Assessment of Soil Fertility and Underground Water Quality of different Villages of Depalpur Block of Indore District, Madhya Pradesh

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF

Master of Science (Agriculture)

in

Soil Science - Soil and Water Conservation

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To,

The Registrar
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Sir,

I have great pleasure in forwarding the thesis entitled **"Assessment of Soil Fertility and Underground Water Quality of different Villages of Depalpur block of Indore district, Madhya Pradesh"** submitted by **Mr. Vinod Prajapat** (ID No: 19430SAC017) in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in **Soil Science – Soil and Water Conservation**, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University.

I certify that the entire scheme of investigation reported here in, was planned and carried out by the candidate under my guidance. To the best of my knowledge and belief, the data presented in the thesis are genuine and original. No part of the work has been submitted for any degree or distinction.

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ACKNOWLEDGEMENT

I bow my head before the feet of the "Lord Shiva", the „Almighty" due to whose blessings I am able to reach at this stage and I feel that everything on this earth could be possible only with the blessings of this invisible but omnipresent supreme force.

At the outset, being the student of this great Institute, I bow my head with great reverence to the lotus feet of Bharat Ratna Mahamana Pandit Madan Mohan Malaviya Ji, the founder of the Banaras Hindu University, whose everlasting desire was to serve mankind. I am fortunate to perceive the prodigious path to tread upon precisely through precious guidance in this university.

I would like to express my profound sense of reverence and indebtedness to my Supervisor, Dr. Y.V. Singh, Associate Professor, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University for his meticulous guidance, compassionate initiation, congenial discussion, constructive criticism and soothing affection during the course of this investigation and preparation of this manuscript. It was a matter of sheer luck and opportunity to work under his guidance.

A special word of acknowledgement for Prof. Nirmal De, H.O.D (SWC) Soil Science & Agricultural Chemistry, Banaras Hindu University. Significant inputs from him have helped to enrich my work.

I offer my heartfelt gratitude to Dr. Ashish M Latare (Assistant Professor, Department of Soil Science and Agricultural Chemistry) R.G.S.C. (BHU) Barkkachha, Mirzapur, Institute of Agricultural Sciences, Banaras Hindu University for their constant encouragement, critical suggestions and inspiration during entire period of investigation and the members of the advisory committee Prof. P.K. Sharma Assistant Professor Department of Soil Science and Agricultural Chemistry Institute of Agricultural Sciences, Banaras Hindu University.

I would like to convey my gratitude to MR. Pawan Kumar Anand (Horticulture),R.G.S.C. (BHU) Barkkachha, Mirzapur, Dr. R. Meena (Assistant Professor, Department of Soil Science and Agricultural Chemistry), Institute of Agricultural Sciences, Banaras Hindu University.

I am grateful to Prof. P. Raha, Prof. A.K. Ghosh and Dr. A. Rakshit. I am thankful to non-teaching staff members of Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University for all kinds of help to me during my study period.

My special thanks to Dr. Triyugi Nath, Dr. Savita Dewangan, for their guidance, construction criticism, affectionate behavior and moral support during investigation of this research work.

I would like to thank sincerely from the bottom of my heart to my dearest friends Anuj Saraswat, Abhishekh Kumar Maurya, Kanhaiya Gawande, Harish Thakur, Vishal Panwar, Ram Kumar Raghuwanshi, Sonal Sharma, Thirumalesh Basam, Paneru Vennela and Shubham Mewada for their kind encouragement and support during the conduct of research as well as while writing thesis.

Words with me are insufficient to express my feelings of my heart to acknowledge my gratitude to my beloved mother Smt. Sunita Prajapat and my father Shri Narpat Prajapat. For their co-operation, inspiration and support in all the way and other family members who have providing all kinds of help and love.

Without the help of seniors none can learn the lesson of life and cannot teach the same to loving juniors. So, heartfelt and special thanks to my seniors for their cooperation during the study and investigation.

I would like to thank my juniors and others for always being supportive and helping and also thank to everyone who was involved in completing this work.

I would like to extend my sincere thanks to Sita Ram Yadav, Lab attendant, SS-SWC, RGSC, BHU. Last but not the least, I record my sincere thanks to all beloved and respected people who helped and could not find separate mentions. I still solicit their benediction to proceed at every step of respected destined life.

It's like drop in the ocean by my all regards to Maa Vindhyavasini and Baba Vishwanath, for providing me energy and patience without which I would have been none.

