with silt (0.002), with clay (0.121), with pH (0.027), with EC

(0.001), with OC (0.239**), with nitrogen (0.181*), and with P (0.167*). Ca was negatively correlated with sand (-0.145), with silt (-0.020), with pH (-0.063), and with P (-0.077) and was positively correlated with EC (0.061), with OC (0.221**), with N (0.244**), and with K (0.071). Mg was positively correlated with sand (0.001), with clay (0.039), with OC (0.192*), with N (0.141), with P (0.095), with K (0.046) and with Ca (0.593**) and was negatively correlated with silt (-0.047), with pH (-0.217**). S was negatively correlated with sand (-0.153*), with pH (-0.317**), and was positively correlated with silt (0.166*), with clay (0.065), with EC (0.078), with OC (0.403**), with N (0.154*), and with P (0.008), with K (0.062), with Ca (0.055) and with Mg (0.153*). B was negatively correlated with sand (-0.116), with pH (-0.004), with P (-0.056), with K (-0.108), and with Mg (-0.027) and was positively correlated with silt (0.030), with clay (0.133), with EC (0.078), with OC (0.146), with N (0.079), with Ca (0.010), and with S (0.080). CEC was negatively correlated with sand (-0.129), with silt (-0.041), with clay (0.213**), with pH (-0.112), with P (-0.005) and with B (-0.022) and was positively correlated with EC (0.023), with OC (0.255**), with N (0.278**), with K (0.110), with Ca (0.908**) and with Mg (0.780**) and with S (0.089). $CaCO_3$ was negatively correlated with sand (0.008), with clay (-0.044), with OC (-0.063), with P (-0.140), with K (-0.084), with Mg (-0.052) , and with CEC (-0.008) and was positively correlated with silt (0.063), with pH (0.007), with EC (0.240**), with N (0.009), with Ca (0.009), with S (0.033), and with B (0.007). Zn was negatively correlated with sand (-0.076), with pH (-0.172*) , with $CaCO_3$ (-0.054) and was positively correlated with silt (0.026), with clay (0.081) , with EC (0.153*),with OC (0.272**), with N(0.180*), with P (0.044), with K (0.097), with Ca (0.210**),with Mg (0.230**), with S (0.128), with B (0.189*) and with CEC (0.269**).Cu was negatively correlated with sand (-0.193*), with P (-0.088), and with $CaCO_3$ (-0.027) and was positively correlated with silt (0.032), with clay (0.238**) , with pH (0.052), with EC (0.050), with OC (0.423**), with N (0.279**), with K (0.160*), with Ca (0.209**), with Mg (0.159*), with S (.176*), with B (0.126), with CEC (0.212**), and with Zn (0.395**). Fe was negatively correlated with sand (-0.111), with pH (-0.398**), with EC (0.044), with P (0.005), with K (0.097) and with $CaCO_3$ (0.047) and was positively correlated with silt (0.046), with clay (0.112), with OC (0.294**), with N (0.153*), Ca (0.254**), with Mg (0.290**), with S (0.295**), with B (0.102), with CEC (0.273**), with Zn (0.299**) and with Cu (0.299**). Mn was negatively correlated with sand (-0.163*), and with pH (-0.171*),and was positively correlated with silt (0.089), with clay (0.147), with EC (-0.038), with OC (0.252**), with N (0.018), with P (-0.008), with K (-0.055), with Ca (0.235**) , with Mg (0.231**), with S (0.206**), with B (0.115), with CEC (0.235**), with $CaCO_3$ (-0.029), with Zn (0.194*), with Cu (0.097) and with Fe (0.463**).

4.2.1.1.6. Correlation coefficient (r) among the different soil properties if Ramban District.

It was observed that silt was negatively correlated with sand (-0.664**). Clay was negatively correlated with sand (-0.647**) and with silt (-0.141). pH was positively correlated with sand (0.032) and with clay (0.075) and was negatively correlated with silt (-0.116). EC was positively correlated with sand (0.268**) and was negatively correlated with silt (-0.094), with clay (-0.260**) and with pH (-0.028). OC was negatively correlated with sand (-0.184*), with pH (-0.252**) and with EC (-0.027) and was positively correlated silt (0.126) and with clay (0.115). N was negatively correlated with sand (-0.361**), with silt (-0.123) and with EC (-0.131) and was negatively correlated and positively correlated with clay (0.603**) with pH (-0.122) and with OC (0.190*). P was positively correlated with sand (0.086), with silt (0.045) and with OC (0.049) and was negatively correlated with clay (-0.160*), with pH (-0.157*) ,with EC (-0.076) and with N (-0.170*). K was negatively correlated with sand (0.062), with pH (-0.320**) and positively correlated with silt (0.043), with cay (0.038), with EC (0.094) with OC (0.216**) with nitrogen (0.218**) and with P (0.116). Ca was negatively correlated with sand (-0.165*), with pH (-0.009), with EC (-0.048), with P (0.019), with K (0.111) and was positively correlated with silt (0.035), with clay (0.181*) with OC (0.062) and with N (0.149).Mg was negatively correlated with sand (-0.006), with clay (-0.053), with pH (-0.115), with EC (-0.063), with P (-0.007) and was positively correlated with silt (0.058), with OC (0.091) ,with N (0.052) , with K (0.199*) and with Ca (0.573**). S was negatively correlated with sand (-0.216**), with pH (-0.042), with EC (0.048), with K (-0.085), with Mg (-0.034) and was positively correlated with silt (0.018), with clay (0.267**), with OC (0.203**), with N (0.244**) with P (0.089) and with Ca (0.055) .B was negatively correlated with sand (-0.211**),with silt (-0.001), with EC (-0.161*), with P (-0.002). with K (-0.133) and with Mg (-0.128) and was positively correlated with clay (0.280**), with pH (0.069), with OC (0.003), with N (0.134), with Ca (0.029) and with S (0.209**). CEC was negatively correlated with sand (-0.180*), with EC (-0.054), with pH (-0.064) and with B (-0.035) and was positively correlated with silt (0.067) with clay (0.169*), with OC (0.097) , with N (0.235**), with P (0.000) ,with K (0.202**) ,with Ca (0.902**) ,with Mg (0.727**) and with S (0.052).$CaCO_3$ was positively correlated with sand (0.076) ,with silt (0.032), with EC (0.234**) , with P (0.023), with K (0.151) and with CEC (0.181*) and was not correlated with pH (0.000) , and was negatively correlated with clay (-0.133) with OC (-0.030) ,with N (-0.107) with Mg (0.145) and was negatively correlated with S (-0.159*) with B (-0.169*) and was positively correlated .Zn was negatively correlated with sand (-0.245**), with silt (-0.166*), with EC (-0.173*), with P (-0.046), with Mg (-0.013) and with $CaCO_3$ (-0.166*) and was positively correlated with clay (0.493**) with OC (0.195*), with N (0.383**),with K (0.103), with Ca (0.175*), with S (0.161*), with B (0.292**) and with CEC (0.166*) Cu was negatively correlated with sand (-0.145), with silt (-0.018), with EC (-0.074), with P (-0.025), with Mg (-0.080) and with $CaCO_3$ (-0.293**) and was positively correlated with clay (0.211**), with pH (0.062), with OC (0.329**), with N (0.151), with K (0.024), with Ca (0.038) , with S (0.148), with B (0.122), with CEC (0.030) and with Zn (0.332**). Fe was negatively correlated with sand (-0.062), with clay (-0.042) , with pH (-0.456**), with P (-0.040), with S (-0.084) and with B (-0.048) and was positively correlated with silt (0.122), with EC (0.008), with OC (0.286**), with N (0.081), with K (0.276**), with Ca (0.099) , with Mg (0.200**) ,with CEC (0.143), with $CaCO_3$ (0.040), with Zn (0.172*) and with Cu (0.088). Mn was negatively correlated with sand (-0.156*), with pH (-0.262**), with EC (-0.101), with P (-0.076), with S (-0.018) with $CaCO_3$ (-0.092) and with Cu (-0.052) and was positively correlated with silt (0.165*) with clay (0.039) and with OC (0.160*) with N (0.122) and with K (-0.052) and Ca (0.098) and with Mg (0.048) with B (0.069) CEC (0.114) with Zn (0.096) and with Fe(0.337**).

Table 4.2.10: Correlation coefficient (r) among the different soil properties if Kishtwar District.

	Sand	Silt	clay	pH	EC	OC	N	P	K	Ca	Mg	S	B	CEC	$CaCO_3$	Zn	Cu	Fe
Silt	-0.689**																	
Clay	-0.771**	0.070																
pH	-0.022	-0.039	0.065															
EC	0.006	0.032	-0.037	-0.243**														
OC	-0.287**	0.140	0.272**	-0.195*	0.006													
N	-0.507**	0.087	0.622**	0.005	-0.029	0.314**												
P	0.089	0.001	-0.124	-0.130	-0.029	0.085	-0.030											
K	-0.089	0.002	0.121	0.027	0.001	0.239**	0.181*	0.167*										
Ca	-0.145	-0.020	0.218**	-0.063	0.061	0.221**	0.244**	-0.077	0.071									
Mg	0.001	-0.047	0.039	- 0.217**	0.008	0.192*	0.141	0.095	0.046	0.593**								
S	-0.153*	0.166*	0.065	-0.317**	0.078	0.403**	0.154*	0.008	0.062	0.055	0.153*							
B	-0.116	0.030	0.133	-0.004	0.078	0.146	0.079	-0.056	-0.108	0.010	-0.027	0.080						
CEC	-0.129	-0.041	0.213**	-0.112	0.023	0.255**	0.278**	-0.005	0.110	0.908**	0.780**	0.089	-0.022					
$CaCO_3$	-0.008	0.063	-0.044	0.007	0.240**	-0.063	0.009	-0.140	-0.084	0.009	-0.052	0.033	0.007	-0.008				
Zn	-0.076	0.026	0.081	-0.172*	0.153*	0.272**	0.180*	0.044	0.097	0.210**	0.230**	0.128	0.189*	0.269**	-0.054			
Cu	-0.193*	0.032	0.238**	0.052	0.050	0.423**	0.279**	-0.088	0.160*	0.209**	0.159*	0.176*	0.126	0.212**	-0.027	0.395**		
Fe	-0.111	0.046	0.112	-0.398**	0.044	0.294**	0.153*	0.005	0.097	0.254**	0.290**	0.295**	0.102	0.273**	0.047	0.299**	0.193*	
Mn	-0.163*	0.089	0.147	-0.171*	-0.038	0.252**	0.018	-0.008	-0.055	0.235**	0.231**	0.206**	0.115	0.235**	-0.029	0.194*	0.097	0.463**

****. Correlation is significant at 1% level of significance; *. Correlation is significant at 5% level of significance**

Table 4.2.11: Correlation coefficient (r) among the different soil properties if Ramban District.

