Dynamics of Hydraulic and Physio-chemical Characteristics of Soils in Potohwar Region

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CERTIFICATE

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Key words:

EC	electrical conductivity
SAR	sodium absorption ratio
dS	deci siemen
OM	organic matter
P	phosphorus
Zn	zinc
B	boron
DC	zero error correction
DS	temperature error correction
TDS	total dissolved solids
EDTA	ethylenediamineteraacetic acid
IDW	inverse distance weighted

ABSTRACT

Rainfed regions are those where cultivation mostly depends upon rainfall. The climate of Pakistan is uneven and almost two-third of the country has an arid type climate. A significant population is feeding on Barani agriculture in Pakistan. Potohwar plateau is an upland area lying between the Indus and Jhelum River mainly comprising of Attock, Chakwal, Jhelum, and Rawalpindi districts with a total area of 28500 km^2. Soil erosion and water management are the main constraints for agriculture production in this area. The present study has been conducted to evaluate the physiochemical and hydraulic characteristics of soil in this region and its impacts on crops/vegetation growth. For this purpose, 30 sites were selected based on a uniform grid of 30 km^2 in the whole region. The samples for each site were taken by auger at three layers i.e. surface, middle, and bottom-up to 1 m depth. Soil texture, infiltration rate, and bulk density were found of each layer. By analysis of soil paste extract EC, pH, Na, Ca and Mg were found for the calculation of SAR. Results of the study reveal that soil was sandy to loam in the Attock district and patches of sandy clay loam in some parts of the Potohwar which can support low water demanding crops (gram, groundnut, and wheat crops as well as orchards). The infiltration rate was observed that variant between 20 mm/hr for medium soil and > 40 mm/hr for sandy soils (require special conservation practices). Bulk density of all soil samples was in the normal range, however, organic matter content was highly variable (0.5-1.5%) depending upon rainfall and natural vegetation. The pH of the whole region was in the range of 7.4-8 (neutral) and EC was between 35-120 dS/m. So, it is concluded that there is no salinity problem. Regression analysis was done among different parameters and most

of the *p* values were > 0.05, which showed that the results were insignificant. Based on these results it is concluded that the soil of the Potohwar region is fully capable of, to produce a satisfactory yield of crop. Adoption of modern soil and water management practices can improve the potential of crop growth and orchard

Chapter 1

1. INTRODUCTION

The Potohwar Zone is a highland area that situated from 32.5˚N to 34.0˚N Latitude and from 72˚E to 74˚E Longitude. Potohwar region locates between the Indus River and the Jhelum River and covers the area of the salt range northward to the foothills of the Himalayas. This plateau lies about 500 to 1000 m above of the mean sea level (MSL) and its location is that in the north the Kala-Chitta and the Margalla ranges, in the east the Jhelum River, in the south the Salt Range, and in the west the Indus River is present. Most of the plateau slopes from north to east and flows into the Indus River through the Suan River. However, the southeastern part of the plateau slopes eastward and drains into the Jhelum River.

1.1. **:** Map of Potohwar region

A large part of the arable land is under rainfed conditions, relying on rainfall to produce crops. The Potohwar Plateau mainly consists of a rainfed area. This area can realize the production of food crops under rainfed conditions. The crops which are grown in Potohwar include wheat, corn, barley, bagels, gram, and peanuts. From the perspective of total rainfall, about 80% occurred only between July and October, mainly supporting the efficiency of corn. (Kazmi & Rasul, 2012).

1.1. Barani area of Pakistan:

Pakistan has an uneven climate, with an approximately two-thirds area of an arid climate. Humid climate prevails in the narrow bands of the sub-mountain areas. The climate of the northern part of the country is humid, but the extreme mountains in the north are comparatively dry. The mountainous areas in the north and northeast, which are composed of towering hills, experience a climate similar to the temperate climate, while the arid and semi-arid climate present in the southern region, having little rainfall and high temperatures. Soil properties are very important because the mineral composition, texture, and surface roughness of the soil are the core properties of the soil (Gorji, Sertel, & Tanik, 2017). This pattern is bimodal, with summer rainfall of 60-70% from July to September, and the rest in winter. (Baig, Shahid, & Straquadine, 2013) The area, population, and distribution of crops in the Barani area are shown in Table 1.1 below:

Table 1.1: Characteristics of districts of Potohwar region

Features	Districts Lying in Potohwar Region			
	Rawalpindi	Chakwal	Attock	Jhelum
Area (km^2)	259	6524	6857	3587
Population	5,405,633	1,495,982	1,883,556	1,222,650
Rainfall (mm)	1200	519	539	842
Tempe. (^oC)	22.2	22.3	22.2	23.6
Crops	Wheat, Barley, Corn, millet	Wheat, Groundnut, Oilseed, Grams, Lentils, Masoor, Mung mash, maize	Peanuts, Wheat, Maize, Millet, vegetables	Wheat, Rice, Fruits, Vegetables, Fodder

1.2. Agriculture of Potohwar region:

Agriculture of the whole world is important to feed the population as it is said that global food production will need to increase by 38% by 2025 (Rengasamy, 2006). So, to know about the agriculture of Pakistan it is important to know its soil.

71% of wheat production comes from the Punjab region, while the Barani region of Punjab accounts for 25% of the province's wheat production. Due to climatic conditions, the production risk of Barani (rainforest) crops is relatively high, because these farmers are using traditional methods in crops, due to scarcity and variability of rainfall in time. Inappropriate availability of water in the reproductive stage obstructs the growth of wheat and also negatively affects the yield of wheat. Rain-fed areas account for only 12% of the country's total wheat production (Kazmi & Rasul, 2012).

The major crops in the Potohwar region are wheat, corn, peanuts, and gram. At the minor level millet, mungbean and tarramira are grown. In this period, two crop grapes and olives area emerging in the Potohwar region the soil attributes and climatic conditions are much favorable with their yield and growth. Many of the farmers are dragging their attention to the production of these two crops.

High temperatures may have a positive effect on crop yields. The population that depends on agriculture is highly affected by climate change. The water demand mainly depends on climatic conditions, such as agronomic factors such as air temperature, solar radiation, relative humidity, wind speed, and crop growth stage. Due to rainfall in rainfed areas, crop cycles fluctuate greatly. The yield depends entirely on the amount and intensity of rainfall. As the temporal and spatial distribution of rainfall affects crops, the rainfall in the Potohwar region, especially Rawalpindi, Kalmar, Chakwal, and Jhelum, has a great variation in yield.

1.3. Habitants lifestyle of Potohwar region:

The rain channel of Potohwar is one of the poorest and food-poor areas. 70% of the population of the Potohwar region live in rural areas, with limited employment opportunities. This is why this part of the country contributes less to the agricultural sector. On average, all livelihood products of small farmers are in short supply. Most farmers (90%) have less than 5 hectares of operational land resources. With unstable climatic conditions, increasing population, and limited land and water resources, land productivity is also very low. Male labor has been transferred to urban areas, especially non-agricultural activities in the public sector. (Sajida Taj & Mirza, 2007)

1.4. Common Constraints in rainfed agriculture:

Ramakrishna (2009) has said in his study about the common constraints in rainfed agriculture worldwide:

- Soil organic matter is essential for maintaining the water cycle in the ecosystem. The depleted organic content has a significant negative impact on permeability and porosity, local and regional water cycles, water productivity, plant productivity, the resilience of agroecosystems, and global carbon cycles.
- The general consumption of nutrients in agricultural soil is the main reason for the decline in yield, low on-site water productivity, and on-site water pollution. Salinity, alkalinity, and waterlogging threaten the most productive land in the world and pollute groundwater.
- Intensified soil erosion on farms has led to a large amount of yield loss and caused precipitation and degradation of downstream water bodies, water, and irrigation systems, which is the main cause of investment disasters.
- Globally, agriculture is the main consumer of water, and water shortage is a major problem for farmers in Africa, Asia, and the Near East. Agriculture is also the main factor causing non-point source water pollution, while urbanization has caused more and more wastewater. Water quality problems are usually as serious as water supply problems, but they have not attracted enough attention in developing countries.

1.5. Objectives:

The last century showed major physical, chemical, and/or biological destruction in land resources and resulted in serious consequences to global natural resources (Shrivastava & Kumar, 2015). According to the geographical attributes of the Potohwar region, this area possesses highly variable climatic conditions, soil type, nutrients level, cropping system, organic matter, and agricultural activities. The rain channel has made important contributions to agriculture and livestock production (Arif & Malik, 2009a).

Pakistan is a largely agricultural country, so its main economy depends on crop yields. And Potohwar region comprises a major part of the population in the country so their income source is mainly agriculture. This study is conducted to analyze the hydraulic and physicochemical characteristics of the soil of the Potohwar region under the supervision of Malik et al., 2019 in labs of PCRWR, and their effects on its crops. So, the objectives of this study are the following:

1. Assessment of hydraulic characteristics and physicochemical properties of soils in the Potohwar region.
2. Impacts of hydraulic characteristics on crop yields and natural vegetation of the area.

2. REVIEW OF LITERATURE

2.1. Barani region:

Rainfed regions are those where cultivation mostly depends upon rainfall. (Adnan, Mahmood, & Khan, 2009). The Barani region is described by diverse and complex agriculture, defining the interaction of land and soil types, rainfall variability, and socio-economic factors in farmer management (Sheikh, Byerlee, & Azeem, 1988).

2.2. Barani region in Pakistan:

Pakistan has 79.9 million hectares of land, of which 22 hectares are designated as cultivated land (Abas, Khan, Hussein, Hanjara and Akbar, 2013). Among the total area of 11.83 million hectares of arable land in Punjab, the Barani region occupies 3.1 million hectares, with different ecological regions, soil types, and rainfall patterns (Mahmood et al., 2019). According to the rainfall distribution pattern, Barani Potohwar is divided into three areas: low rainfall area-receiving <500 mm rainfall, medium rain band-receiving 500-750 mm rainfall, and high rainfall zone-750mm rainfall. (Sheikh et al., 1988)

Barani or rainfed areas have made important contributions to Pakistan's agricultural production. Of the total cultivated area of 20 million hectares, about 5 million hectares (25%) are rainfed land without irrigation. In Punjab, 20% of crops are raised by rain. (*Wheat in Barani Areas 0 Northern Punjab : A Synthesis of On-farm Research Results*, 1990).

Rainfed agriculture plays an integral part in Pakistan’s economy, and these areas account for 17% of the country’s total crop area. (Adnan et al., 2009)

Rainfed farming is of high importance in Pakistan as, out of the 23 Mha area under cultivation, around 4 Mha is under rainfed farming. (Mahmood et al., 2019)

2.3. Soil types in the Barani region:

The main soils in Barani areas have developed from transported material such as loess, piedmont, alluvium, and river alluvium. They are generally medium textured with a fair proportion of clay soils. (*Wheat in Barani Areas 0 Northern Punjab : A Synthesis of On-farm Research Results*, 1990)

2.4. Physical properties of soil:

2.4.1. Soil texture:

Generally, the soil of the Potohwar Plateau has a medium to coarse texture, because these soils mainly come from sandstone and loess parent material, which contain a large number of fine particles (Ali, 1967). Soil crusts reduce portability, which leads to increased runoff, which results in loss of water and nutrients.