Date:
Place: *Varanasi* ***(Vinod Prajapat)***

Contents

LIST OF SYMBOLS AND ABBREVIATIONS

%	Per cent
Agri.	Agriculture
B.D.	Bulk density
BIS	Bureau of Indian standards
Ca	Calcium
Cm	Centimeter
Cmol (P+) kg^{-1}	Centimol per kilogram
DSm^{-1}	Decisimen per meter
DTPA	Diethyline Triamine Penta acetic acid
EC	Electrical conductivity
EDTA	Ethylene di amine tetra acetic acid
Et al.	Et alia, and others
G kg^{-1}	Gram per kilogram
Ha.	Hectare
i.e.	Id est. that is
J	Journal
K	Potassium
Kg ha^{-1}	Kilogram per hectare
Meq 100g^{-1}	Milli equivalents per 100 gram of soil
Mg	Magnesium
Mg kg^{-1}	Milligram per kilogram
Mha	Million hectare
Mm.	Millimeter
N	Nitrogen
Na	Sodium
NIV	Nutrient index value
O.C	Organic carbon
P	Phosphorus
P.D	Particle density
pH	Puissance de hydrogen
S	Sulphur
Fe	Iron
Mn	Manganese
Zn	Zinc
Cu	Copper
Sq. km	Square kilometer
viz.,	Vide licet, namely
WHC	Water holding capacity
WQI	Water quality index

LIST OF TABLES

LIST OF FIGURES

Chapter I

INTRODUCTION

Agriculture is the primary occupation and the backbone of the Indian economy. More than 70% of India's population is dependent on agriculture, either directly or indirectly (Reddy, 2011). Farmers and ranchers are responsible for supplying us with the food and fibre we need on a regular basis. Soil is an essential component of good agriculture because it is the source of the nutrients we use to cultivate our crops. Soil holds the nutrients and water for plants. They clean the water that passes through them by acting as a filter. The food we eat and the materials we use, such as paper and garments, are all dependent on soil.

Generally soil is defined as " A dynamic three- dimensional (having length, breadth and depth) piece of landscape with a three phase (solid, liquid and gaseous) system on the surface of earth in which plants grow, composed of mineral and organic materials and living forms". Soil and its roles within an ecosystem vary from one place to the next due to a number of factors such as climate, plant and animal life living on them, parent material of the soil, topography and soil age. The thin layer on the earth surface where soil develops is known as Pedosphere. This thin layer functions as a "great integrator," acting as a vital natural resource that has an effect on every aspect of the environment.

Since soil is so significant, we must focus on it. It is living, breathing world supporting nearly all terrestrial life on earth, but still most people do not realize it and yet they are taken for granted. It is a valuable natural resource that supports life and helps to maintain a socio-ecological balance in food production. It is estimated that our soils generate 95 % of our food, either directly or indirectly. Maintaining soil quality is the most efficient way of ensuring enough food to sustain life. Soil quality refers to the state of the soil in relation to the needs of one or more biotic organisms, as well as any human need or function. As per the USDA Natural Resources Conservation Service "Soil quality is the capacity of a particular type of soil to operate, within natural or managed ecosystem boundaries, to sustain plant and animal creation, preserve or boost water and air quality, and support human health and habitation" (Karlen *et al*., 1997).

The word "soil health" is often used to describe a productive farming method. Soil health refers to a soil's ability to perform its ecosystem functions in a manner that is conducive to its surroundings. Soil health and soil quality are synonymous terms. Healthy soils grow healthy crops, which in turn nourish people and animals. Indeed, soil quality is directly related to food quality and quantity. The other term which includes soil fertility, is characterised as a soil's ability to provide the conditions necessary for plant development. It is the product of physical, chemical, and biological processes working together to provide the plant with nutrients, water, aeration, and stability, as well as freedom from any substances that may inhibit growth (Stockdale *et al*., 2002). Soil fertility varies year to year due to changes in the quantity and availability of mineral nutrients caused by the addition of fertilisers, manure, compost, mulch, and lime, as well as leaching.

It is widely agreed that 17 essential elements are needed for plant development and completion of their life cycle (Troeh & Thompson 1993). A lack of any of these essential nutrients can severely restrict crop yield. So that, it is essential to investigate the soil in order to determine which nutrients are deficient and how much should be added. The nutrients that the plant absorbs are classified as primary nutrients, secondary nutrients, and micronutrients. Carbon, hydrogen, and oxygen, which are the most abundant plant nutrients, are all Universal elements that are obtained from air and water. The other 14 elements are only taken up by plants in the form of minerals from the soil or must be added as fertilisers.