	Sand	Silt	clay	pH	EC	OC	N	P	K	Ca	Mg	S	B	CEC	$CaCO_3$	Zn	Cu	Fe	Mn
Silt	-0.664**																		
Clay	-0.647**	-0.141																	
pH	0.032	-0.116	0.075																
EC	0.268**	-0.094	-0.260**	-0.028															
OC	-0.184*	0.126	0.115	-0.252**	-0.027														
N	-0.361**	-0.123	0.603**	-0.122	-0.131	0.190*													
P	0.086	0.045	-0.160*	-0.157*	-0.076	0.049	-0.170*												
K	-0.062	0.043	0.038	-0.320**	0.094	0.216**	0.218**	0.116											
Ca	-0.165*	0.035	0.181*	-0.009	-0.048	0.062	0.149	-0.019	0.111										
Mg	-0.006	0.058	-0.053	-0.115	-0.063	0.091	0.052	-0.007	0.199*	0.573**									
S	-0.216**	0.018	0.267**	-0.042	-0.048	0.203**	0.244**	0.089	-0.085	0.055	-0.034								
B	-0.211**	-0.001	0.280**	0.069	-0.161*	0.003	0.134	-0.002	-0.133	0.029	-0.128	0.209**							
CEC	-0.180*	0.067	0.169*	-0.064	-0.054	0.097	0.235**	0.000	0.202**	0.902**	0.727**	0.052	-0.035						
$CaCO_3$	0.076	0.032	-0.133	0.000	0.234**	-0.030	-0.107	0.023	0.151	0.135	0.145	-0.159*	-0.169*	0.181*					
Zn	-0.245**	-0.166*	0.493**	-0.154*	-0.173*	0.195*	0.383**	-0.046	0.103	0.175*	-0.013	0.161*	0.292**	0.166*	-0.166*				
Cu	-0.145	-0.018	0.211**	0.062	-0.074	0.329**	0.151	-0.025	0.024	0.038	-0.080	0.148	0.122	0.030	-0.293**	0.332**			
Fe	-0.062	0.122	-0.042	-0.456**	0.008	0.286**	0.081	-0.040	0.276**	0.099	0.200**	-0.084	-0.048	0.143	0.040	0.172*	0.088		
Mn	-0.156*	0.165*	0.039	-0.262**	-0.101	0.160*	0.122	-0.076	-0.052	0.098	0.048	-0.018	0.069	0.114	-0.092	0.096	-0.052	0.337**	

****. Correlation is significant at 1% level of significance; *. Correlation is significant at 5% level of significance.**

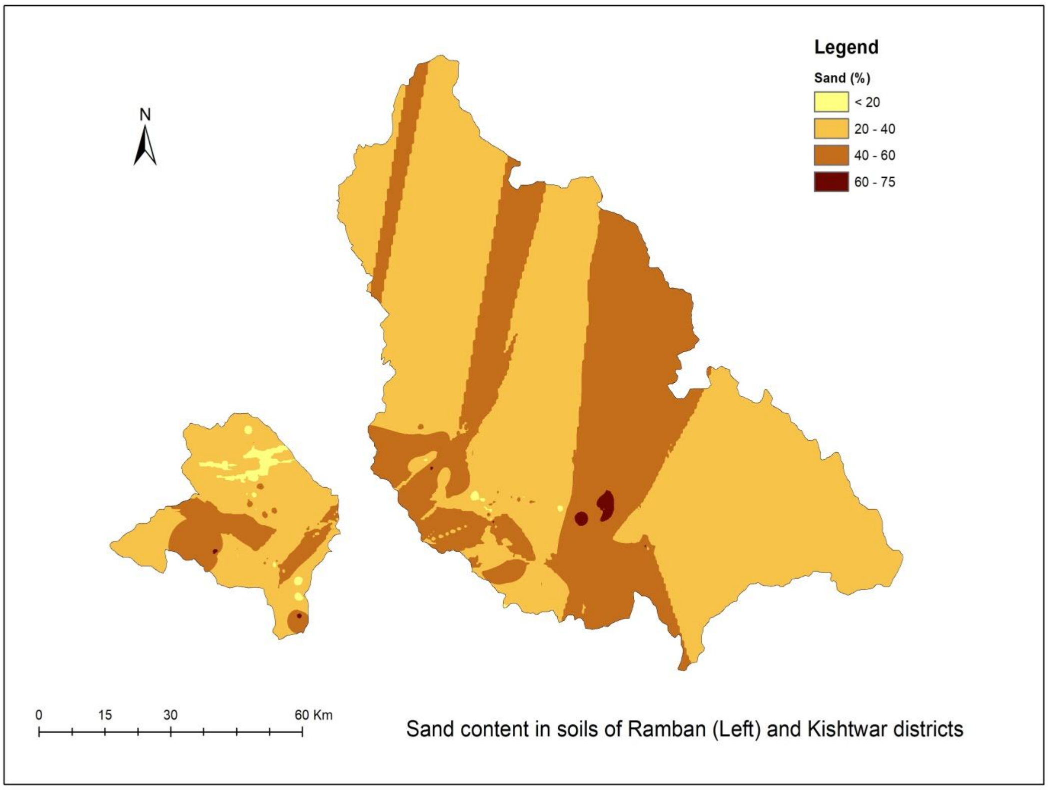


Figure 1: Sand content of Ramban and Kishtwar District.

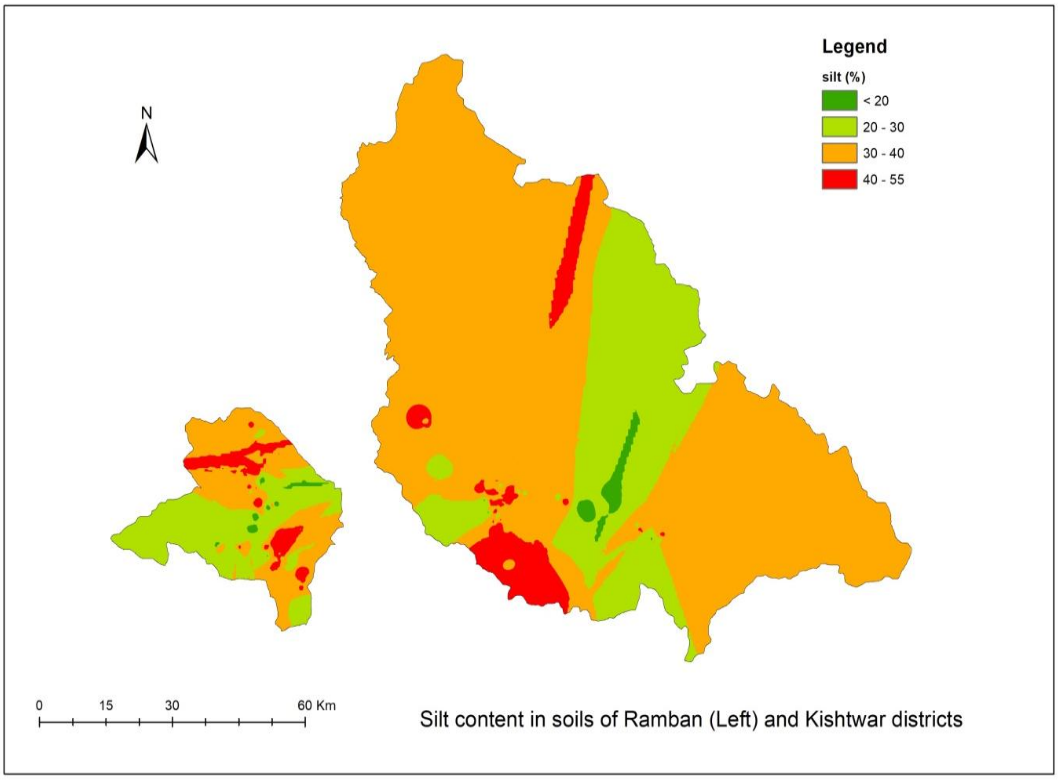


Figure 2: Silt content of Ramban and Kishtwar District.

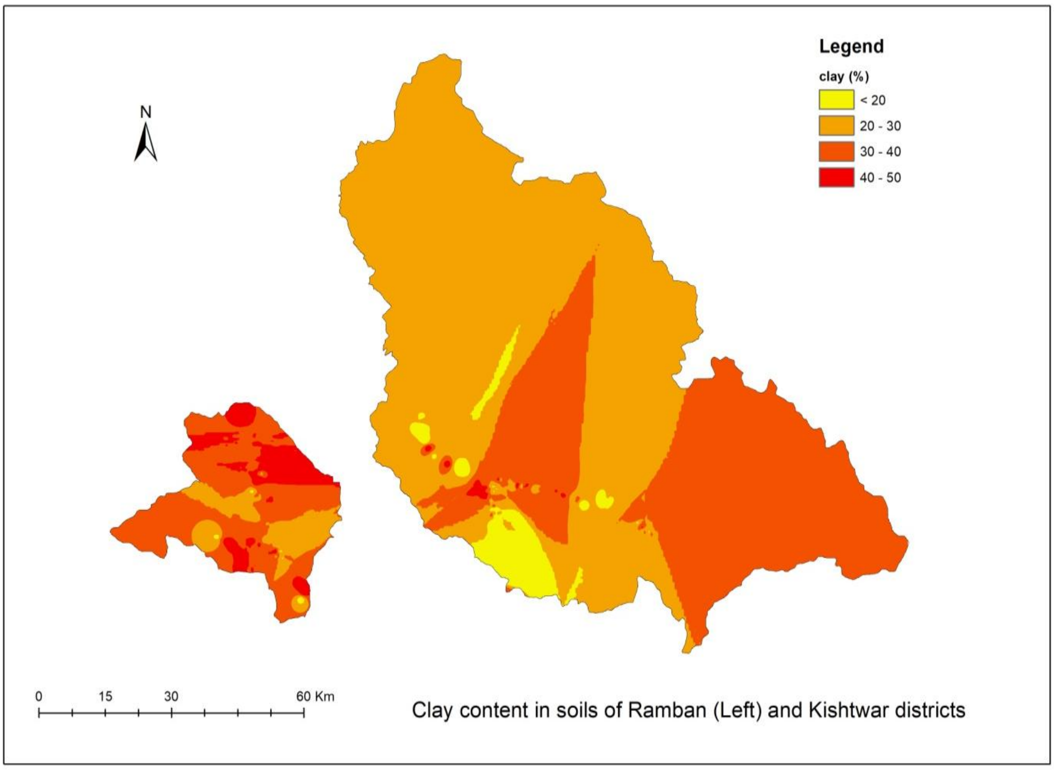


Figure 3: Clay content of Ramban and Kishtwar District.