2.4.2. Organic matter and water infiltration:

The impact of organic matter loss is not limited to production losses but also disrupts the water cycle. The reduction of soil organic matter causes the collapse of soil aggregates and therefore the crusting and sealing of the soil surface. It results in the reduction of porosity, reduction of permeability, and increased runoff. This change increases the risk of flooding and water erosion. Higher run-off also affects channels in the form of gullies and rills.

2.5. Chemical properties:

Shaheen et al. (2016) determined the chemical properties of these Barani soils. Among the soil characteristics of selected fields, the pH values of the eight soil series can quantify the selected soil characteristics and nutrient status of eroded soil. pH, EC, and, the organic matter lies in the medium amount in these soils. All soils are generally deficient in nutrients.

2.6. Effects on plant and crop growth:

Climate change directly affects temperature and precipitation, which are the two most important parameters affecting the cultivation of rainfed crops

As rain is an important factor in the production of crops in rainfed areas in Pakistan, extreme weather is occurring more and more, which has become a major threat. (Mahmood et al., 2019)

It is understood that the decrease in plant growth is the result of changes in many physiological activities in plants (Han & Lee, 2005), which may be due to the physical characteristics of the soil (Han & Lee, 2005). The main reasons for the low productivity of rain-fed crops are low soil fertility and soil water stress, which are caused by increased rain loss due to erosion. When rainwater is used to remove clay and organic matter, soil fertility decreases. (Shaheen et al., 2015)

2.7. Crop yield constraints in the rainfed area:

- Little investment in rain-fed agriculture
- Lack of policy support and infrastructure

  Including market and credit
- Traditional varieties
- Use less fertilizer
- Rainwater utilization efficiency is low
- Pests and diseases
- Compartment method
- Rainwater utilization efficiency is low
- Pests and diseases
- Compartment method

CHAPTER 3

3. MATERIALS AND METHOD

3.1. Study Area:

The Potohwar plateau is an area of gigantic and indo-gigantic synclinorium. The topography of this area differs from plain to mountainous. Potohwar is a semi-arid that comprising the districts of Punjab; Attock, Rawalpindi, Chakwal, and Jehlum showed in fig. 3.1 which is reproduced from PCRWR (Malik *et al*., 2019). This region is with an area of 28488.9 sq. Km. The height of this region is dynamic from sea level. The nature of the soil of this region is fertile and rich in nutrients, contains a low level of nitrogen and phosphorus but an acceptable level of potassium. (Arif et al., 2009)

The diverse range of flora and fauna is present here due to the dynamically merge of hills, plains, and climate (Arshad et al., 2014). According to the Soil Survey Report, rain is unpredictable. 60 to 70% rainfall occurs in mid-June to mid-September.

It is pertinent to mention that site selection, sampling, and soil physio-chemical analysis were conducted by the PCRWR team understudy " characterization Hydrology of the Eastern Rivers of the Indus Plain (Sutlej, Ravi, Jhelum, and Chenab)" as part of the umbrella project "Strategic Strengthening of Flood Warning and Management Capacity of Pakistan Phase II" completed in 2018 by Malik *et al*., 2019.

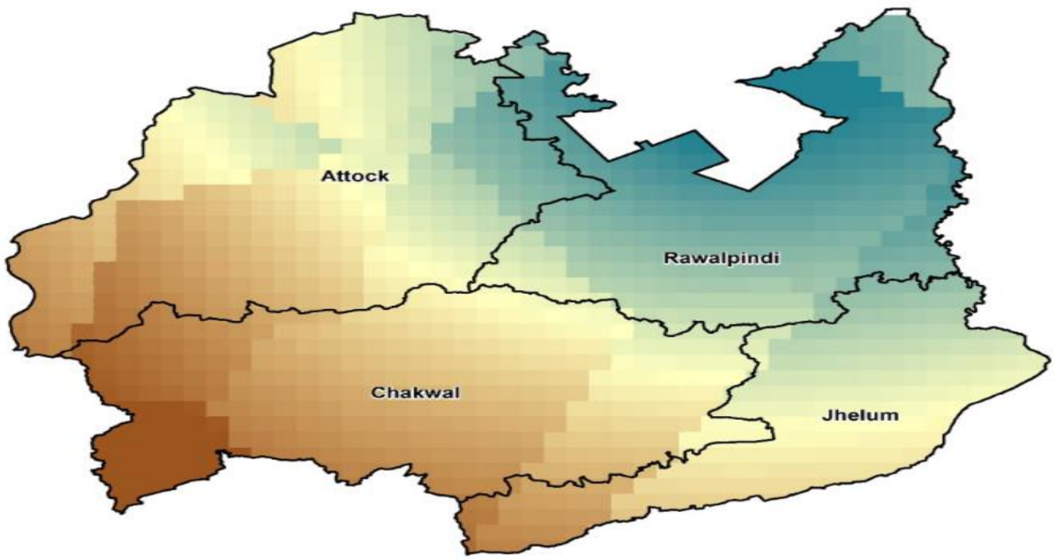

Figure 3.1: Map of Potohwar region, Pakistan

Sampling and analysis were done by PCRWR in their laboratories. For analysis which equipment and procedure were used as described below.

3.2. Methodology Layout:

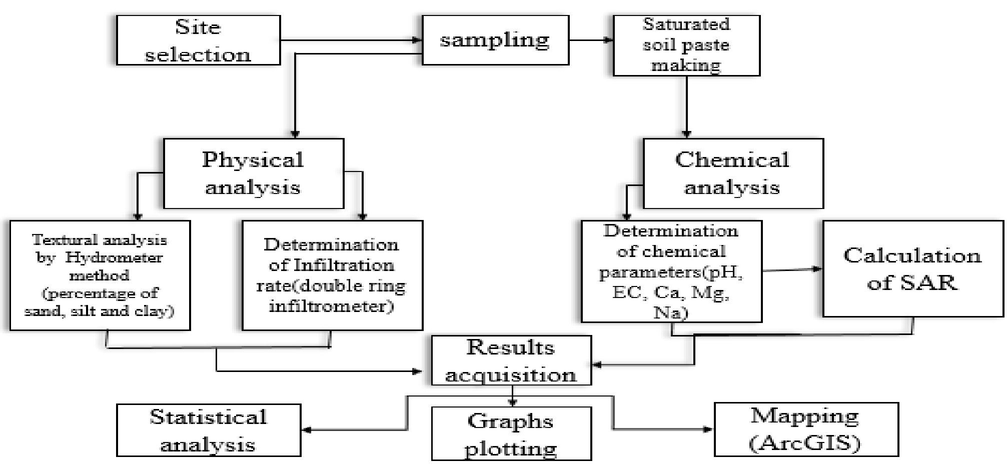

Figure 3.2: Layout of methodology

3.3. Site Description of Sample Potohwar Plateau:

For the study of soil in total 30 sites were selected for sampling in the Potohwar region by Malik *et al*., 2019 in PCRWR report. Which are shown in figure 3.3 and described in table 3.1.