The primary nutrients consist of nitrogen, potassium and phosphorus. These are the major nutrient, which are provided by fertilisers to plants in large quantity compared to secondary and micronutrients. A nutrient is said to be essential if it is directly involved in metabolism and plant can not complete its life cycle in lack of that particular nutrient.

Secondary macronutrients include calcium, magnesium, and sulphur, which are absorbed in smaller quantities by plants for growth and metabolism. The main sources of calcium and magnesium deposition in soil are dolomite, limestone, and calcite. Calcium and magnesium are present in these minerals in the form of calcium oxide and magnesium oxide, respectively. A variety of fertilisers are also available in addition to these. Sulphur fertilisers include potassium sulphate, magnesium sulphate, gypsum, and elemental sulphur. Depending on local air quality, contaminants in rainfall also provide 10 to 20 pounds of nitrogen and sulphur per acre per year.

Micronutrients include boron, chlorine, copper, iron, manganese, zinc, and molybdenum, which are needed in trace amounts by plants. Copper sulphate, manganese sulphate, zinc sulphate, zinc oxide, and oxy-sulphates are some of the fertilisers available. Chelated forms of micronutrients are added to soil. Chelates are soluble organic compounds that form complexes with metals to increase their solubility and make them accessible to plant roots.

In comparison with world soils, the fertility and sustainability of indigenous soils currently are very poor. This is due to the combined impact of various factors such as a lack of moisture, a lack of plant nutrients, and poor soil management. As a result, assessing the fertility status of an area's or region's soils is critical in the context of sustainable agriculture (Kavita and Sujatha, 2015). A good understanding of the soil is completely important in order to increase soil productivity. The knowledge of the status of plants in the soil helps to decide the quantity of and fertilizers and manures to be used for the crops. It aids in the avoidance of fertilizer related economic losses. The general overview of the available information shows the fact that the nitrogen in Indian soils is low.

Apart from soil, water is also the most essential natural resource, as it is needed for the survival of all living organisms. Water is a resource that can be used for a variety of purposes, including recreation, transportation, hydroelectric power, as well as domestic, agricultural, and commercial purposes. It also plays a major role in the earth's biodiversity, biosphere, and biogeochemical cycles. It is an important input in agricultural production and contributes to food security. Agriculture consumes about 70% of all fresh water (Baroni *et al*., 2007).

Not only the soil quality, but quality of irrigation water applied to the plant also influences its growth and development. Thus, high quality irrigation water is always a necessity for living organisms and crop production. The concentration and condition of organic and inorganic materials suspended in water are generally referred to as irrigation water quality. Quality is determined by in-situ measurements as well as laboratory examination of samples. The type and quantity of salts dissolved may have a big impact on the water used for irrigation. The salts in irrigation water come from a variety of sources, including rock weathering, dissolution lime, gypsum and other minerals, sea water intrusion, and so on. When such water is added to the plant, the osmotic potential rises, making it impossible for the roots to absorb water from the soil; additionally, when the water evaporates, salts collect on the soil's surface as a white layer. Thus, water quality testing is an integral part of environmental monitoring and plays an important role in monitoring plant life. Chemical, physical, and biological properties are the properties of water that are used to assess its quality. The general requirements for irrigation waters include salinity, sodicity, and element toxicities.

Soil and water quality are closely connected by a dynamic network of interactions, and any improvement in one would have varying degrees of impact on the other. Changes in land use pattern and management practise must be made based on soil and water quality because they have a direct effect on crop production and yield. Much of the current concern with regards to environment quality is focused on water and soil because of its importance in maintaining the human health and health of the ecosystem. The quality of water and soil in any ecosystem provides valuable information about the available resources for supporting life in that ecosystem. The quality of water and soil depends as a large number of physico-chemical parameters and analysis. As a result, various metrics must be used to determine soil and water quality variables in order to know the condition of soils and increase productivity.

In Madhya Pradesh, the agriculture sector accounts for nearly one-third of the state's Gross State Domestic Product (GSDP) and constitutes the backbone of state economy. Agriculture employs more than 65 percent of the rural population and produces 60-75 % of rural income. Madhya Pradesh, with its large area, enjoys diverse climatic and soil conditions suitable for a broad range of agricultural products. The state has 5 crop zones, 11 agro-climatic regions, and 4 soil types, which contribute to the state's biodiversity and favour the production of various agriculture and horticulture crops. According to the Agriculture Census of 2000-01, the state had 73.60 lakhs operational holdings. Traditional agriculture also accounts for 65 percent of the state's agriculture, which is largely rainfed.