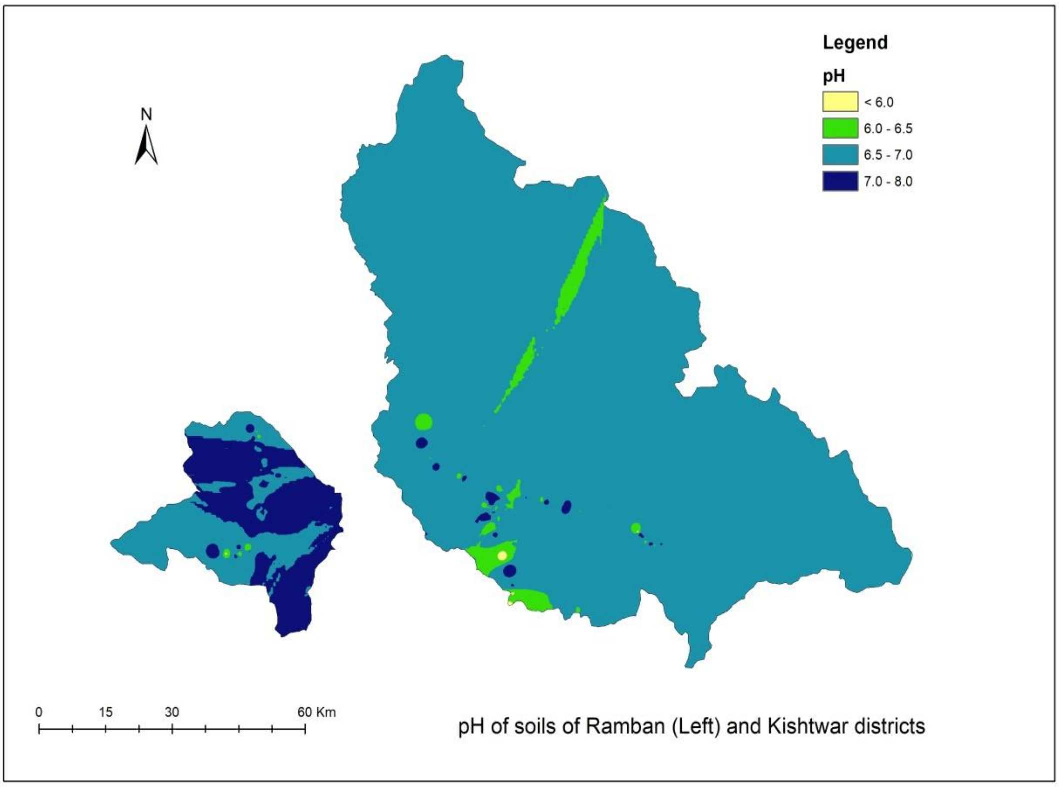


Figure 4: pH content of Ramban and Kishtwar District.

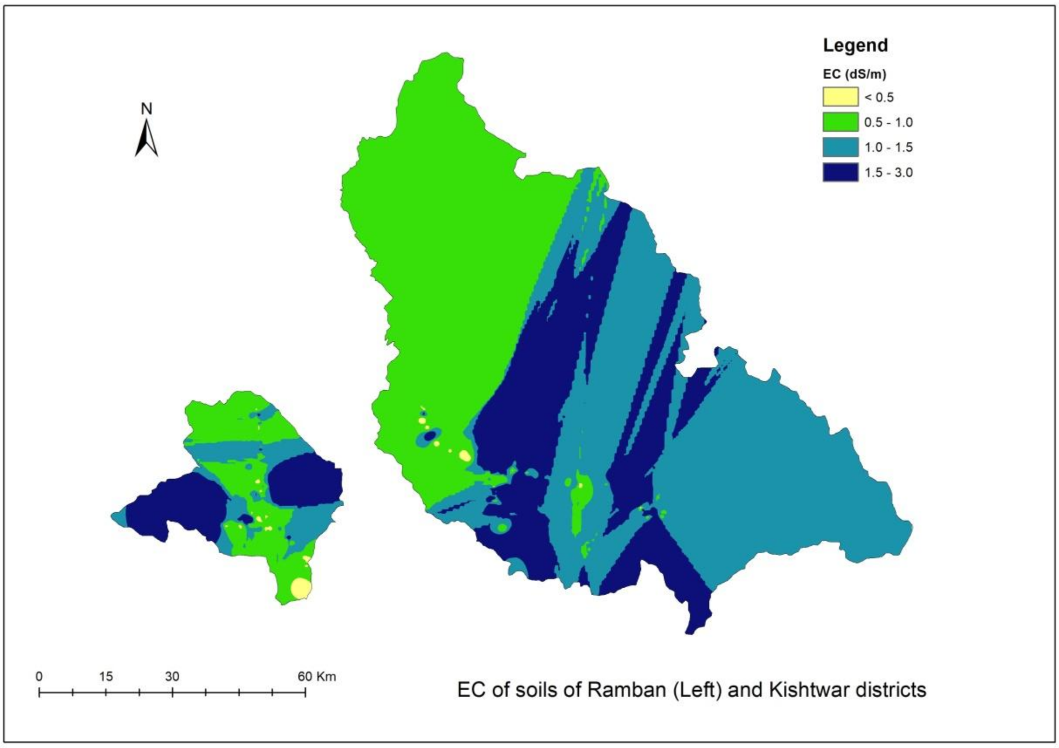


Figure 5: EC content of Ramban and Kishtwar District.

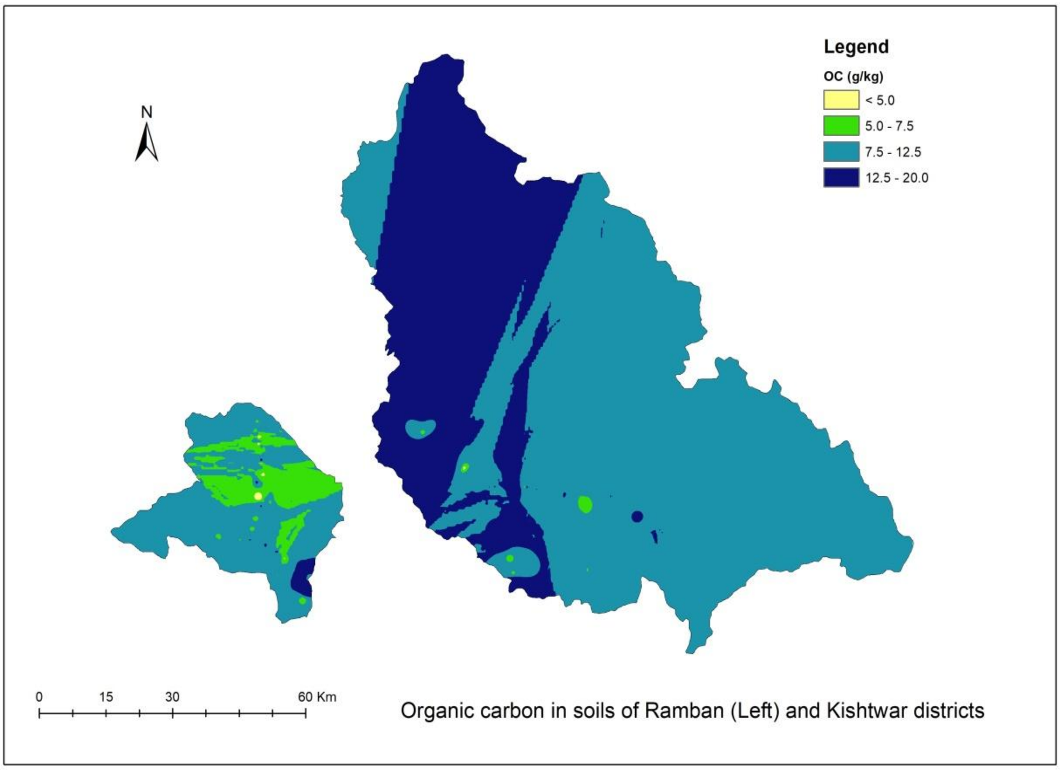


Figure 6: OC content of Ramban and Kishtwar District.