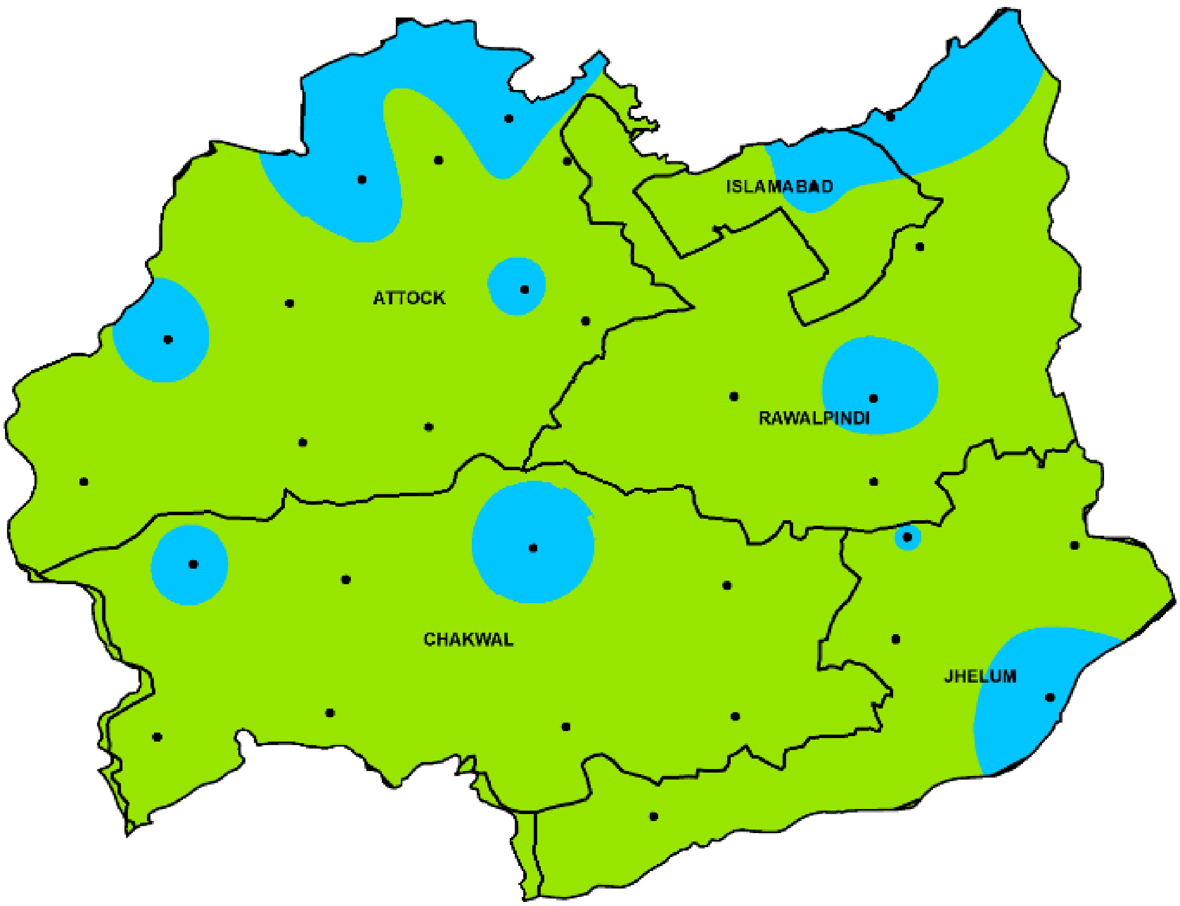

Figure 3.3: Sampling sites of Potohwar region

Table 3.1: Sample site description (*Malik et al.*, 2019) in report by PCRWR

Code	Geographic Coordinates		Altitude	Area
	Latitude	Longitude		
PTH-01	33.7477	72.7069	442	Brahma, Taxilla, Rawalpindi
PTH-02	33.8239	72.6039	390	Dhokhabdullah, Hasan abdal, Attock
PTH-03	33.3264	73.2508	516	Gulparah, Gujjar khan, Rawalpindi
PTH-04	33.7028	73.1453	532	Rawal lake, Islamabad
PTH-05	33.3299	73.0036	477	Mohra, Rawalpindi, Rawalpindi
PTH-06	33.5961	73.3339	549	Nathot, Kahuta, Rawalpindi
PTH-07	33.7497	72.4786	3349	Pin triar, Attock, Attock
PTH-08	33.5197	72.6319	465	Hastel, Fatheh jang, Attock
PTH-09	33.8258	73.2811	806	Salgran, Murree, Rawalpindi
PTH-10	33.7158	72.3428	311	Nakodar, Attock, Attock
PTH-11	33.2753	72.4614	431	Khaur, Pindigheb, Attock
PTH-12	33.4939	72.2144	357	Dhok chooi, Jand, Attock
PTH-13	33.4639	72.74	563	Khairee, Fateh jang, Attock
PTH-14	33.0661	73.6078	272	Sagri, Dina, Jhelum
PTH-15	32.8992	73.2903	400	Dhok fateh masti, Sohawa, Jhelum
PTH-16	33.0808	73.3106	489	Mian Mohra, Sohawa, Jhelum
PTH-17	32.7961	73.5647	221	Rasulnagar, Jhelum, Jhelum
PTH-18	32.5847	72.86	205	Saroba, Pindi gheb, Jhelum
PTH-19	33.0606	72.6467	439	Begal, Chakwal, Chakwal
PTH-20	32.7443	72.7048	730	Manak, Kalarkahar, Chakwal
PTH-21	33.0051	72.3143	383	Mogla, Talagang, Chakwal
PTH-22	32.7686	72.286	618	Thoa mehram khan, Talagang, Chakwal
PTH-23	32.7258	71.9794	424	Changa, Lawa, Chakwal
PTH-24	33.0326	72.0436	330	Khurd, Talagang, Chakwal
PTH-25	32.9949	72.9915	493	Bheen, Chakwal, Chakwal
PTH-26	33.1778	73.2518	480	Bhagwal, Gujjar khan, Rawalpindi
PTH-27	32.7616	73.0055	610	Dheri jaba, Choa saidan sha, Chakwal
PTH-28	33.2479	72.2372	304	Dhandi, Pindigheb, Attock
PTH-29	33.1782	71.8496	374	Nakka, Jand, Attock
PTH-30	33.4315	71.9986	351	Jand city, Jand, Attock

3.4. Sampling method:

Samples were taken by the team of PCRWR according to the sampling design by Malik *et al*., 2019. To collect samples of soil, undisturbed soil was taken from three layers i.e. top, middle, and bottom as shown in fig 3.2, by following these steps:

1. Used a steel tank with a diameter of 50 mm and a length of 30 mm to collect undisturbed soil samples from three layers (surface, middle, and bottom), as shown below:

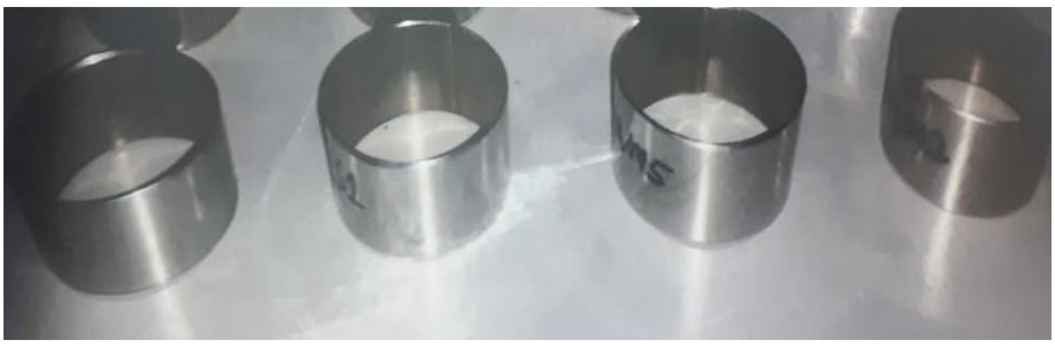

Figure 3.4: Picture courtesy by Malik *et al*., 2019 (PCRWR) Steel cans to collect an undisturbed soil sample

2. Cans were inserted in the soil surface with some force then pulled back.

3. Removed the extra soil from underneath. Separated the sample from the can and saved it in the packet.

4. Transferred to the laboratory and preserved as shown in fig 3.4.

5. For various types of analysis given in methodology, 7-8 samples were taken from each site.

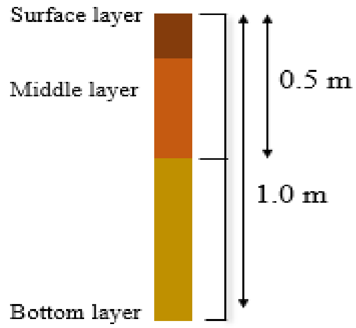

Figure 3.5: Depth of soil layers for sampling

Figure 3.6: Picture courtesy by Malik *et al*., 2019 (PCRWR) Soil sample storage racks

3.5. Physical analysis:

3.5.1. Soil texture:

Soil particles are of various sizes and the relative proportion of the sand, silt, and clay in the soil medium, collectively is called soil texture. These particles range from < 2mm to 2 mm but bigger than this size are not considered as soil particles and are categorized in

Table 3.2. There are different textural classes according to the particle sizes of the soil.

Table 3.2: Soil types with their particle size

Name of Particle	Particle Diameter
Clay	Below 0.002 mm
Silt	0.002 to 0.05 mm
Sand	0.10 to 0.25 mm

Soil texture is the basic physical feature of the soil such as the pore size, total surface area, and soil structure which is formed by particles sticking together thus forming aggregates. All physical and chemical process takes place on the surface of the soil particles. Ion exchange is the most important one, among all these physio-chemical processes.

3.5.1.1. Textural analysis by hydrometer method:

For determination of the texture of the soil (sand, silt, and clay) the trustworthy method is the hydrometer method which was selected and done by PCRWR report. Its procedure works according to Stoke's law and sedimentation of the suspended particles. To disperse the aggregates and complexes we use calcium hexametaphosphate as an agent in which sodium ion acts as adsorbed flocculating cations in the soil-water. The diffused layer of saturated with sodium ion works as individual particles in suspension and the size of their particles determines their settlement rate. The theory of Stoke's law which forms its basis is explained below:

3.5.1.2. Theory of mechanical analysis:

Sizes of the soil particles influence the settlement of the particles suspended in the solution. Settlement occurs faster when the size of the particles is large. Because the particle becomes heavy its density becomes more than of water so it goes down in the bottom surface of the water body faster. For the determination of the settling time of soil particles hydrometer was used and stirring the soil suspension purpose plunger was used as shown in figure 3.5. Calculations have been done with the following formula of stock's law.

The setting rate is given by stoke's law:

$$V = \frac{2 (\rho_s - \rho_w) g r^2}{9 \eta}$$

Where:

v = settling velocity (cm/s)

ρ_s = particle density (gm/cm^3)

ρ_w = water density (gm/cm^3)

g = acceleration due to gravity(cm/s^2)

r = the radius of particle(cm)

η = water viscosity (gm/cm.s)

The Time required for the settling can be determined by the velocity with which soil particle is going towards the bottom. In the same manner, substituting the appropriate values in Stoke's law equation creates the range of time like 40 seconds for very fine sand particles while 2 hours for silt. So, if the soil sample completely and appropriately distributes in the water and agitated then sand, silt, and clay uniformly divided at the start of the time, for the settlement of clay and silt in the 10 cm depth only 40 minutes were required, as by that time and sand would have settled. In the same manner, a sample took 2 hours for only clay particles.

A hydrometer determines the density of the soil suspension, calibrated to read in grams of solids per liter when the sand and silt settles down (shown in figure 3.4).

Figure 3.7: Hydrometer used for determination of soil texture in suspended medium

The rate of sedimentation is affected by concentration and temperature. Incomplete dispersion of the clay soil is the main error in this procedure because this is bounded with the various types of organic matter and chemical agents. The hydrometer is calibrated in grams per liter on 68^{o} F, for the determination of the particle size distribution. The hydrometer readings were taken of soil solution in 1000 ml glass cylinder maintained at 68^{o} F, after this purpose cylinders were fixed in the circulating bath for safety purposes and maintaining the temperature. Plunger was mage according to the design by Malik *et al*., 2019.

Figure 3.8: Picture courtesy by Malik *et al*., 2019 (PCRWR) Controlled length plunger compatible with the standard cylinder for stirring the soil suspension

Calculated the percentage of clay, silt, and sand with the formulas as following:

(silt + clay) % = [DC (40)/DS] ×100

Clay % = [DC (20)/DS] ×100

Silt % = (silt +clay) % - (clay)%

Sand %= 100 - (silt +clay) %

(DC = zero error correction, DS = temperature error correction)

3.5.1.3. Determination of the textural class of soil:

Soil is categorized based on the percentage of sand, silt, and clay. The soil has designated the sand if it comprises 85% of the sand size particles but if it contains just 40% of the clay-size particles it would refer to clay soil. Loam soil having a more or less equal proportion of sand and silt but slightly more than clay. The USDA textural triangle contains twelve textural classes, each of which can comprise various combinations of sand, silt, and clay. Each leg of the triangle represents sand, silt, or clay and is divided into a percentage from 0 to 100%. Different percentages of three types of the soil always would be results in 100. To determine the textural class of the soil based on the mechanical analysis procedure given in "identification of class on USDA soil texture classification triangle" was followed.

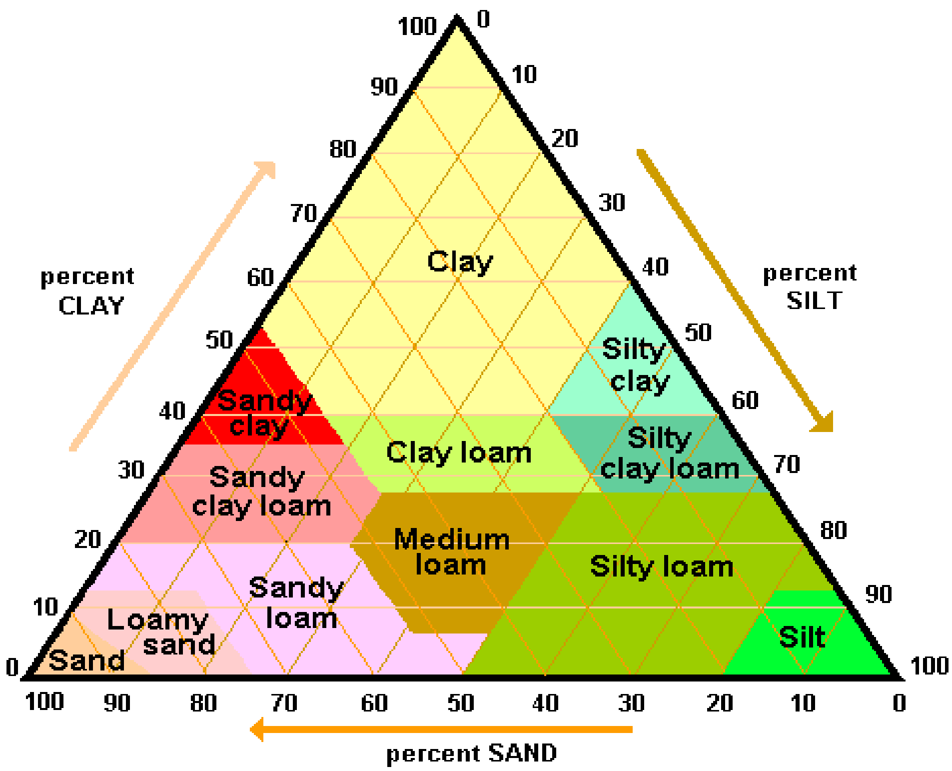

Figure 3.9: Identification of class on USDA soil textural classification triangle

3.5.2. Infiltration rate:

There are many methods for measuring permeability, such as single-ring infiltrometer and double-ring infiltrometer. The double ring infiltrometer is more feasible. Used to determine the permeability. The schematic diagram of the double ring infiltrometer is shown in Figure 3.7. It consists of two metallic cylindrical rings with a setup for determining water infiltration in the inner ring.