Indore district is located in the heart of the Malwa plateau and spans 3831 square kilometres. It is bounded by N latitudes 22° 31' and 23° 05' and E longitudes 75° 25' and 76° 15'. It is situated at an elevation of 553 metres above sea level and is bordered by Ujjain district in the north, Khandwa district in the south, Dewas district in the east, and Dhar district in the west. Four tehsils and four development blocks make up the Indore district. The district is located in the Chambal sub-basin of the Ganga basin (75%) and the Narmada basin (25%). Chambal, Gambhir, Khan, and Shipra are the major rivers that drain the district in the north.

Medium and deep black coloured soil is widely found in the Narmada River Valley, Malwa Plateau, and Satpura mountain range of Madhya Pradesh, containing approximately 20% to 60% clay and having a depth of approximately 1 to 2 metres. Regur (humus) soil is another name for it. Basaltic rocks, which are mostly found in the Deccan Trap, make up black soil (malwa plateau). These soils are mostly composed of iron and lime rocks. Its black colour is due to the presence of iron, and the presence of lime increases its moisture retaining potential, requiring less irrigation. Cotton and soya beans are the best crops to grow in such soil. Black soil has higher levels of calcium, magnesium, aluminium, iron, potassium, and magnesium carbonate, but it lacks nitrogen, phosphorus, and carbonic elements. In this state, the problem of soil erosion is almost non-existent; however, due to unsustainable land use, the problem of soil erosion is escalating.

Wells and tube wells are the primary source of irrigation in Madhya Pradesh, accounting for nearly 66 percent of the net irrigated area. Canals account for 18 percent of irrigated land, while tanks account for 2 percent. The proportion of irrigated land to net irrigated land from other sources is 14%. Rivers in Madhya Pradesh are mainly seasonal and rain fed, with the monsoon season receiving the most water supplies. The non-monsoon flow in some perennial rivers is mostly due to flow from groundwater. The availability of water in the rivers is not uniform spatially or temporally. There are 3960 large, medium- and minor dams / reservoirs built for irrigation potential on nearly all the major rivers in Madhya Pradesh (2001-02).

Taking into account all of these aspects, an attempt has been made to examine and characterize the soil and water quality status of Depalpur block in Indore district, Madhya Pradesh, using various concepts, procedures, and techniques with the following goals in mind:-

1. To investigate the soil and water quality status of various villages in the Depalpur town of the Indore district of Madhya Pradesh.
2. To determine the fertility status of soils and to create a nutrient-wise map for identifying nutrient constraints in various villages in the Depalpur block of the Indore district of Madhya Pradesh.
3. To study the correlation matrix between soil physico-chemical properties and water quality parameters.

Chapter II

REVIEW OF LITERATURE

Soil and water are two very significant aspects of life that are crucial for crop production. These resources are strongly linked by a dynamic network of interactions, and any improvement in one mechanism would have varying degrees of effect on the other. Changes in management practises as well as land use must be made in response to changes in soil and water quality, as they have a direct effect on crop yield. As a result, efforts are being made to assess the current status of soil and water quality in the Depalpur block. Based on the existing sources and information gathered, literature is reviewed under following sections.

Physico-chemical properties of soil

- ❖ Soil pH
- ❖ Electrical Conductivity (EC)
- ❖ Organic Carbon (OC)
- ❖ Bulk Density (BD)
- ❖ Particle Density (PD)
- ❖ Water Holding Capacity (WHC)
- ❖ Porosity

Status of Primary Macro-nutrient in soil

- ❖ Nitrogen (N)
- ❖ Phosphorus (P)
- ❖ Potassium (K)

Status of Secondary Macro-nutrient in soil

- ❖ Sulphur (S)

- Calcium (Ca)
- Magnesium (Mg)

Physico-chemical properties of water

- Water pH
- Electrical conductivity (EC)
- Total dissolved solids (TDS)
- Chloride (Cl^-)
- Sodium and potassium (Na^+ and K^+)
- Calcium and magnesium (Ca^{2+} and Mg^{2+})
- Carbonate and Bicarbonate (CO_3^{2-} and HCO_3^-)

Irrigation water quality parameters

- Sodium adsorption ratio (SAR)
- Residual sodium carbonate (RSC)
- Soluble sodium percentage (SSP)
- Permeability index (PI)
- Kelly's ratio (KR)