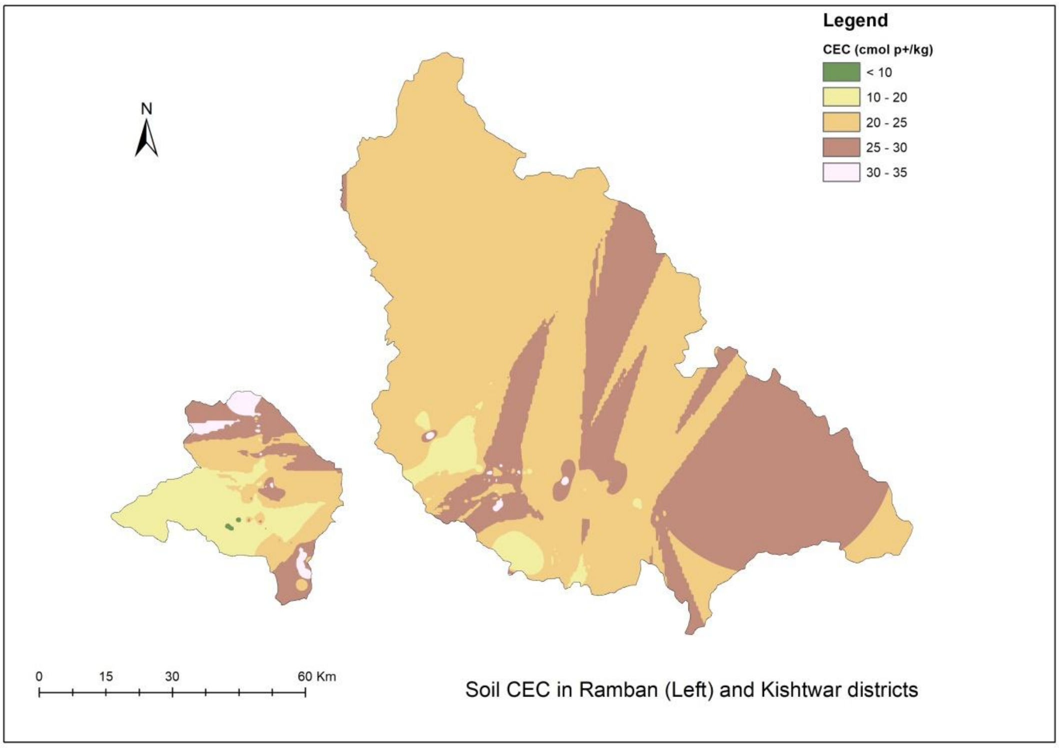


Figure 7: CEC content of Ramban and Kishtwar District.

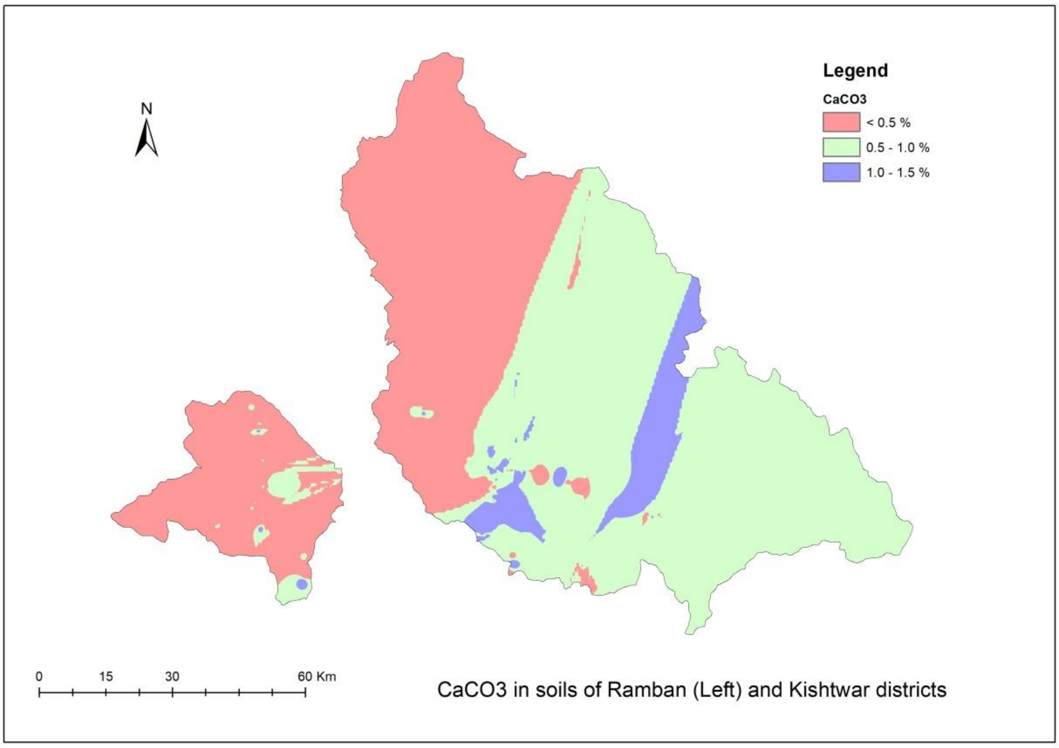


Figure 8: $CaCO_3$ content of Ramban and Kishtwar District.

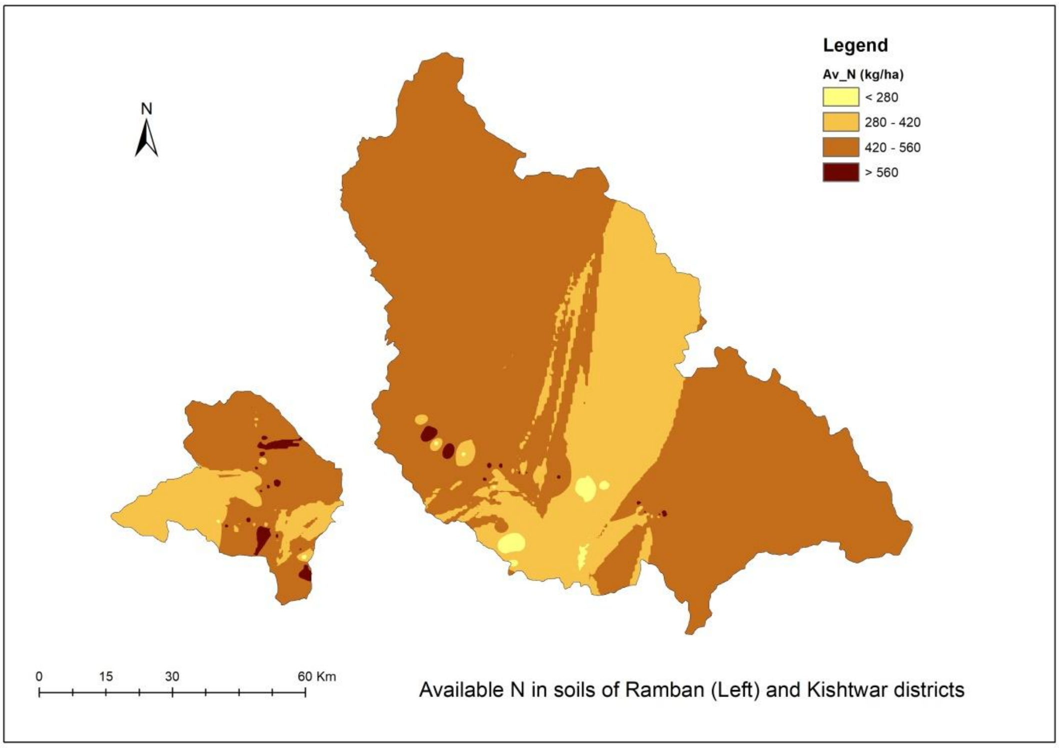


Figure 9: Available N content of Ramban and Kishtwar District.

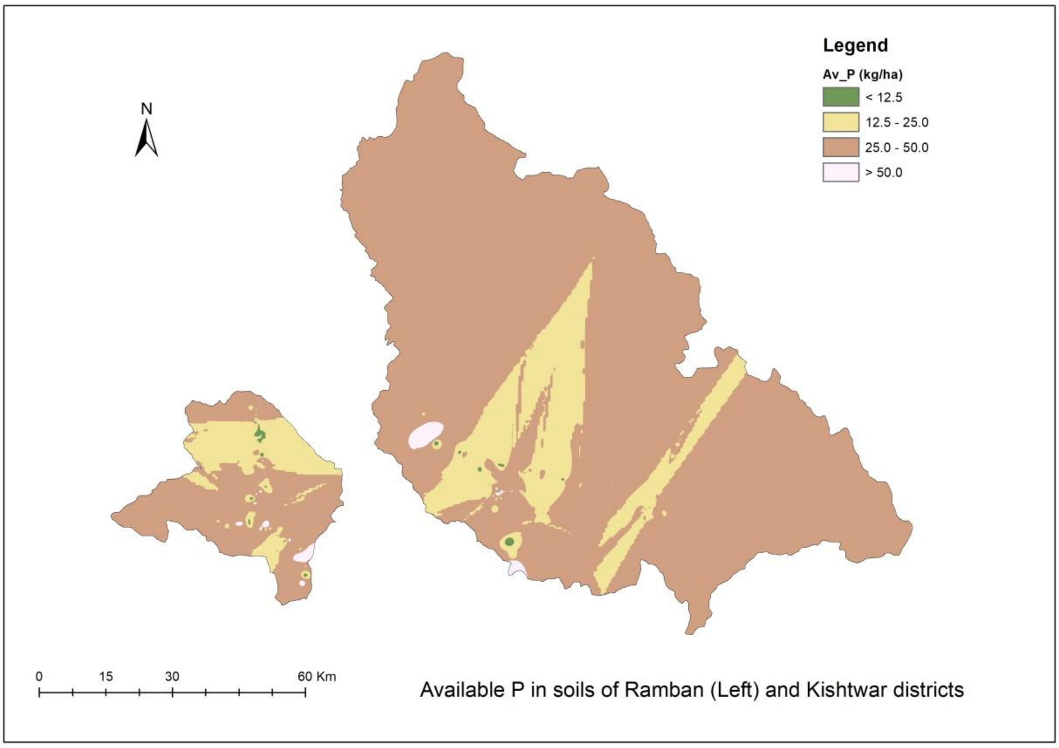


Figure 10: Available P content of Ramban and Kishtwar District.