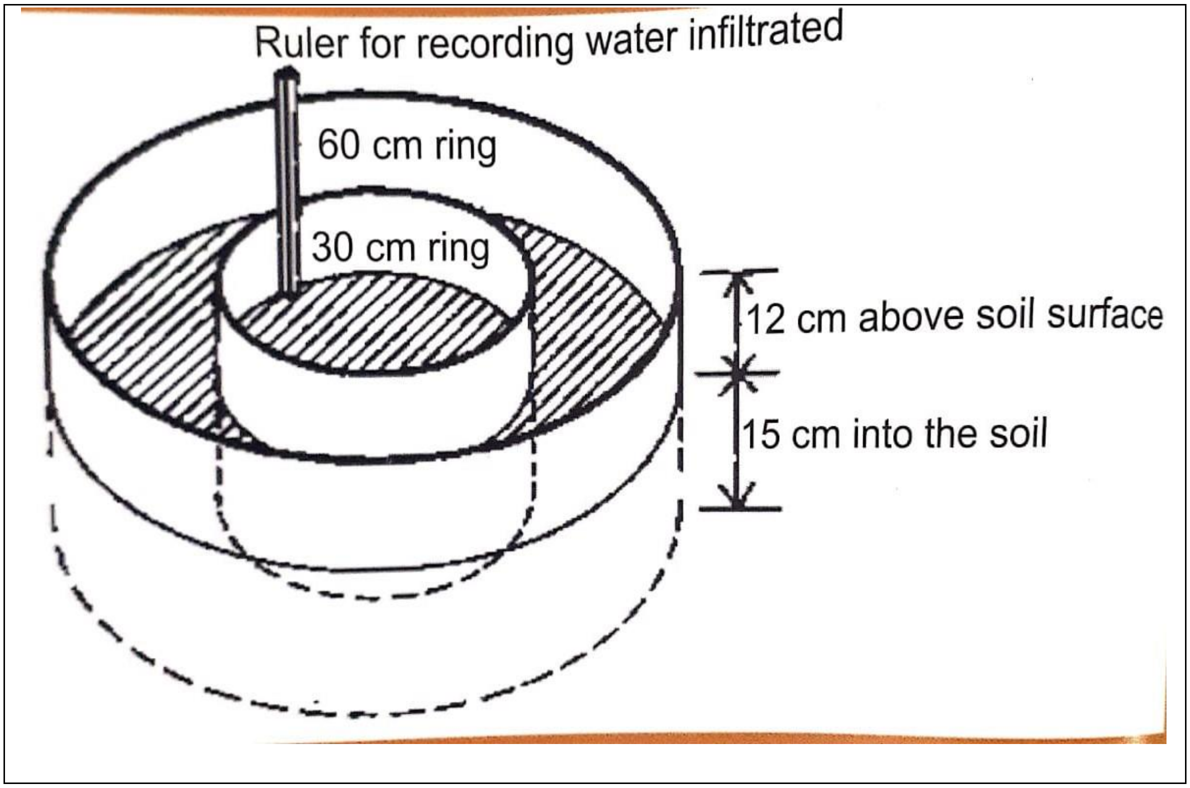

Figure 3.10: Procedure for measuring infiltration rate

3.5.2.1. Equipment required:

Double ring infiltrometer, shovel, hammer (2-4 kg), cross frame for hammering the ring, jute cloth (30 cm diameter piece), stopwatch, 1liter graduated measuring cylinder, bucket for water, and at least 100 liters of water in a container.

1. Selected a smooth surface.
2. Drove 15 cm of the outer ring into the soil avoiding the cracks.
3. Drove the inner ring in the same manner by making both rings concentric and leveled.
4. Before filling the inner ring filled the out ring to the depth of 10 cm.
5. Then filled the inner ring to the depth of 10 cm retained the same water level in both rings by using a hooked bar setup. Shown in Figure 3.8

Figure 3.11: Picture courtesy by Malik *et al*., 2019 (PCRWR) An angle with steel bar provided with steel hooks and a spirit level for leveling the infiltration rings and maintaining water depth

6. Started taking readings at proper intervals.
7. Made the water level the same in both rings inner and outer.
8. Find out the volume of water infiltered at the proper time intervals about 3-4 hours and saved data.
9. Determined the depth of water infiltrated.
10. Determined the cumulative infiltration depth at the end of each time step.

11. Fitted the data by optimizing the parameters S and A by the following equation:

    $I\ (t) = St^{1/2} + At$

    Where,

    $I(t)$= cumulative infiltration

    t= sorptivity (mm.min$^{-1/2}$), a measure of capillary adsorption capacity of the porous medium

    A= constant parameter

12. After fitting the curve, determined the parameters S and A by the following equation,

    $i(t) = ½\ St^{-1/2} + A$

    Where i(t) is infiltration rate (mm/min)

3.5.3. Moisture content:

Before taking the soil in a china dish. It was dried in the oven to avoid any moisture content in its porcelain. After this, weighed it. Then took 10 g of dried soil in a china dish. Then dried it in the oven at 105^{o}C for 24 hours as shown in figure 3.9. After this cooled it in a desiccator for 30 minutes then reweighed it (Eaton et al., 2005). Moisture content was determined by the following equation:

Moisture content (%) = (W1-W2/W1) × 100

Where,

W1= wet weight

W2= dry weight

Figure 3.12: Picture courtesy by Malik *et al*., 2019 (PCRWR) Samples in oven

3.6. Chemical analysis:

3.6.1. Saturated soil paste:

Saturated soil paste was made with a standard method. Took 300-400 g soil air-dried and passed it through the 2 mm sieve. Added deionized water in sieved stirred the soil until it's surface shiny and soil paste became nonstick to the spatula. Paste left for 2-3 hours and rechecked. Then filtered this paste with filter paper. Used that extract for the determination of different parameters.

3.6.2. Parameters:

1**.**Total dissolved solids (TDS)

2**.**Electrical conductivity (EC)

3. pH

4. Calcium (Ca),

5. Magnesium (Mg)

6. Sodium (Na)

3.6.3. Total dissolved solids:

Total dissolved solids were determined by the TDS meter with the standards procedures given in the National Water Quality Laboratory, Pakistan Council of Research on Water Resources.

Procedure:

- Took a saturated extract of the soil in the beaker.
- Wrote the sample number on the beaker for identification.
- Calibrated the meter with standard and run that sample on HACH TDS meter.
- Noted that reading.

Figure 3.13: Picture courtesy by PCRWR lab: Total dissolved solids meter

3.6.4. Electrical conductivity:

EC is measured by a conductivity meter. The procedure was followed according to the National Water Quality Laboratory, Pakistan Council of Research on Water Resources.

Procedure:

- Plugged in the power supply to EC meter.
- Washed glassware and electrode properly to avoid contamination.
- Calibrated EC meter (JENWAY) with a standard sample (1413 µS/cm).
- Poured 50 ml of sample in a beaker and dipped the electrode in it.
- When the value becomes stable recorded it.
- Removed the electrode and dipped it into deionized water.

FORMULA:

EC = TDS/10

TDS = total dissolved solids

Figure 3.14: Picture courtesy by PCRWR lab: Electrical conductivity meter

3.6.5. pH:

The negative log of hydrogen ion Is called pH. These values were determined by the pH meter. The procedure was followed was according to the National Water Quality Laboratory, Pakistan Council of Research on Water Resources.

Procedure:

- put the pH meter on the solid surface which was free of air currents and vibration.
- Plugged in AC power supply
- Washed glassware and electrode properly to avoid contamination.
- Calibrated the pH meter (HANNA) of known pH.
- Poured 50 ml of sample in a beaker and dipped the electrode in it.
- When the value becomes stable recorded it.
- Removed the electrode and dipped it into deionized water.

Figure 3.15: Picture courtesy by PCRWR lab: pH meter

3.6.6. Calcium (Ca) and Magnesium (Mg):

Soluble calcium and magnesium were determined from the extract of the soil with the method of titration with EDTA. These reagents were used:

a. Buffer solution (NH_4Cl-NH_4OH)
b. Eriochrome black indicator
c. Ethylene Diaminetetraacetic (EDTA)≈0.01 N,
d. Sodium hydroxide solution (NaOH)
e. 2N, Ammonium purpurate indicator ($C_8H_8N_6O_6$)
f. Standard stock calcium chloride solution ($CaCl_2.2H_2O$), 0.01N

The standard procedure was used for the analysis of calcium and magnesium concentration. Calculations were done with the following formula:

Ca or Ca+Mg (meq/l)=(V-B)× N×R×1000/Wt

Mg(meq/l)= Ca+Mg (meq/l)-Ca(meq/l)

For soluble calcium or magnesium in soil:

Where the volume of EDTA titrated for the sample (mL)

B= Blank titration volume (mL)

R= Ratio between the total volume of the extract and extract volume used for titration

N= Normality of EDTA solution

Wt= Weight of the air-dry soil

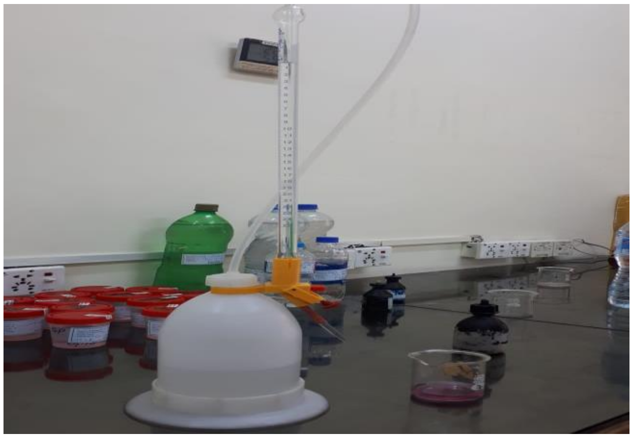

Figure 3.16: Picture courtesy by PCRWR lab: Titration with EDTA for the determination of Ca and Mg

3.6.7. Sodium:

Flame photometer (Digiflame) was used for the detection of sodium according to its principle. Took the sample, run it on the flame photometer, noted the results.