Physico-chemical properties of soils

Singh *et al.* (2017) studied physical properties in soil of block Sihawal and Gapad Banas of Sidhi District, Madhya Pradesh, India. Soil samples were collected at a depth of 0-15cm, 15-30 cm and 30-45cm from 8 sampling points and the study revealed that PD of samples ranged from 2.45-2.73 g/cm^3, BD ranged from 1.09-1.25 g/cm^3 and WHC varied from 56.83-68.35%. It made clear the soil has adequate water holding capacity and has good physical condition. Soil is ideal for almost all tropical and sub-tropical crops

Deoli *et al.* (2020) analysed soil quality using physico-chemical parameters of soil in Dehradun, Uttarakhand. 24 soil samples were collected from villages of saheshpur block of dehradun and compared with standard values of soil quality. The result showed that moisture content of the soil was directly proportional to WHC. The moisture content in soil samples were ranged from 3.38 percent to 8.87 percent, with a mean of 4.29 percent, and the bulk density varied from 1.14 gm/cm^3 to 1.47 gm/cm^3, with a mean of 1.23 gm/cm^3. Bulk density was influenced by soil compaction and consolidation, but it was inversely proportional to organic matter (Iram and Khan 2018).

Ingle *et al.* (2018) studied agricultural soil quality in Khandesh area of Maharashtra. Total 108 soil samples were collected and analysed for physico-chemical properties. The results revealed that bulk density of soil samples were ranged from 1.06 – 2.17 g/cm^3 with a mean value of 1.65 g/cm^3. Porosity ranged from 28-59% with mean of 47.32%. WHC of analysed soil samples were ranged from 13.8 – 48.6 %.

Chaudhari *et al.* (2013) studied the dependence of bulk density on texture, organic matter content and available nutrients (macro and micro nutrients) for soil of Coimbatore. Soil samples were taken at a depth of 15 cm from eight separate locations. The bulk density of the soil was found to range between 1.25 and 1.57 Mg/m^3, and bulk density was found to be dependent on calcareous and saline soil, but independent of soil pH. Bulk density had a strong negative correlation with calcium carbonate (r = -0.4952) and electrical conductivity (r = -0.6611). The correlation between bulk density and pH, on the other hand, was negative but not statistically significant (r = -0.2371).

Patle e*t al.* (2018) conducted an experiment on cultivated land at CAEPHT campus Gangtok, Sikkim for evaluation of infiltration rate from soil properties using regression model. The result of analysed samples showed that the bulk density and particle density were ranged from 1.412–1.716 g/cm^3 and 2–3.03 g/cm^3, respectively. The basic infiltration rate was varied from 0.3 - 6.8 cm/h. bulk density had negative correlation with infiltration rate by −0.33 and particle density had positive correlation with infiltration rate by 0.18.

Ahad *et al.* (2015) analysed soil bulk density as related to texture, organic matter content and porosity in soils of Kandi, Kupwara district (Kashmir valley), India. Soil samples were collected from five different locations at 20- 35 cm depth. The result showed that bulk density of the soils ranged from 1.24 – 1.46 gm/cm^3. There was a strong negative correlation of bulk density with organic matter (r = -0.87) and porosity (r = -0.79).

Kumar *et al.* (2014) assessed soil physical health and productivity of Kharkhoda and Gohana blocks of Sonipat district (Haryana), India. Undisturbed soil samples were collected from 66 villages to evaluate soil health. Result showed that bulk density in 75% of total area in 15-30 cm soil layer had BD >1.6 mg/m^3, which indicated the presence of hard pan in subsurface**.**

Viji and Prasanna (2012) studied water holding capacity of major soil series of Lalgudi, Trichy, India. Soil samples were collected from five different locations at 15 cm and 30 cm depths. The results showed that at 15 cm depth the BD of soil samples ranged from 1.19-1.42 g/cm^3, PD ranged from 1.46-1.79 g/cm^3, porosity ranged from 17.98-22.16% and WHC ranged from 30.69-20.88%. Whereas at a depth of 30 cm the BD of soil samples ranged from 1.21-1.41 g/cm^3 , PD ranged from 1.45-1.74 g/cm^3 , porosity ranged from 15.92-19.60% and WHC ranged from 20.46-29.33%.

Lohiya *et al.* (2018) conducted a study on soils of village golpura in Dhar district of Madhya Pradesh to evaluate fertility status and its relationship with physico chemical characteristics for identifying nutrient deficiencies. The study revealed that soil pH of Golpura village ranged from 6.8-7.6 with a mean value of 7.25 which was characterized under neutral to alkaline and EC ranged from 0.19-0.86 dS/m with a mean value of 0.36 dS/m which was less than 1 ds/m comes under safe limit for all soil. Organic carbon content ranged from 0.31% to 0.72% with mean of 0.55% which indicated that soils of Golpura village was low to medium in organic carbon content.