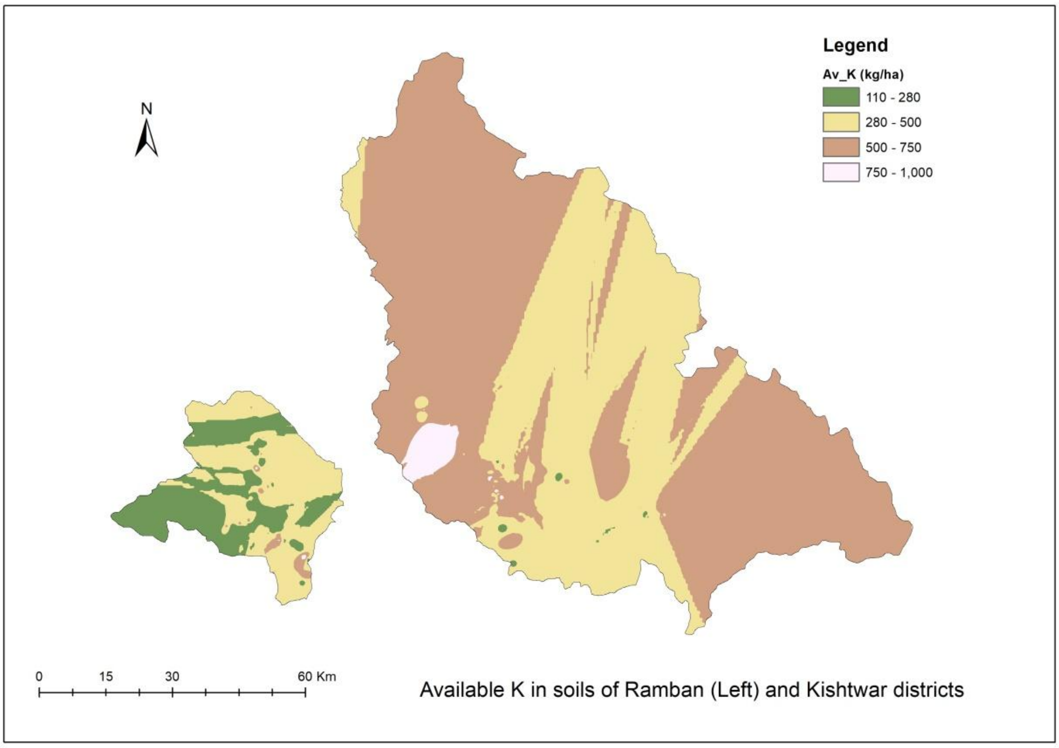


Figure 11: Available K content of Ramban and Kishtwar District.

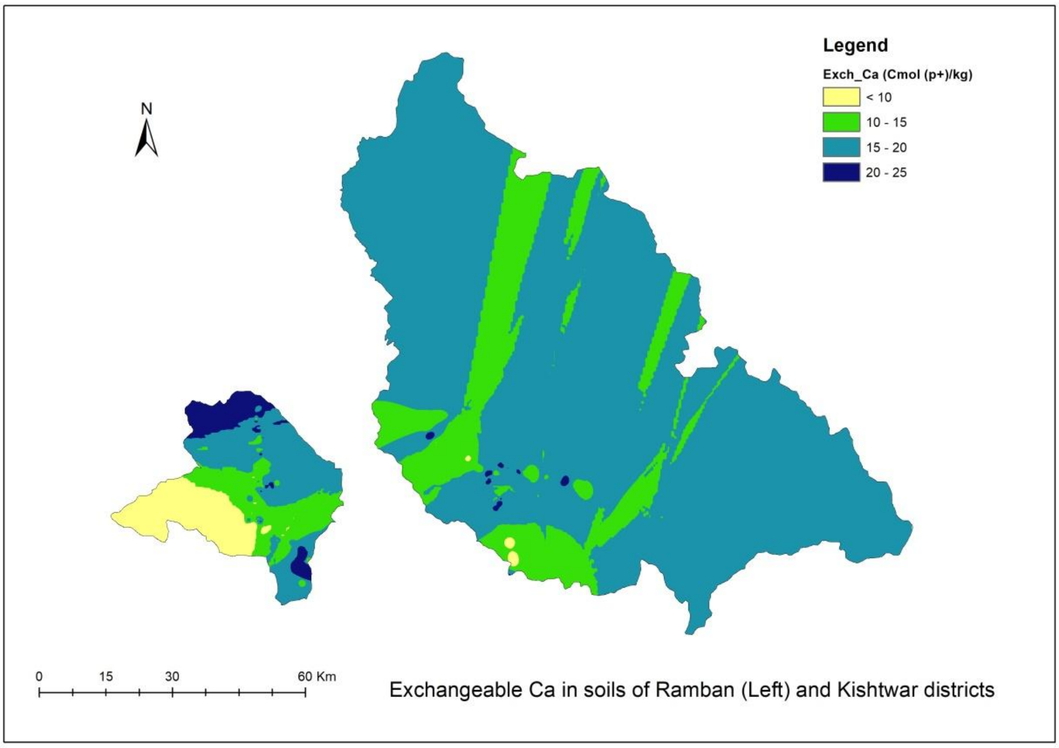


Figure 12: Exchangeable Ca content of Ramban and Kishtwar District.

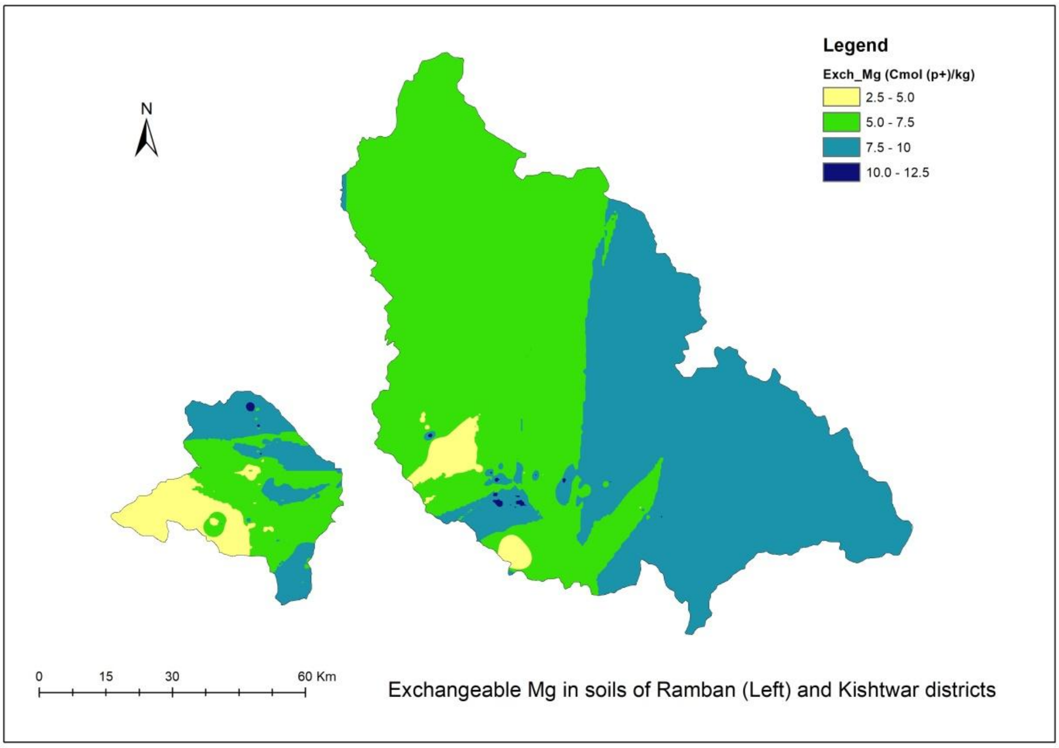


Figure 13: Exchangeable Mg content of Ramban and Kishtwar District.

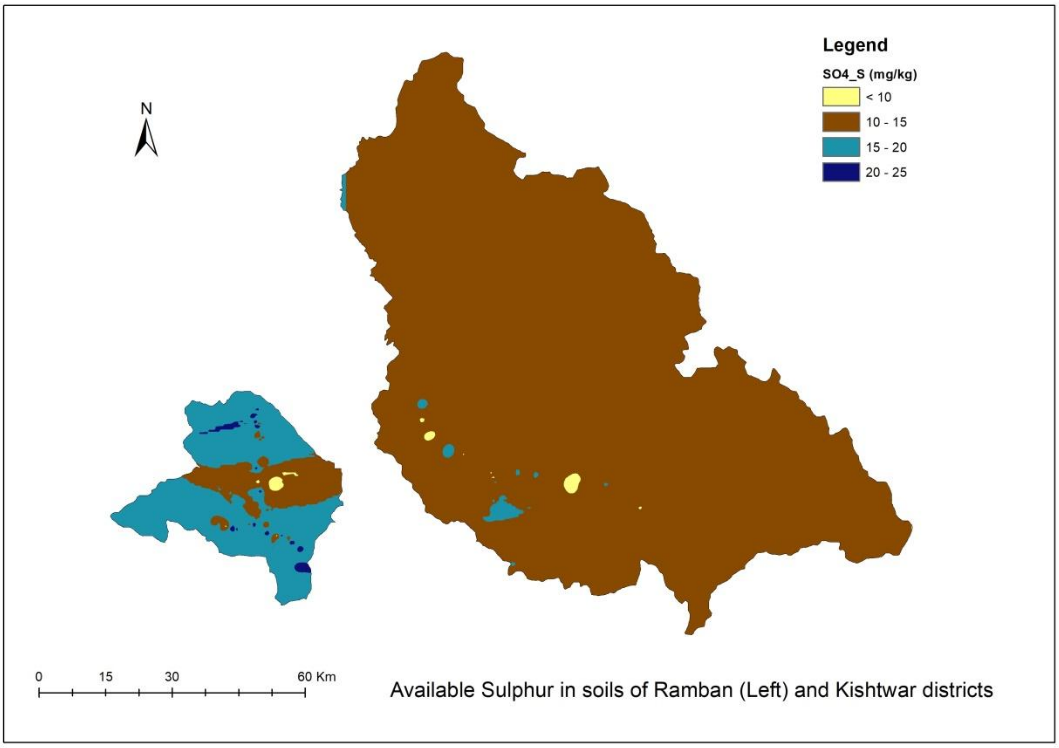


Figure 14: Available S content of Ramban and Kishtwar District.