Figure 3.17: Picture courtesy by PCRWR lab: Flame photometer

3.6.8. Sodium adsorption ratio:

Sodium adsorption ratio was measured with the help of values of Na, Ca, and Mg according to the following formula:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

3.7. Organic matter:

By the ignition method, organic matter of soil and mulch was determined (Nikolski et al., 1963). Before taking soil in the china dish, it was dried to remove moisture content that was already present in its porcelain and weighed it. Then took 10 g of dried soil in a china dish. Put the sample in the muffle furnace at the temperature of 365^{o}C. After this removed the sample from here and cooled it in the desiccator for 30 minutes and reweighed it.

3.8. Mapping with ArcGIS:

Remote sensing is used to detect, collect, and interpret distance data through sensors (Al-khaier, 2003). Maps of the study area were reproduced from data of PCRWR report with the reference of Malik *et al*., 2019 by the software ArcGIS, with standards procedure step were as following:

1. Imported latitude/longitude data in ArcGIS
2. Generated interpolated surface using IDW from the toolset

3. Applied the (relevant) criteria in the symbology of the generated layer by creating several classes based on their values
4. Based on the criteria, assigned labels, and colors in the symbology layer
5. Named point of the samples collected in the attribute table
6. Switched to the layout view to generate a map along with the addition of titles, legend and other map elements

Chapter **4**

4. RESULTS AND DISCUSSION

The crop yield and vegetation of the area depend on the soil conditions such as its salinity, nutrient contents, organic matter, infiltration rate, and hydrodynamics. All these characteristics of the soil are due to geography and atmospheric conditions. These properties of the soil are defined by the long era and weathering processes. Anthropogenic activities also affect but in minor proportion. In this study, it is concluded that the Potohwar region has different soil properties in different parts.

4.1. Geography of Potohwar region:

The Potohwar plateau covers an area of about 28488.9 sq. Km. Crop yields in the Potohwar plateau are low as compared to irrigated regions. Maize, sorghum, and millet are grown in winters. Rainfall is highly undistributed and uneven, and the area is under erosion effect as shown in figure 4.1 (Shaheen, 2016).

Figure 4.1: Soil Erosion

The soils of this tract are low in natural fertility, deficient in nitrogen and phosphorous, however, potassium level is adequate. Similarly, the soils are also low in organic matter and having a pH of 7.5 to 8.5. Rainfall is irregular and varies greatly from 1000 mm in

the north-east to 250 mm in the south-west part of the region. More than 70% of annual precipitation falls in the summer months.(Arif & Malik, 2009b)

4.2. Parameters:

Descriptive statistical parameters (mean, median, mode, minimum, maximum, and standard deviation) for pH, EC, SAR, Fc, organic matter, and bulk density of four districts of the Potohwar region (Rawalpindi, Chakwal, Attock, and Jhelum) is summarized.

4.3. VARIATION IN PARAMETERS:

4.3.1. Physical parameter:

4.3.1.1. Soil texture:

Figure 4.2 gives the percentage distribution of different soil classes in the surface, 0.5 m, and 1.0 m depth in the Potohwar region. The sandy loam, loam, and silt loam are the dominant soil classes in the region. However, coverage of the sandy loam decreases with the increase with the sol depth. One of the reasons is the washing down of fine soil particles with rainfall seepage. Furthermore, soil erosion and deposition are more dominant in the slope lands. In erosion and deposition, fine particles are dislodged first and deposited in the depressions earlier than coarse particles. In addition to that fine particles are dislodged with light and as well as heavy rainfall while coarse particles get eroded just with the heavy rainfall light one does not affect them significantly. Therefore, the deposition and dislodged of the fine particles in the depression are underneath the coarse particles enhances the dominance of the coarse particles in the surface and the fine particles I the middle and the bottom layer. Especially in the deep lands. This dominance further prevails when stirring is least and the area is uncultivated. That makes the admixture of soil classes more diversified in this region.

Table 4.1 and pie graphs (figure 4.1) are showing the total percentage of the soil type in the region. Which is depicting that sandy loam is prevailing and in high percentage in all the layers. After that loam coming with the second most existing soil in the region. And then the presence of soil type on the third number is silt loam. The reason of this percentage has discussed above.

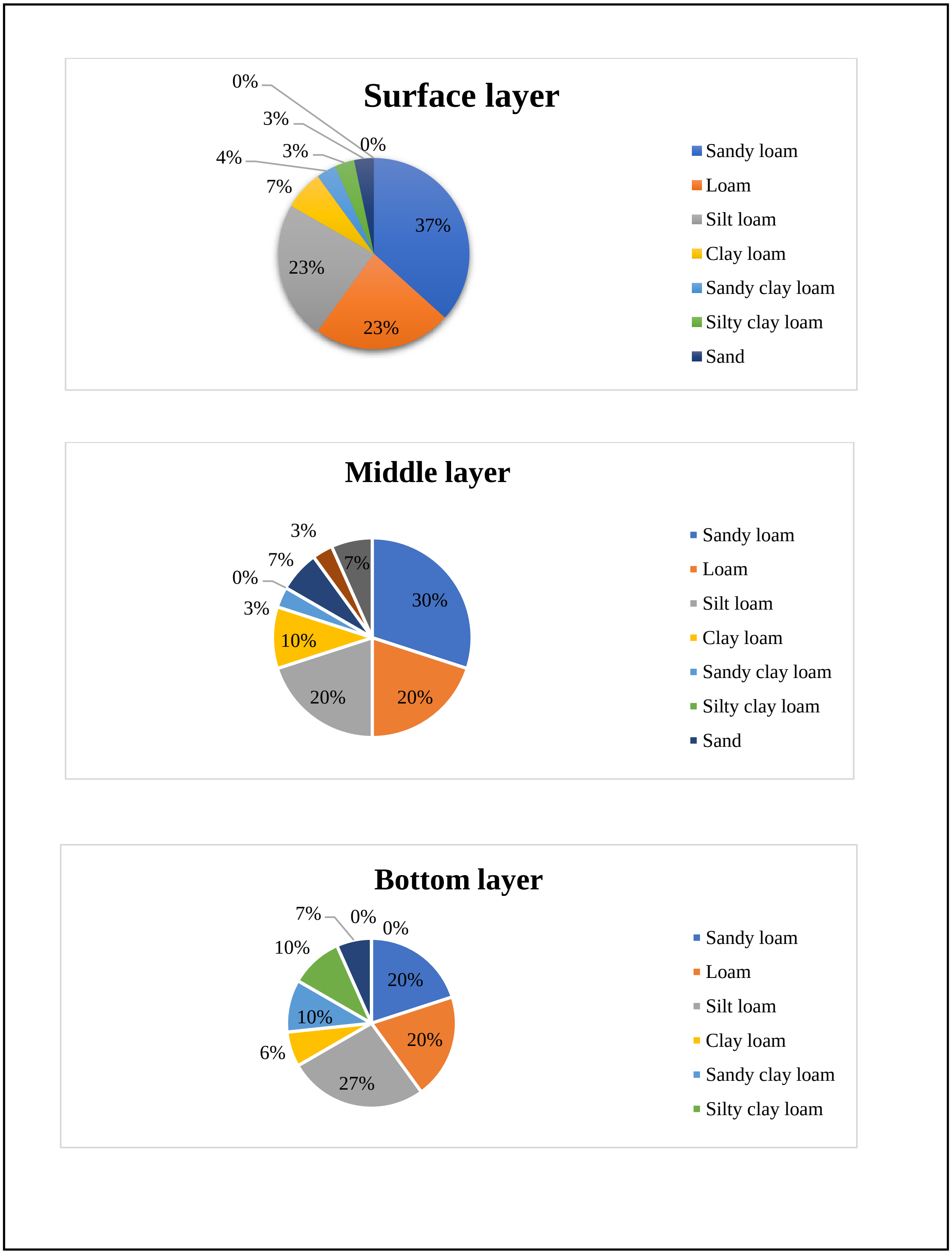

Figure 4.2: Picture courtesy by PCRWR report: Percentage of soil type in Potohwar region

Soil type	**Layers**		
	Surface	**Middle**	**Bottom**
Sandy loam	11	9	6
Loam	7	6	6
Silt loam	7	6	8
Clay loam	2	3	2
Sandy clay loam	1	1	3
Silty clay loam	1	0	3
Sand	1	2	2
Sandy clay	0	1	0
Clay	0	2	0
Total	30	30	30

Table 4.1: Soil type percentage

4.3.1.2. Organic matter:

The organic matter directly affects soil infiltration and soil moisture retention characteristics. Figure 4.3 shows spatial and up to 1.0 m depth distribution of organic matter in the Potohwar region while table 4.2 shows the percentage of values of the Potohwar region having different values of the organic matter (%). The percentage values vary from 0.2 to 2.5 %. The highest organic matter is in the surface layer at the Himalayan piedmont where rainfall and vegetation cover are normally higher than the other areas. Qureshi et al., (2000) found an organic matter of 0.25%-0.8% in the tehsil Gujar khan area. The organic matter also decreases with depth. The lowest organic matter both at the surface and up to 1.0 m depth is in the southwest region, where vegetation is sparse owing to low rainfall. Organic matter in the deep soil is only due to the decay of plant roots. Therefore, organic matter decreases with the depth and that trend prevails over the entire region.

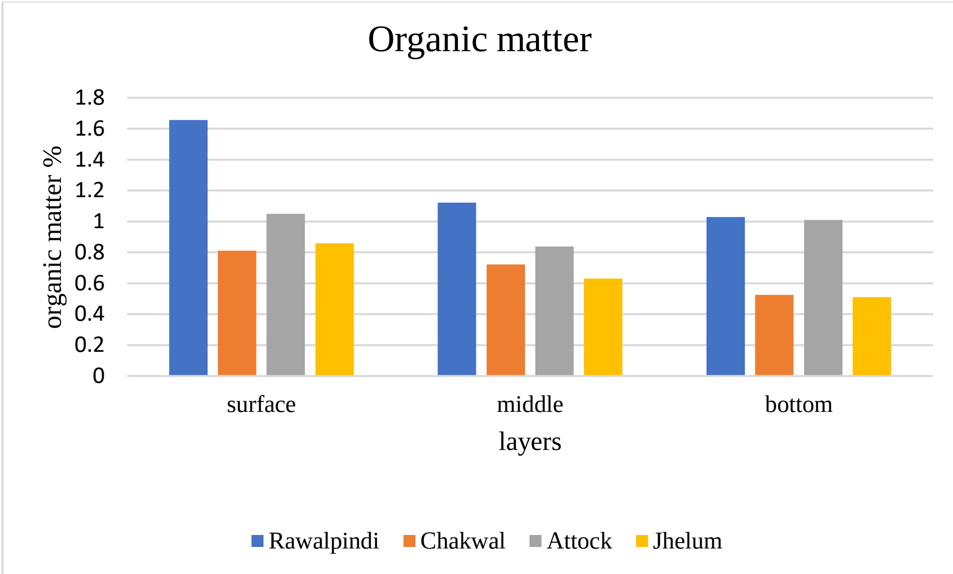

Figure 4.3: Percentage of average organic matter in Potohwar region

Organic matter classes (%)	Percent area		
	Surface layer	**Middle layer**	**Bottom layer**
0.2 to 0.5	2.8	4.7	15.8
0.5 to 0.75	15.1	23.9	36.5
0.75 to 1.0	21.2	49.3	37.1
1.0 to 1.5	42.8	21.5	10.6
1.5 to 2.0	15.8	0.6	0.1
2.0 to 2.5	2.4	0	0
Total	**100**	**100**	**100**

Table 4.2: Percentage of organic matter with percentage area

Statistical table 4.3 shows that the organic matter present is high in the Rawalpindi and Attock region. While in the Chakwal and Jhelum organic matter contents are comparatively lower than both earlier mentioned districts. The reason that anthropogenic activities like cropping and cultivation are high in these areas rather than the other ones, due to the presence of salinity patches and salt range. Due to the cultivation application of fertilizers and green manure is done which results in the richness of the organic matter.