Wani *et al.* (2014) studied Physical and chemical properties from different locations from the Gwalior city of Madhya Pradesh. 16 soil Samples were collected (4 from agricultural, 3 from highway, 3 from industrial, 3 from barren and 3 from market sites) and result showed that agricultural soil samples were more fertile as compared to other. Soil samples were sieved with <2.0mm test sieve and prepared (1:2) soil and water solution and kept it for 1 hour were at rotatory shaker as described by Tandon for analysis of EC and pH. EC (dS/cm) of agriculture soil at different sites were 0.6±0, 0.6±0, 0.6±0, 0.5±0 at site 1, 2, 3 and 4 respectively. However pH was ranged from 9.8 to 10.1 respectively. The organic carbon in the soil samples at different sites were 8.66±1.03, 8.99±0.02 and 8±0 at site 1, 2 and 3 respectively. The organic carbon content of all cultivated soil samples was found to be high.

Emmanuel *et al.* (2018) the study was conducted to analyse the soil reaction (pH), Electrical Conductivity (EC) and organic carbon (OC) in soil. Result showed that pH of analysed soil samples was slightly acidic with a pH mean of 6.26 and mean value of EC was 1.82 ds/m. The soil organic carbon and organic matter of the soil samples of studied area were recorded low and moderate in locations.

Verma *et al*. (2013) conducted a study to evaluate the fertility status in Inceptisols of Malkharauda block, Chhattisgarh during 2011-2012.The study showed that soils were found to be acidic to alkaline in reaction, with a pH ranging from 4.7 to 7.1 and an average of 6.0. With a mean value of 0.20 dS/m, the electrical conductivity ranged from 0.05-0.74 dS/m. All of the samples have EC levels that are within a healthy range for crop growth and production. The usual EC could be due to salt leaching to lower horizons as a result of its light textured existence, as well as heavy rainfall and surface runoff. The organic carbon status of the soils ranged from 0.11-0.78 percent, with a mean value of 0.49 percent. The rate of oxidation of organic matter in the soil increased as the temperature and aeration in the soil increased, resulting in a decrease in organic carbon content.

Kumar *et al.* (2011) analysed 100 soil samples from tsunami-affected areas in Tamil Nadu's Sirkali Taluk. Soil samples were taken from 100 sites in 18 villages, ranging in depth from 0 to 15 cm. The pH of the soil samples ranged from 6.78 to

7.95, electrical conductivity from 0.07 to 0.62 dSm-1, and organic carbon content from 0.20 to 7.54 percent, according to the findings. Organic carbon levels were found to be low in 64 percent of the samples because vegetation was in poor condition and organic matter decomposition was occurring at a faster rate due to the hyper-thermic temperate regime, which resulted in high oxidation.

Patidar *et al.* (2017) studied the major nutrients and chemical properties of vertisols of Ralyawan Village of district Jhabua, Madhya Pradesh. The results showed that electrical conductivity ranged from 0.17 to 0.86 dS/m with a mean value of 0.37 dS/m and pH varied from 7 to 8 with the mean value of 7.5. Organic carbon content in this soil was from 0.23% to 0.80% with a mean value of 0.53%. In general, the organic carbon status of soils of Ralyawan village was low to medium.

Ingle *et al.* (2018) carried out a comprehensive soil survey in the Bareli watershed in the Indian state of Madhya Pradesh with the aim of determining the soil nutrients status. Soil pH from 6.1 to 7.8 which indicated that soils was acidic to alkaline, based on soil fertility ratings and organic carbon varied from 0.38 to 1.94 per cent with a mean value of 1.08The most significant soil nutrients constraints that could affect sustainable crop production in the study area were found to be low electrical conductivity (deficient) and high iron (Fe), manganese (Mn), and copper (Cu) levels.

Jain *et al.* (2014) studied the physico-chemical characterization of farmland soil in Lunawada Taluk, Gujarat, India. In this investigation, 15 soil samples were collected from various villages and analysed for physicochemical parameters. According to the findings, the pH of the soil samples ranged from 6.5-7.8, electrical conductivity ranged from 0.3-1.3 dS/m, and organic carbon ranged from 0.3-0.8%.