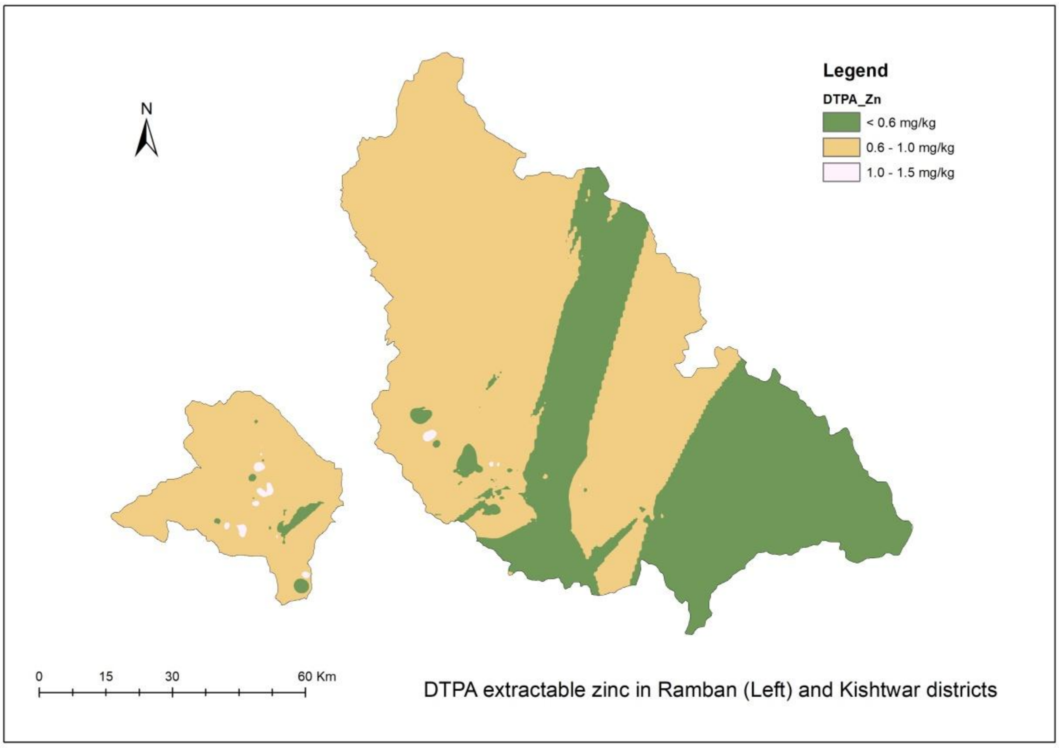


Figure 15: DTPA Zn content of Ramban and Kishtwar District.

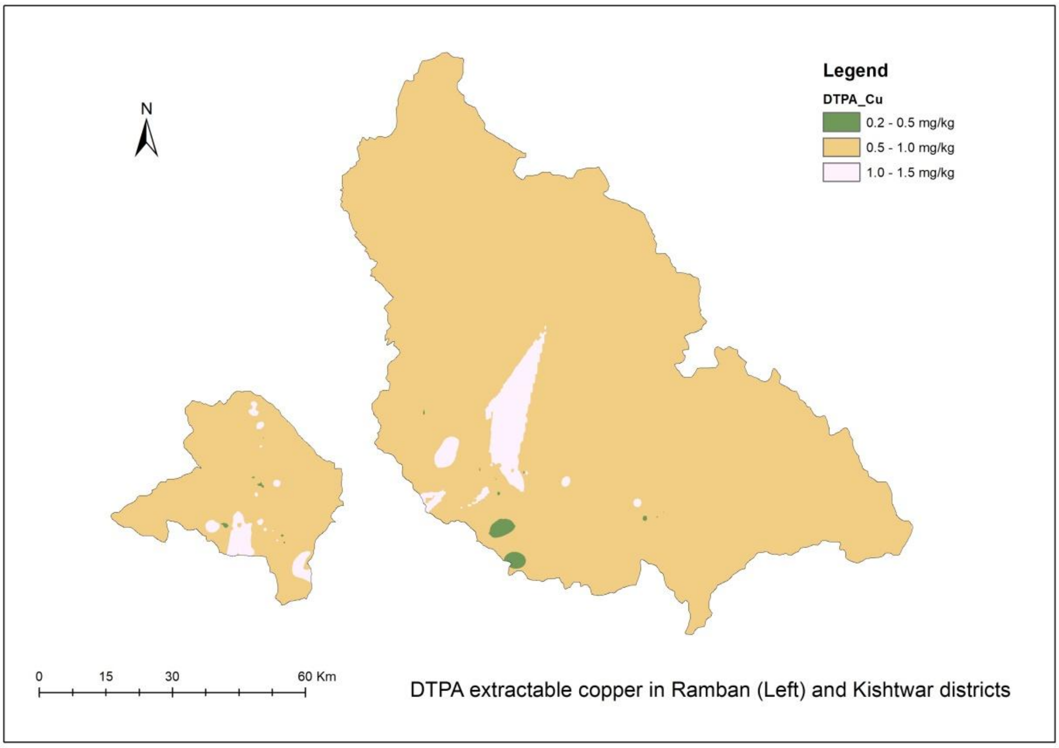


Figure 16: DTPA Cu content of Ramban and Kishtwar District.

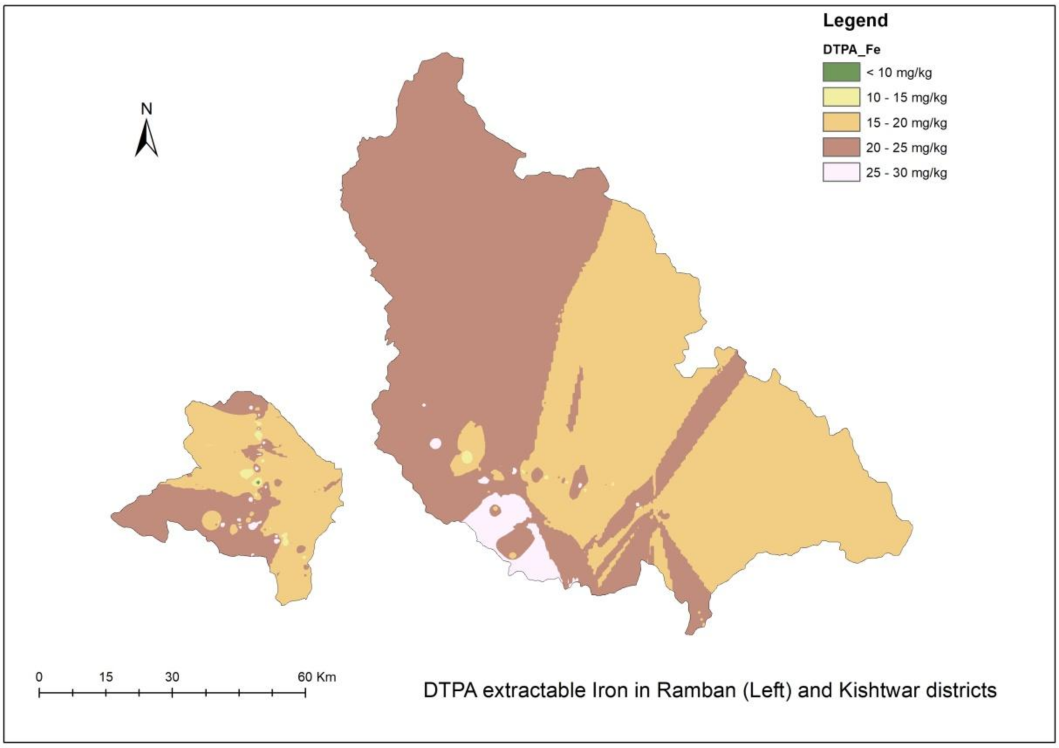


Figure 17: DTPA Fe content of Ramban and Kishtwar District.

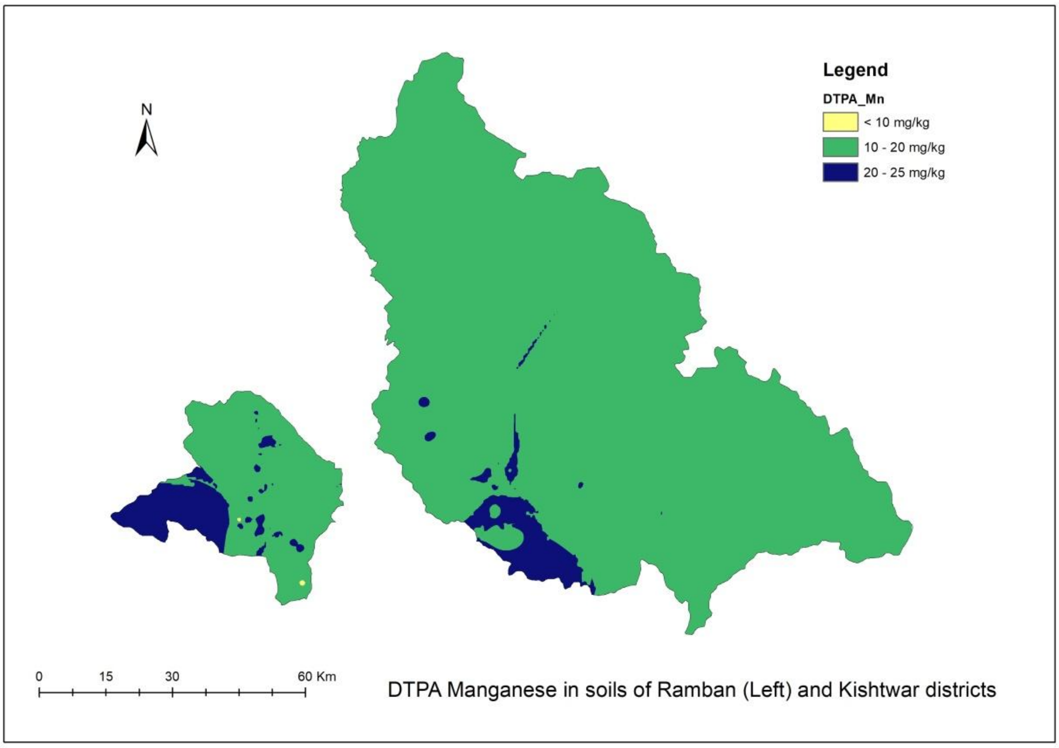


Figure 18: DTPA Mn content of Ramban and Kishtwar District.

DISCUSSION

To study the nutrient status of soils of Kishtwar and Ramban, random sampling was carried out from 167 and 114 locations from Kishtwar and Ramban Districts, respectively and the collected soil samples were analysed in the labs of division of soil science.