Parameter	Districts	Layers	Mean	Median	Min.	Max.	StDev.
Organic Matter	Rawalpindi	Surface	1.656667	1.605	0.5	2.64	0.697558
		Middle	1.121667	1.145	0.52	1.88	0.555785
		Bottom	1.028333	1.02	0.61	1.52	0.376957
	Attock	Surface	1.049	1.049	0.2	2.62	0.663517
		Middle	0.839	0.935	0.19	1.08	0.315505
		Bottom	1.01	0.82	0.3	2.92	0.885904
	Chakwal	Surface	0.811111	0.51	0.33	1.44	0.47517
		Middle	0.722222	0.68	0.34	1.29	0.31519
		Bottom	0.524444	0.38	0.19	0.93	0.280941
	Jhelum	Surface	0.858	0.76	0.56	1.3	0.298362
		Middle	0.63	0.65	0.3	0.97	0.248697
		Bottom	0.51	0.57	0.18	0.66	0.193261

Table 4.3: Statistical analysis of organic matter in Potohwar region

4.3.1.3. Infiltration rate:

Percent area of fc value										
Fc class	≤15	**>15-30**	**>30-45**	**>45-60**	**>60-90**	**>90-120**	**>120-150**	**>150-180**	**>180-210**	**>210-315**
Surface	17.8	31	37	8	6	1	0	–	–	–
Middle	7.9	24	33	14	10	5	2	1	1	1
Bottom	17.6	44	20	9	5	3	1	1	0	–

Table 4.4: Percentage area of infiltration rate

In the statistical analysis in table 4.5, it is shown that the infiltration rate is lower in the Rawalpindi district while other districts having a high infiltration rate. The reason for this pattern is that the Rawalpindi area has clayey soil. As discussed above clayey soil is made up of small particles, which have very minute distance among them. This distance allows just a smaller amount of water to pass. In comparison with sandy or silty soil particle size is bigger with wide distance among them. From this distance, water can pass easily. So, the area has this type of soil texture also has a high infiltration rate.

Parameters	Districts	Layers	Mean	Median	Min.	Max.	StDev.
Fc	Rawalpindi	Surface	16.48	4.735	1.321	68.106	25.7
		Middle	32.08	19.0392	3.777	69.94	24.62
		Bottom	18.69	12.0225	0.5791	50.72	17.75
	Attock	Surface	36.37	16.703	0.2191	129.85	44.98
		Middle	71.9	21.0065	0.8534	312.114	106.79
		Bottom	50.17	16.493	0.1143	194.13	67.69
	Chakwal	Surface	32.17	21.9	4.2877	91.82	28.75
		Middle	36.48	16.47	0.6314	103.369	39.97
		Bottom	24.35	16.23	0.0001	61.98	23.27
	Jhelum	Surface	36.33	42.535	14.5	61.148	19.81
		Middle	31.99	27.343	6.0629	59.56	22.56
		Bottom	28.32	17.85	3.86	73.32	26.84

Table 4.5: Statistical analysis of Infiltration rate

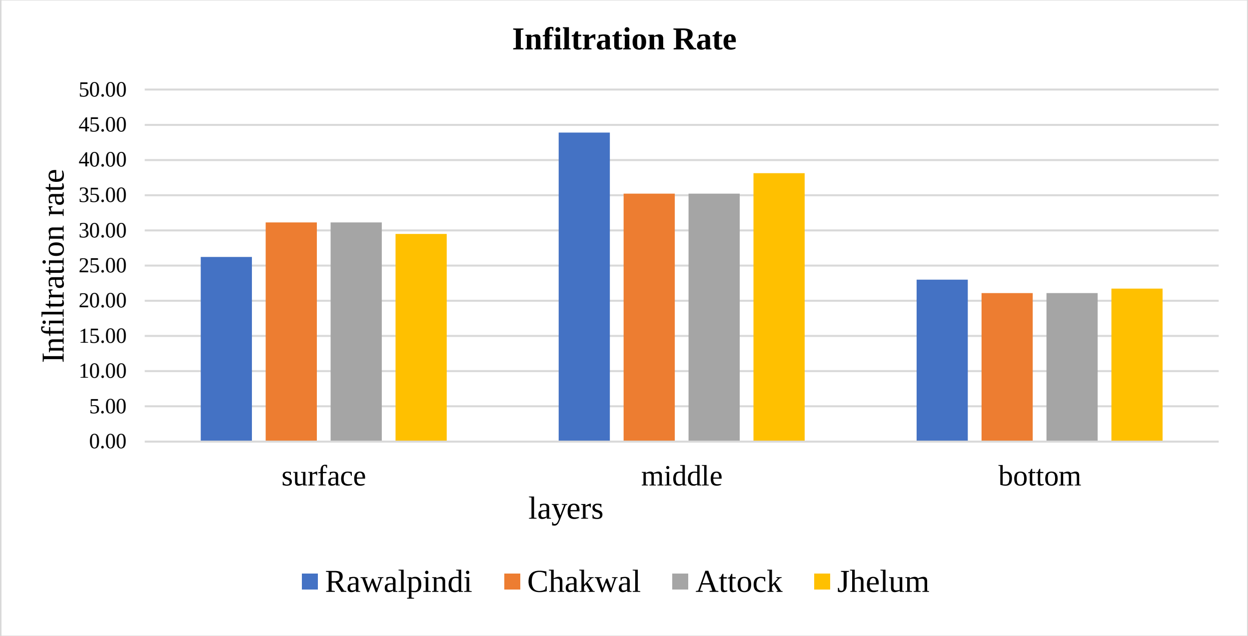

Figure 4.4: Graph of average values of infiltration rate

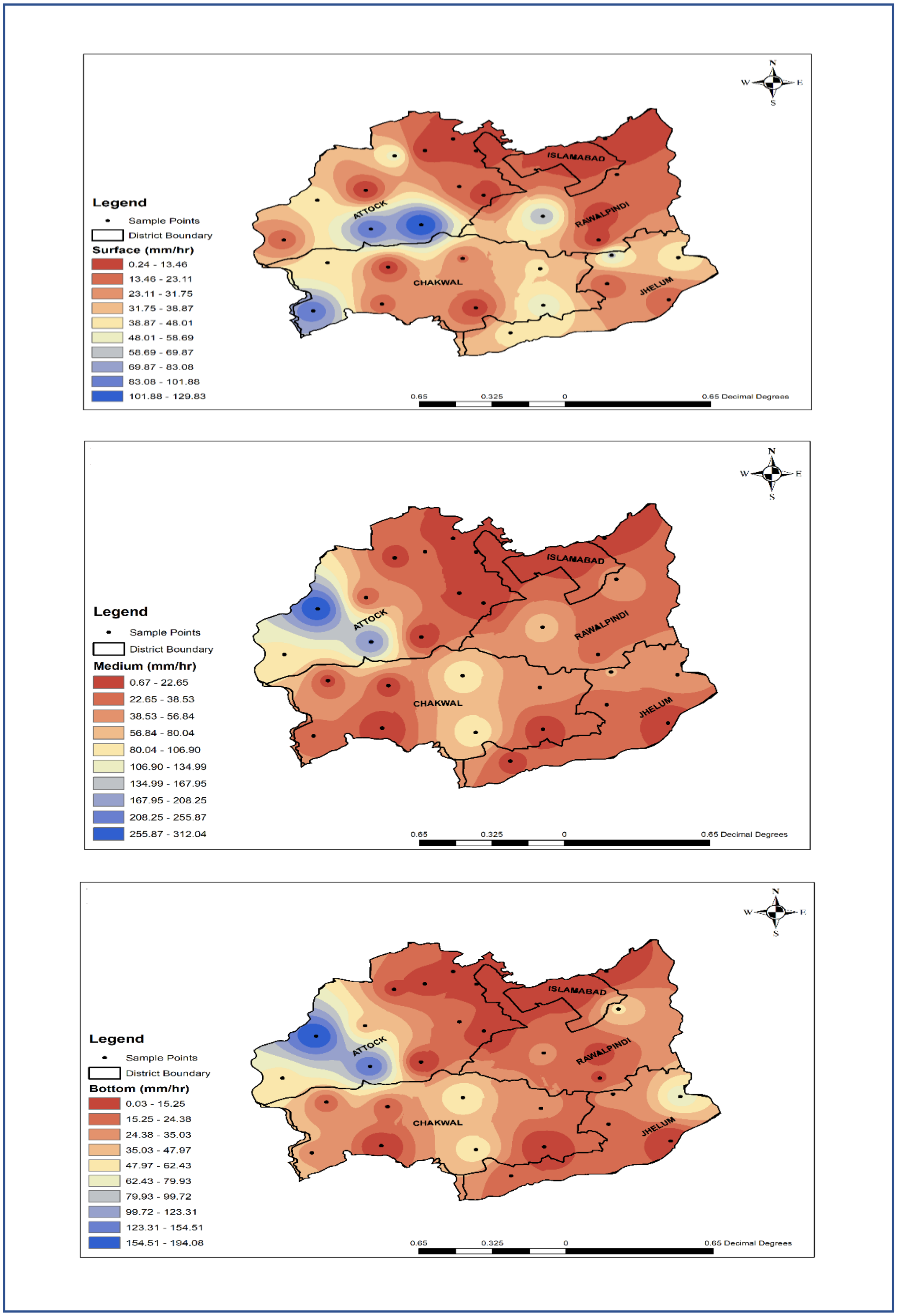

Figure 4.5: Picture courtesy by PCRWR report**:** Maps of infiltration rate of three layers

4.3.2. Chemical parameters:

4.3.2.1. Electrical conductivity:

In table 4.1 there is the electrical conductivity of all the four districts along with their different layers, which are depicting that there is no significant difference within layers but showing significant difference among districts of the Potohwar region. Because the electrical conductivity is mainly the number of salts present in the soil and salts are the combinations of cations and anions, so the presence of Mg, Na, and Ca indicates the EC of soil.(*Manzoor Ahmad Malik Muhammad Ashraf Islamabad - Pakistan*, n.d.) The outlier value of EC of the surface layer in the Rawalpindi district is due to any human activity that occurred just before the sampling. According to the US standards when the EC value is <4 dS/m the soil is considered normal but when it exceeds 4 dS/m then the soil is counted as saline of various degrees. The soil having the values of SAR greater than 13 along with the pH value of >8.5 is referred to as sodic soil. Soils possibly are saline, sodic or saline-sodic. It is not necessary that saline soil should the sodic at the same time. In the past the word sodic soil and alkali were confused. However, the sodic term is used when the sodium amount is high in the soil whereas the pH value may be high with or without high sodium content. In simple words, a soil having high sodium contents may also have pH>8.5 but it is not compulsory that soil with high pH should have high sodium contents. The soil having pH>8.5 without the value of SAR more than the permissible limit is called as alkali. (*ASAChap_RashidetalDrylandAgri2004.pdf*, n.d.). However, the soil which has SAR less than 13 but high Mg contents can have serious concerns.