Dhakad *et al.* (2020) carried out a study to know status of soil pH, EC, OC and micronutrients levels in Madhya Pradesh. The study highlighted that soil pH was affecting a wide area of Madhya Pradesh. The soil in Madhya Pradesh was naturally alkaline to slightly alkaline and was poor in status of micronutrients nutrients. Study also told that organic matters one of the most essential components of soil; a large amount of organic matter in the soil significantly increases the soil nutrients. Organic matter decay releases nitrogen, phosphorus, and micronutrients, which are then available to crops.

Bharteey (2017) analysed the soils of the Narayanpur block of the Mirzapur district of Uttar Pradesh and discovered that the pH of the soils ranged from 6.4 to 8.2 with an average value of 7.5, indicating that these soils were neutral to alkaline in reaction. The EC values ranged from 0.11 to 0.32 dS/m, with an average of 0.18 dS/m, suggested that salinity was not a concern in these soils. The organic carbon content of the soils ranged from 0.14 to 0.86 percent, with a mean value of 0.42 percent which suggested a low to medium status.

Kadam *et al.* (2016) studied the physico-chemical properties of soil in Maharashtra's Deulgaon Raja district. 60 soil samples were collected from various villages in the Deulgaon Raja area for this analysis. The soil type was clay loamy, and the pH of the soil samples ranged from 5.20 to 6.8, with 1.37 % of the soil samples being acidic and 92.64 %of the soil samples being in the usual range. The EC of soil samples ranged from 0.30-0.46 dS/m, and the organic carbon content was extremely high, ranged from 2.15 to 3.66 %.

Kumar *et al.* (2016) conducted a research to identify the nutrients status of cultivated soils in Ganga canal area of Meerut, Uttar Pradesh. Soil samples were obtained from surface (0-15 cm) and sub-surface (15-30) at six different location of Meerut district. Results conclude that surface and subsurface soil samples were found to be natural to alkaline reaction, with pH values ranged from 6.15 to 8.49 and 7.12 to 8.92, respectively and soil samples were characterised as non-saline. Organic carbon of study area varied from 6.50 to 13.44 and 3.39 to 9.90 g/kg.

Singh *et al.* (2017) analysed the pH, EC, and organic carbon of soils in the Lahar block of Bhind district, Madhya Pradesh, and found that the pH ranged from 7.23-8.03 with a mean value of 7.68 and electrical conductivity ranged from 0.32-0.82 dS/m with a mean value of 0.62 dS/m. Organic carbon of these soils ranged from

0.24-0.49 percent with an average value 0.33 percent. The EC of the soils was normal and in 100% soil samples, organic carbon was poor (<0.50%).

Annepu *et al.* (2017) Assessed the soil fertility status of the Mid Himalayan region of Himachal Pradesh and determined that the pH values ranged from 6.59 to 7.81 (neutral to slightly acidic), with a mean pH value of 7.36. EC of soil ranged between 0.049 and 0.793 dS/m, with a mean of 0.426 dS/m. The studied area's soils have high organic carbon (OC) content, ranged from 0.15 to 1.98 %.

Nisha *et al.* (2017) evaluated soil physico-chemical parameters in Kadi, Gujarat. The pH of the soil samples ranged from 7.4-7.9, showed alkaline origin, while the EC of the soils ranged from 0.3-0.6 dS/m, indicated the leaching of bases on the soil surface was due to high rainfall.

Das and Poongothai (2014) analysed soil and water quality in Tsunami-affected areas of Tamilnadu's Nagapattinam District. 10 surface soil samples from unaffected areas were collected up to a depth of 20 cm from ten different villages. The results showed that pH of soil samples ranged from 6.82 to 8.60, and electrical conductivity (EC) ranged from 0.327 to 1.250. EC of the soils decreased in relation to the values immediately after the tsunami of 2004, which may be attributed to rainfall flushing out surface salts thereby lowering soil EC.

Chaurasia *et al.* (2013) conducted a research in 12 villages of Varuna River in Varanasi district. From each village, soil samples were collected for study from depth of 0-15cm. The result revealed that all soil samples were moderately alkaline, ranged from 7.97 to 8.83, with an average of 8.4. EC of the soil ranged from 0.92 to 1.22 dS/m, and Organic carbon concentrations range from 0.40 to 0.76 percent.