5.1 Descriptive statistics

5.1.1. Physico-chemical properties

The pH of the soils of Kishtwar varied from acidic (4.8) to neutral (8.0) with mean value of 6.7, having coefficient of variation (CV) 8.4 %. The pH of Ramban district varied from slightly acidic (6.2) to basic (8.4) with an average of 6.9 having CV value of 6 % .CV of pH is in consonance with the findings of Aishah *et al.*, (2010) and Tagore *et al.*, (2010). Kishtwar was having lower pH than that of Ramban district. It might be due to the reason that Kishtwar was having temperate climate leading to slow decomposition of litter and other plant and animal residues that might lead to more accumulation of humic acid and derivatives. Forest soils in both the districts were having lower pH than that of other land uses which could be attributed to acidic nature of decomposing biomass litter. Whereas high pH under wasteland could be attributed to the accumulation of CaCO3 and salts (Regmi and Zoebisch, 2004). The wide variation in soil pH was mainly observed due to variation in topography, slope and use of amendments at varying rates (Jatav *et al.*,2007).

EC of soils of District Kishtwar was mainly below 4.0 dS m-1 except some patches having higher values. EC of soils of Kishtwar District ranged from (0.34 -4.4) with an average of 2.29 dS m-1, while EC of the soils of Ramban ranged from (0.16-6.9) dS m-1 with an average value of 1.01 dS m-1. Average EC of Kishtwar was higher than that of Ramban this might be due to reason that Kishtwar is a drought prone area having less average annual rainfall leading to aridity resulting in capillary rise of salts from deeper layers to upper layers. Area under study was found non-saline to slightly saline with lowest mean value of EC in forest and highest in wasteland which could be due to accumulation of CaCO3 and salts in case of wasteland and higher amount of decomposing litter in forests. Kiflu and Beyene, (2013) also reported similar findings. Overall lower EC in both districts might be attributed to runoff and undulating topography of the region (Jatav *et al.*, 2007).

Organic carbon of Kishtwar ranged from 0.13-2.77 % with an average of value of 1.17% which was higher than that in case of Ramban where it ranged from 0.11-1.74 % with an average of 0.86%. Ramban soils were found to have less OC as compared to that in Kishtwar soils inspite of the fact that texture of Ramban soils was more fine than that of Kishtwar soils. This might be due to subtropical nature of climate in Ramban as compared to temperate in Kishtwar favouring OC accumulation. Forest soils recorded highest OC as compared to other land uses which could be attributed to high biomass production and lower decomposition rate at higher reaches (Yitbarek *et al.,* 2013). Whereas lower values in agricultural land use is due to continuous organic matter oxidation subjected to anthropogenic activities (Najar *et al*.2009).Lower values of OC in wasteland is due to sparse vegetation and no application of organic amendments (Mansha and Lone 2013).

5.1.2 Available nutrients

Available nitrogen in the study area was mainly medium to high except some patches where it was deficient. Average available nitrogen in Kishtwar and Ramban was 432.91 kg ha-1 and 468.08 kg ha-1, respectively. Highest mean nitrogen was recorded in forest land use and least in wasteland, which could be attributed to high organic matter (OM) and overall high turnout of N during decomposition in forest as compared to other land use systems. These results are in consonance with Yihenew *et al*., (2015). Available phosphorus in Kishtwar and Ramban districts was found between medium to high range with mean values 30.22 kg ha-1 and 28.42 kg ha-1 respectively. Higher content of available P might be due to intensive and regular use of Diammonium phosphate (DAP) leading to build up of residual P**.** Comparable trends were found in similar type of soils in Punjab by Benbi and Biswas, (1999). Available potassium in the study area varied from medium to as high as 1110.71 kg ha-1.This trend might be due to presence of Illite mineral, less cropping intensity and less removal of K by crops. Similar results were found by Gupta *et al*., (1977).

5.1.3 Interpolation and mapping

Mapping of spatial distribution of soil properties require spatial interpolation methods. In the present study, interpolation technique inverse distance weighting (IDW) was employed and soil maps of each property were generated. These interpolation techniques have been commonly used in mapping of soil properties (Schloeder *et al*. 2001; Caridad-Cancela *et al*. 2005; Nayak *et al.* 2009; Amirinejad *et al* .2011). Some workers found that the kriging method performed better than IDW (Panagopoulos *et al*. 2006; Yasrebi *et al*. 2009) while others showed that kriging was no better than alternative methods (Gotway *et al*.,1996; Mueller *et al*., 2004).

5.1.4 Soil maps and fertility patterns

Maps of both of the districts indicated wide range of variation in soil physiochemical properties, as both the districts are located under varying terrains and climatic conditions leading to high variability of soil properties. Sandy loam and clay loam texture were usually dominant textural group in Kishtwar and Ramban, respectively. Sand content in Kishtwar district was mainly less than 20 per cent and strips of 40 to 60 per cent sand were present across the district. Whole of the tehsil Padder and major area of tehsil Kishtwar of district Kishtwar was having sand content between 20-40 per cent. In Ramban district majority of area had sand between 20 – 40 per cent. In Banihal tehsil of Ramban district some area in the form of small patches was having sand content less than 20 per cent. Whereas in Ramban tehsil some area had sand content greater than 60 per cent. In case of silt majority area of Kishtwar district had silt content between 30 to 40 per cent on both east and west ends. In the Central part of the district silt content was in between 20 to 30 per cent, with some scattered patches having greater than 40 per cent silt. Half of the area of Ramban district spread over north and south ends had silt content ranging between 30- 40 per- cent, whereas other half of the area located in the central part of the district had silt content between 20-30 per cent. Silt content in some patches of the district was greater than 20 per cent, whereas a very small area in form of scattered patches had silt content less than 20 per cent. In case of clay content major area of Kishtwar district had 20-30 per cent clay followed by the area on central and eastern side of the district having 30- 40 per cent clay. In Ramban district clay content varied from 30 -40 per cent in majority of the area present on the northern and southern sides, whereas it was 20 -30 per cent in rest of the area between the two ends. Soils in few patches scattered over the district had clay content between 40 -50 per cent, whereas few patches with small area towards southern part of the district had clay content less than 20 per cent. Soil texture becomes coarser as clay is eroded, soil texture is function of parent material and soil forming processes.

Soils of almost entire district of Kishtwar were found to be neutral in reaction. Very small patches of the district were having soils with acidic and basic reaction. Soils of almost half of the Ramban district towards south-west and northern side were neutral in reaction, whereas soils of the area on the eastern and central part of district were basic in reaction. Acidic soils dominant as majority of soils are present on hilly terrain and leads to leaching of salts which leads to soil acidity.EC was found to be within the safe limits in both the districts, however EC of soils of both districts had great variation, western side of Kishtwar was having EC ranging from 0.5 to 1.0 dS m-1 and on eastern side it varied between 1.0 and 1.5 dS m-1. Some strips across north and southern side of Kishtwar district had EC between 1.5 and 3.0 dS m-1. In Ramban district soils on northern and southern side had EC mainly in between 0.5 to 1.0 dS m-1 and on eastern and western side it was mainly in the range of 1.5-3.0 dS m-1.Soil organic carbon (OC) of both the districts was in high range (>12.5 g/kg) especially in forest blocks. In Kishtwar district, marwah tehsil had higher content of OC ranging from 12.5 to 20.0 g/kg. In rest of the district it ranged between 7.5-12.5 g/kg. Major part of Ramban district had OC ranging from 7.5-12.5 g/kg, whereas central part of the district covering Banihal tehsil had lower OC (0.5-7.5 g/kg) as compared to Ramban tehsil. While comparing two districts higher content of OC was recorded in Kishtwar district. Available nitrogen (N) was not limiting in the entire Kishtwar district. In Marwah and Padder tehsils of Kishtwar district majority area was having N in medium range (420-560 kg/ha). In Central part of the district stretching from north-east to southern side had N in the medium range (280-420 kg/ha). In Ramban N varied from 280-560 kg/ha with some patches greater than 560 kg/ha, northern part of District covering Banihal tehsil and part of Ramban tehsil had N in Medium to High range (480-560 kg/ha), area lying on eastern and western part of Ramban tehsil of the district had N in medium range (280-420 kg/ha). Available Phosphorus (P) in whole of the Kishtwar district was sufficient. Major part of the district had available P in high range (25.0 to 50.0 kg/ha), whereas some central part of district lying in Chatro tehsil was having P in medium range (12.5-25.0 kg/ha). In Ramban district also major part was having available P in the high range (25.0-50.0kg/ha), whereas some areas on the northern side of the district covering Banihal tehsil had P in medium range (12.5-25.0 kg/ha). Available potassium (K) in whole of the Kishtwar district was mainly in high range from 500 to 750 kg/ha. North, northwest and south east area of the district covering part of Marwah, Chathro and Padder tehsil was having high content of K ranging from 500-750kg/ha. Whereas central part of the district stretching from north-east to southern side had available K in high range (280- 500 kg/ha). Major part of Ramban district had available K in the high range (280-500 kg/ha). Other area of the district lying on eastern and northern side was having K in medium range (110- 280 kg/ha).Secondary nutrients Calcium, Magnesium and Sulphur were in medium to high range in almost entire areas of both of the districts, except in some areas of Ramban district where they were on lower side. Almost whole of the Kishtwar district had secondary nutrients in high range, except some strips in the district were found in medium range. In Ramban district some area on the northern tip had very high content of secondary nutrients, western part of Ramban district covering part of Ramban tehsil had secondary nutrients in low range**.** Whereas in middle part of the district secondary nutrients were in medium range. Rest of the district had these nutrients in high range. Calcium in major part of Kishtwar was in the range of 15-20 m.eq/100g, whereas in case of district Ramban on western side of tehsil Ramban it was less than 10 m.eq/100g. Exchangeable Magnesium also followed the same trend. All the micronutrient except zinc (Zn) in soils of both the districts were sufficient and well above the critical limit (0.6 ppm). As such there was no problem of their deficiency. Soils of south-eastern part of Kishtwar district covering Padder tehsil and centrally located elongated strip stretching from north east to south were deficient in DTPA zinc content. Available copper was mainly sufficient in both the districts except some negligible patches in Chattro tehsil of Kishtwar district, where it was found deficient. In Kishtwar district, Chattro tehsil recorded higher iron content as compared to other tehsils of the district. In Ramban district Ramban Tehsil had higher iron than that in Banihal tehsil.