Mapping of the EC values of soil samples taken from the surface, 0.5 m, and 1.0 m depth in the Potohwar region are given in figure 4.5. EC values of soil fall below 2 dS/m in most of the areas and within the permissible values in the entire area except at a few patches. The site of the EC value of the highest range (>8 dS/m) is in Rawalpindi districts. Some area of the Chakwal falls in the region of the appreciable rain above 600 mm. Therefore, the spot values of the salinity might be results of the saline seep. So, the spots which are showing salinity may be in the results of the saline seep. Saline spots due to saline seep develop on undulating soil where shallow permeable soil is underlain by impermeable rocks. The horizontal movement if infiltrated water under such conditions remains dominant due to the impeding layer underneath. The horizontal movement of the water carries soluble salts from upslope towards depressions. Water evaporates from the depression and saline spots are formed (Miller at al., 1981). This phenomenon may be seen on a large scale as well as a smaller scale. Potohwar is prone to saline seep spots owing to its peculiar topography, and shallow soils.

However, EC values 4 dS/m in the Attock area are quite possible owing to the barren tract falling out of the monsoon belt. On the overall basis, EC values are well with admissible range and decrease with an increase in depth to 1.0 m especially in the Gujjar khan area, which is supported by the results presented (Shaheen, 2016).

The area of the Rawalpindi district is depicting high mean values of the different layers as compared to the other districts and Attock is on the second number. The Chakwal and Jhelum districts are showing in table 4.6, not a significant difference.

Parameters	Districts	Layers	Mean	Median	Min.	Max.	StDev.
EC	Rawalpindi	Surface	242.33	1454	27.6	1060	411.83
		Middle	41.616	26.1	18.9	126.6	41.815
		Bottom	29.233	26.75	18.4	43.7	9.6787
	Attock	Surface	96.19	54.3	20.9	284	93.007
		Middle	120.02	58.5	18	445	158.64
		Bottom	68.77	30.9	17.1	392	114.45
	Chakwal	Surface	62.188	36.7	17.4	260	76.472
		Middle	40.733	29.3	17	86.7	43.783
		Bottom	31.033	26	13	86.7	23.365
	Jhelum	Surface	45.88	32.6	18.3	89.5	30.180
		Middle	68.12	32.1	13.3	139.7	65.178
		Bottom	81.14	49	15.8	185.5	75.853

Table 4.6: Statistical analysis of electrical conductivity

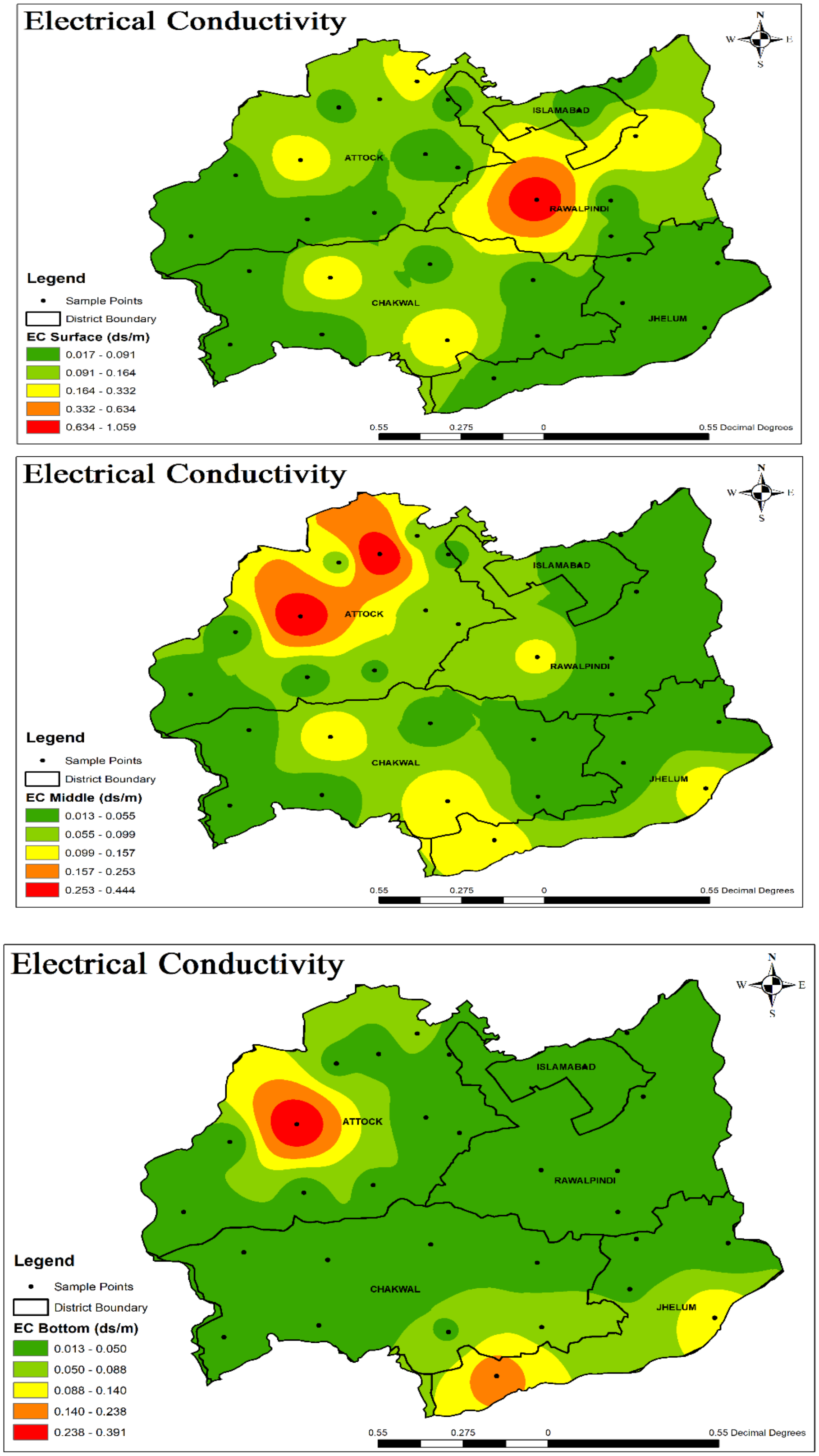

Figure 4.6: Picture courtesy by PCRWR report**:** Maps of EC distribution in Potohwar region

4.3.2.2. Sodium absorption ratio and pH:

Sodium absorption ratio for surface, middle (0.5 m), and bottom (1.0 m) layers were done in the study. SAR values are not in the admissible range of 13 except in patches as was the case with EC. The statistical analysis has shown in table 4.7 (b).

The intensive presence of sodium ion in the soil leads towards extreme destructive conditions in the crop plants like as toxicity in the cellular metabolism (Jaleel, Sankar, Sridharan, & Panneerselvam, 2008) but in general, there is no sodicity hazard in the Potohwar region, but salinity exists in patches due to apparent reason of saline seep. Saline seepage is an accumulation in low-lying areas impeded by the impermissible layer may be a peculiar phenomenon in Potohwar where land is highly undulated, dissected, and outcropped. Such a phenomenon is more dominant in shallow and permeable soils falling in appreciable rainfall area, fallow soils, and the soil that have been overgrazed, deforested, or devoid of vegetation (Abrole et al., 1988). since Potohwar is a rainfed area, secondary salinization is due to the brackish irrigation water is not expected. The main sources of salts in such soil are due to the constitute minerals, which undergo series of changes involving weathering, oxidation, hydration, hydrolysis, and carbonation, etc. that make the salt soluble thereby making them available for transportation with water (Abrole et al., 1988). In Potohwar, soils are least weathered or least developed and therefore salinity and sodicity hazard is seldom found. None of the surveyed sites fall near Kallar Kahar lake which serves as a closed basin where salinity level could be more than elsewhere due to the washing of salts with runoff from upslopes. ("Impact of Land-use Practices on Sediment Yield in the Dhrabi Watershed of Pakistan," 2012)

Although salinity is sparse and sodicity is almost non-existence in the Potohwar region, pH mapping figure 4.7 shows that casually goes beyond 8.4 in all the three layers. Sodic soils are supposed to have a higher value of pH are not necessarily sodic but are called alkali soils (Reed and Sorenson, 1997). Site 17 located near Khurd, on Pind Dadan Khan-Jhelum road has a persistently higher value of the pH in the middle and bottom layers, whereas the same sites are showing the higher values of SAR with depth and exceeded beyond the admissible range in the bottom layer. Being in the salt range, this area has an inherent tendency of sodicity owing to its parent material and therefore, has higher values f SAR and pH. It is pertinent to mention that in this study the carbonate was persistently below the detection limit (5ppm) at almost all the sites and therefore Residual sodium carbonate (RSC) remained undetermined, as the resulting value was negative.

It can be safely concluded that no appreciable salinity is present in the Potohwar region except for some patches.

The statistical tables of pH table 4.7 (a) show that the maximum values of the pH are around 8.5 in each layer of all the districts.

Parameter	Districts	Layers	Mean	Median	Min.	Max.	StDev.
pH	Rawalpindi	Surface	7.956667	8.095	7.05	8.44	0.480028
		Middle	7.82	7.59	7.44	8.41	0.460391
		Bottom	7.936667	7.965	7.42	8.32	0.302699
	Attock	Surface	7.902	7.855	7.4	8.65	0.384586
		Middle	7.937	7.895	7.59	8.53	0.292539
		Bottom	7.849	7.93	7.24	8.6	0.385471
	Chakwal	Surface	7.825556	7.8	7.31	8.6	0.402061
		Middle	7.842222	7.85	7.42	8.28	0.283451
		Bottom	7.875556	7.94	7.17	8.5	0.383116
	Jhelum	Surface	7.41	7.62	6.79	7.69	0.389808
		Middle	7.706	7.54	7.1	8.57	0.598815
		Bottom	7.792	7.67	7.23	8.55	0.558614

(a)

Parameters	Districts	Layers	Mean	Median	Min.	Max.	StDev.
SAR	Rawalpindi	Surface	1.084	0.41363	0.35143	3.557908	1.27
		Middle	0.41	0.35022	0.24595	0.740906	0.23
		Bottom	0.48	0.40194	0.18446	1.054292	0.3
	Attock	Surface	2.18	0.80540	0.32440	8.549333	2.72
		Middle	2.2	0.52539	0.23157	6.09952	2.47
		Bottom	1.49	0.35046	0	6.269191	2.23
	Chakwal	Surface	0.65	0.38727	0.25443	1.597493	0.48
		Middle	0.7	0.38102	0.22135	3.043478	0.89
		Bottom	0.95	0.42599	0.24595	3.060462	1.03
	Jhelum	Surface	1.59	0.79744	0.20866	5.570746	2.24
		Middle	2.28	1.10258	0.17571	14.55493	3.24
		Bottom	3.81	1.3852	0.25568	14.5549	2.02

(b)

Table 4.7: Statistical analysis of pH and SAR (a) and (b)

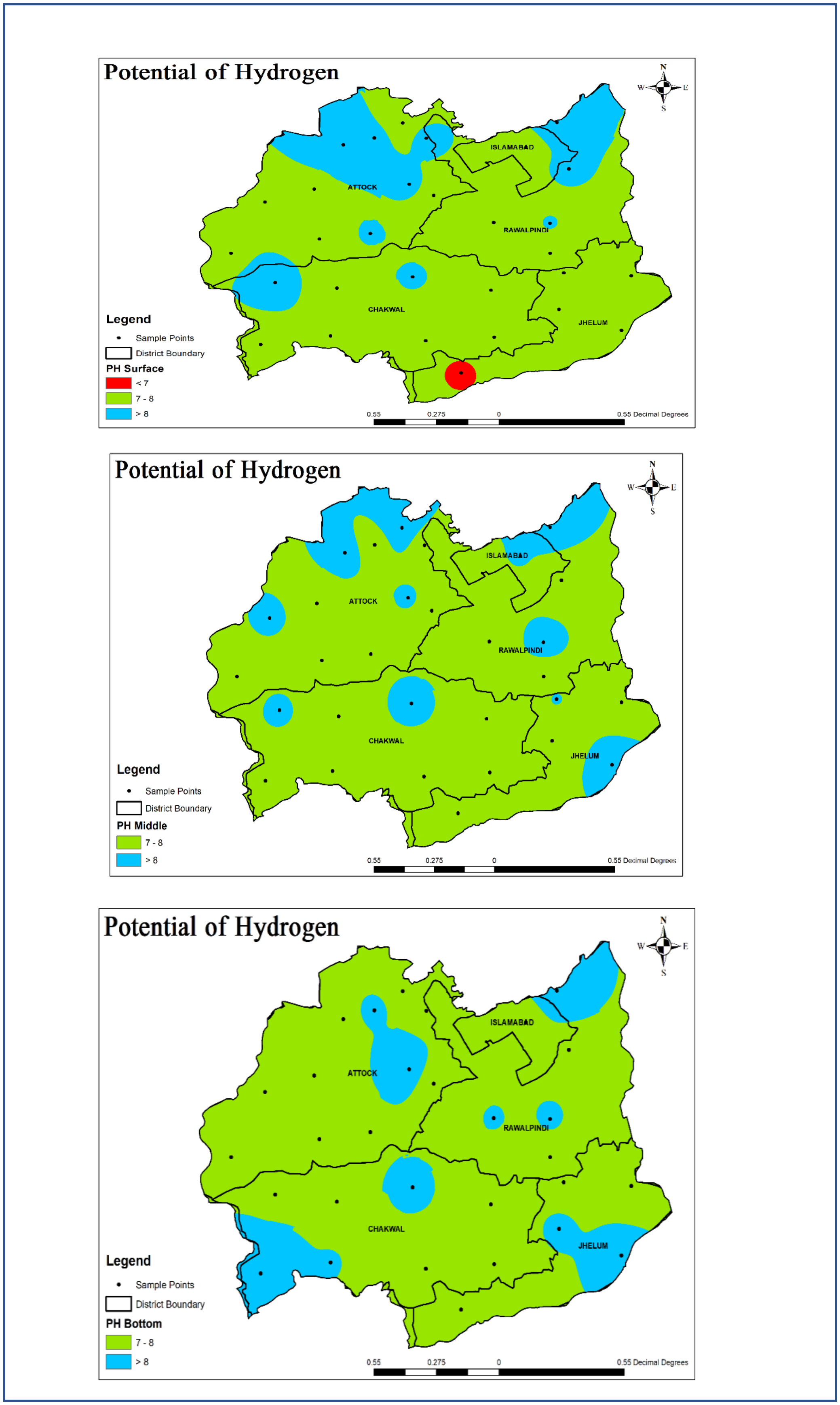

Figure 4.7: Picture courtesy by PCRWR report**:** Maps of pH in Potohwar region

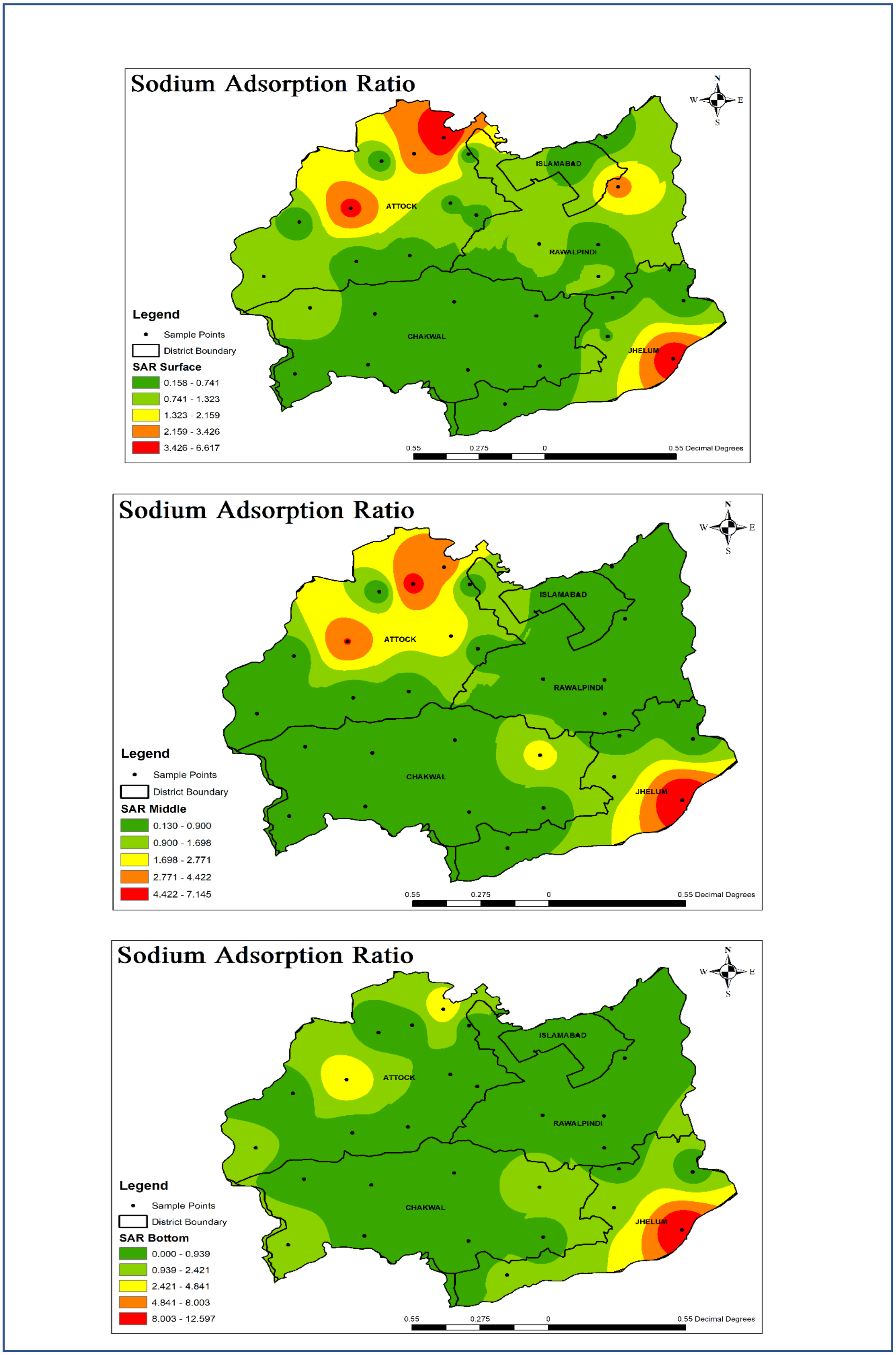

Figure 4.8: Picture courtesy by PCRWR report**:** Maps of SAR of Potohwar

Chapter **5**

5. CONCLUSION AND RECOMMENDATIONS

It is concluded that the soil of the Potohwar region is fully capable of producing a satisfactory yield of the crop. It is free of salinity except for some patches (salt range). Soils are counted in the saline category when their EC value > 4 dSm^{-1} (Whitney et al., 2018) and it is concluded that this area having < 4 dS/m Nutrient contents, infiltration rate, organic matter, pH level, EC and texture are ample. This land is full of potential to produce fruits, peanuts olives, and other cash crops. Only the need is to maintain its moisture contents through appropriate and advance techniques.

Rainfed areas receive enough rainwater, and if rainwater is collected through innovative technologies, it can be used for crop production (Baig et al., 1999; Adnan et al., 2009). By forming furrows of equal height, terraces, and runoff recycling, rainwater can be retained in the soil. In areas where runoff water can be stored and used, small, cost-effective dams can be developed to supplement the water needs of rainfed areas. Water preservation can not only help with appropriate water availability but also a reduction in erosion.

Conservation tillage includes minimal tillage, no-tillage, direct drilling, mulch tillage, stubble mulch, garbage tillage, and strip tillage to enhance infiltration and decrease runoff. Therefore, it helps reduce soil erosion. Deep tillage, plowing, or deep loosening can also be valuable, both increasing the porosity of the soil and destroying compaction that reduces permeability. Under these conditions, deep tillage increased water infiltration, reduced runoff, and checked soil erosion (Baig et al., 1999). Proper farming methods are essential to achieve sustainable crop yields in rainfed areas (Ahmed and Zia, 2003).

If 50% of the runoff is retained in the small/small dam, it can store more than half the capacity of the Tarbela Dam. The construction of dams is not only conducive to irrigation water but also has many indirect benefits, such as groundwater recharge, domestic and municipal water use, soil erosion, and flood control.

The scarce water resources in the region must be used most justly and efficiently with minimal losses. Pakistan has successfully introduced high-efficiency sprinkler and drip irrigation technology on a small scale, which is particularly suitable for rain-fed areas where water is scarce (Khan et al., 2012). Compared with other ground irrigation methods, another advantage is that it can be effectively irrigated even in places with uneven topography. (PCST,2005a).

In soils where the crust is more likely, seeding at a deeper depth can reduce the chance of emergence due to the hardness of the crust. Therefore, sowing at a shallower depth can ensure a greater emergence rate and a higher plant population. (Hadas and Stible, 1977; Nizami,1989; Baig et al,1999).

The addition of organic fertilizer raise the physical and chemical conditions of the soil by improving the pore space and the retention of water and nutrients, so it should be practiced. (Baig et al,2005).

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