SUMMARY AND CONCLUSION

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Mapping and soil analysis are key tools in site specific nutrient management as they give idea of soil fertility in sample and non-sample areas. Awareness about soil fertility is very important in order to improve crop yields by correcting specific area and conserving resources in sufficient areas. Soil maps generated during our study will help policy planners, farmers and help in drafting district fertilization plan in order to optimise resource use and help in resource conservation. In order to achieve our objectives samples were collected and analysed for various parameters. Kishtwar District lies at 32° 53´ to 34° 21´N latitude and 75°1´ to 76° 47´E longitude. It has an average elevation of 1107 meters (3361 feet) from mean sea level. Ramban is located at 33_o 14'N to 75_o 17'E longitudes with an average elevation of 1,156 metres (3792 feet) from sea level. Kishtwar district is having temperate climate and Ramban having subtropical climate predominately. Soil testing and mapping provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendation for maximizing crop yields. Soil samples were collected randomly from (167) sites at Kishtwar District and from (114) sites of Ramban District. Samples were collected at the depth of 0-15cms using global positioning systems (GPS) keeping in view different land use systems. Five adjacent land use types, namely forest, pasture, wasteland, horticulture and agriculture lands were considered for the study. The samples were analysed as per the standard procedure for laboratory analysis. ArcGIS 10.3 was used to digitize the physico-chemical properties map of the district.

Soils Particle Analysis through Bouyoucos Hydrometer method (Bouyoucos, 1962), soil pH by pH meter, EC with EC meter, OC by Chromic Acid Digestion method (Walkly and Black, 1934), available Nitrogen through Kjeldahl method (Subbai and Asija, 1956), available Phosphorus by Olsen method, available Potassium was determined by feeding the extract to flame photometer (Black, 1965), available Sulphur by Turbid metric method, Calcium and Magnesium by Versenate method (Black, 1965), Calcium carbonate by Puri method and micronutrients were analyzed through DTPA extractable method.

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Secondary nutrients Calcium, Magnesium and Sulphur were in medium to high range in almost entire areas of both of the districts, except in some areas of Ramban district where they were on lower side. Almost whole of the Kishtwar district had secondary nutrients in high range, except some strips in the district having nutrients in medium range. In Ramban district some area on the northern tip had very high content of secondary nutrients. Western part of Ramban district covering part of Ramban tehsil had secondary nutrients in low range**,** whereas in middle part of the district they were in medium range. Rest of the district had nutrients in high range. Calcium in majority area of Kishtwar was in the range of 15-20 m.eq/100g, whereas in case of district Ramban on western side of tehsil Ramban it was less than 10 m.eq/100g. Exchangeable Magnesium also followed the same trend. All the micronutrients except zinc (Zn) in soils of both the districts were sufficient and well above the critical limit (0.6 ppm). As such there was no problem of their deficiency. Soils of south-eastern part of Kishtwar district covering Padder tehsil and centrally located elongated strip stretching from north east to south were deficient in DTPA zinc content. Available copper was mainly sufficient in both the districts except some negligible patches in Chattro tehsil of Kishtwar district where it was found deficient. In Kishtwar district, Chattro tehsil recorded higher iron content as compared to other tehsils of the district. In Ramban district Ramban Tehsil had higher iron than that in Banihal tehsil.

Soil testing and mapping provides information regarding nutrient availability in soils, which forms the basis for the fertilizer recommendations for maximizing crop yields. Soil fertility maps are meant for highlighting the nutrient needs. A soil fertility map for particular area can prove highly beneficial in guiding the farmers, manufacturers and planners. It can also act as a Fertilizer Decision Support Tool. From the overall study we can conclude that the natural landuse systems are usually stable and fertile as compared to the systems affected by human interference such as agriculture etc. Wastelands are subjected to vast amount of soil disturbing factors like erosion, sparse vegetation, degradation, poor fertility and productivity etc. Also high variability was noticed in agriculture due to varying management practices.

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APPENDIX

Appendix I. Comparison of means (One-way ANOVA) of different landuses of District Kishtwar.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Sand	Between Groups	1888.298	4	472.075	1.075	.371
	Within Groups	71154.911	162	439.228		
	Total	73043.210	166			
Silt	Between Groups	473.686	4	118.421	.655	.624
	Within Groups	29289.524	162	180.800		
	Total	29763.210	166			
Clay	Between Groups	2764.111	4	691.028	3.127	.016
	Within Groups	35800.727	162	220.992		
	Total	38564.838	166			
pH	Between Groups	3.291	4	.823	2.910	.023
	Within Groups	45.796	162	.283		
	Total	49.087	166			
EC	Between Groups	25.433	4	6.358	2.189	.073
	Within Groups	470.659	162	2.905		
	Total	496.092	166			
OC	Between Groups	1.331	4	.333	1.036	.390
	Within Groups	52.003	162	.321		
	Total	53.333	166			
N	Between Groups	251765.171	4	62941.293	1.667	.160
	Within Groups	6115204.179	162	37748.174		
	Total	6366969.350	166			
P	Between Groups	8383.073	4	2095.768	3.687	.007
	Within Groups	92080.281	162	568.397		
	Total	100463.353	166			
K	Between Groups	565918.185	4	141479.546	2.074	.087
	Within Groups	11049837.455	162	68208.873		
	Total	11615755.640	166			
Ca	Between Groups	63.891	4	15.973	.601	.663
	Within Groups	4308.729	162	26.597		
	Total	4372.620	166			
Mg	Between Groups	263.035	4	65.759	8.486	.000
	Within Groups	1255.321	162	7.749		
	Total	1518.356	166			
S	Between Groups	128.193	4	32.048	4.696	.001
	Within Groups	1105.550	162	6.824		
	Total	1233.743	166			
B	Between Groups	2.853	4	.713	2.185	.073
	Within Groups	52.889	162	.326		
	Total	55.742	166			

CEC	Between Groups	189.936	4	47.484	.867	.485
	Within Groups	8868.860	162	54.746		
	Total	9058.795	166			
CaCO3	Between Groups	7.191	4	1.798	3.680	.007
	Within Groups	79.131	162	.488		
	Total	86.322	166			
Zn	Between Groups	.114	4	.029	.402	.807
	Within Groups	11.498	162	.071		
	Total	11.612	166			
Cu	Between Groups	.865	4	.216	1.404	.235
	Within Groups	24.950	162	.154		
	Total	25.815	166			
Fe	Between Groups	527.312	4	131.828	2.855	.025
	Within Groups	7480.842	162	46.178		
	Total	8008.153	166			
Mn	Between Groups	81.236	4	20.309	.693	.598
	Within Groups	4750.824	162	29.326		
	Total	4832.061	166			

Appendix II. Comparison of means (One-way ANOVA) of different landuses of District Ramban.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Sand	Between Groups	1888.298	4	472.075	1.075	.371
	Within Groups	71154.911	162	439.228		
	Total	73043.210	166			
Silt	Between Groups	473.686	4	118.421	.655	.624
	Within Groups	29289.524	162	180.800		
	Total	29763.210	166			
Clay	Between Groups	2764.111	4	691.028	3.127	.016
	Within Groups	35800.727	162	220.992		
	Total	38564.838	166			
pH	Between Groups	3.291	4	.823	2.910	.023
	Within Groups	45.796	162	.283		
	Total	49.087	166			
EC	Between Groups	25.433	4	6.358	2.189	.073
	Within Groups	470.659	162	2.905		
	Total	496.092	166			
OC	Between Groups	1.331	4	.333	1.036	.390
	Within Groups	52.003	162	.321		
	Total	53.333	166			
N	Between Groups	251765.171	4	62941.293	1.667	.160
	Within Groups	6115204.179	162	37748.174		
	Total	6366969.350	166			

P	Between Groups	8383.073	4	2095.768	3.687	.007
	Within Groups	92080.281	162	568.397		
	Total	100463.353	166			
K	Between Groups	565918.185	4	141479.546	2.074	.087
	Within Groups	11049837.455	162	68208.873		
	Total	11615755.640	166			
Ca	Between Groups	63.891	4	15.973	.601	.663
	Within Groups	4308.729	162	26.597		
	Total	4372.620	166			
Mg	Between Groups	263.035	4	65.759	8.486	.000
	Within Groups	1255.321	162	7.749		
	Total	1518.356	166			
S	Between Groups	128.193	4	32.048	4.696	.001
	Within Groups	1105.550	162	6.824		
	Total	1233.743	166			
B	Between Groups	2.853	4	.713	2.185	.073
	Within Groups	52.889	162	.326		
	Total	55.742	166			
CEC	Between Groups	189.936	4	47.484	.867	.485
	Within Groups	8868.860	162	54.746		
	Total	9058.795	166			
CaCO3	Between Groups	7.191	4	1.798	3.680	.007
	Within Groups	79.131	162	.488		
	Total	86.322	166			
Zn	Between Groups	.114	4	.029	.402	.807
	Within Groups	11.498	162	.071		
	Total	11.612	166			
Cu	Between Groups	.865	4	.216	1.404	.235
	Within Groups	24.950	162	.154		
	Total	25.815	166			
Fe	Between Groups	527.312	4	131.828	2.855	.025
	Within Groups	7480.842	162	46.178		
	Total	8008.153	166			
Mn	Between Groups	81.236	4	20.309	.693	.598
	Within Groups	4750.824	162	29.326		
	Total	4832.061	166			

VITA

VITA

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OGPA	7.69/10.00
Master's degree	M.Sc. Agriculture
	(Soil Science and Agriculture Chemistry)
OGPA	8.40/10.00

CERTIFICATE-IV

Certified that all the necessary corrections as suggested by the external examiner and the Advisory Committee have been duly incorporated in the thesis entitled **"Mapping of nutrients status in soils of Kishtwar and Ramban districts of J&K using geographic information system (GIS)"** submitted by **Mr. Owais Ali Wani,** Registration Number **J-16-M-442.**

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Major Advisor and Chairman
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Place: **Jammu**

Date: 15-11-2018

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