Primary Macro-nutrients in soil (Nitrogen, Phosphorus and Potassium)

Patidar *et al.* (2017) conducted a study to determine the major nutrients and chemical properties of vertisols of Ralyawan Village, Madhya Pradesh. The results revealed that available nitrogen was low ranged from 150 to 298 kg/ha with an average of 236 kg/ha which was in low fertility class as per Nutrient Index Value, thus overall low status of available nitrogen was observed. Available phosphorus was low to medium ranged 7.15 to 38.8 kg/ha with a mean value of 16.4 kg. The Nutrient Index Value for P was in medium fertility class. Available potassium varied from 179 to 826 kg/ha with a mean value of 418 kg/ha. The Nutrient Index Value for available potassium was in highly fertile class.

Yadav *et al.* (2018) Studied spatial variability in physico-chemical properties of soils in Alirajpur, Madhya Pradesh using Geo-statistical approach. 272 surface soil samples were collected from 6 blocks of Alirajpur using GPS during rabi season 2016-17. Samples were analysed in lab with standard procedure and result showed that Nitrogen, Phosphorus, Potassium content of soil varied from 76 to 382 kg/ha, 1.34 to 62.13 kg/ha and 253.52 to 529.85 kg/ha respectively.

Rajendiran *et al.* (2018) conducted an experiment to evaluate soil fertility status of Alirajpur, Madhya Pradesh. 540 soil samples were collected from 90 villages of 6 blocks of Alirajpur district and were analyzed for their physico-chemical properties and available nutrients status. Result revealed that the amount of nitrogen available per hectare ranged from 117.3 to 309.5 kg, with an average of 218 kg. A total of 84.1 percent of the soil samples were found to be low in nitrogen (250 kg N/ha) and remained in the medium range (250-500 kg/ha). Low nitrogen status in soils could be caused by a lack of organic carbon in the soil. The amount of available P ranged 4.29-32.7 kg/ha with a mean value of 12.7 kg/ha. 53 percent soil samples had low phosphorus, 30.6 percent had medium phosphorus, and 16.4 percent had higher phosphorus. Status of available potassium ranged between 122 and 483 kg/ha with an average of 352 kg/ha. Most of the soil samples (69.2%) were found to be under high K (>280 kg K/ha) range. This might be due to the presence of most of the mica (biotite and muscovite) in finer clay fractions.

Ganorkar and Chinchmalatpure (2013) assessed physico-chemical properties of Soil in Rajura Bazar in Amravati District of Maharashtra. Soil samples were collected from six different locations in Amravati district in the month of February 2013. The results showed that the amount of available nitrogen content in the soil samples ranged from 219- 298 kg/ha. P and K content of soils were ranged from 18.5- 25 kg/ha and 445 – 648 kg/ha respectively.

Gehlot *et al.* (2019) studied the nature of soil reaction and status of EC, OC and macro nutrients in Ujjain Tehsil of Madhya Pradesh. By the method of random sampling, 150 GPS based soil samples were collected from depth of 0 – 15 cm and analysed samples showed that available N, P and K ranged from 139-235, 8.00-25.60 and 301-463 kg/ha respectively with mean value of 198.27, 15.8 and 358.85 kg/ha respectively. These soil data can be effectively used with proper nutrient management and monitoring to prevent any nutrients stress on crops.

Nigam *et al.* (2014) conducted an experiment on soils of the Sangharinala watershed in Raipur, Chhattisgarh, and reported that nitrogen (N) availability in different soil samples ranged from 200.70 to 301.06 kg/ha, with a mean value of 220.4 kg/ha. The majority of the samples showed lower N availability. N supply is not only a necessary component of carbohydrates, fats, and oils, but it is also a necessary component of proteins. The amount of N available is an essential factor in rising soil fertility. The amount of P in different soil samples ranged from 4.8 to 9.85 kg/ha, with a mean value of 7.0 kg/ha, and all soil samples were showed lower availability of P. K value varied between 89.6 and 324.8 kg/ha, with an average value of 169.6 kg/ha, and the majority of the soil samples (71.4%) were found to be in the medium range (125-300 kg/ha) and the remains (28.6 percent) were found to be in the low range.

Wagh *et al.* (2013) evaluated the physico-chemical properties of soils of Pune city. The soil samples were obtained from the sugarcane fields in Manjari, Hadapsar, and Phursungi villages in the south-east of Pune between 2009 and 2010. From each village, 12 soil samples were collected. According to the result, P content of soil samples ranged from 10-172.9 kg/ha, which could be attributable to the overuse of phosphatic fertilisers in the fields, while the potassium content ranged from 112-840 kg/ha, suggesting adequate K in the majority of the samples.

Ram *et al*. (2013) evaluated the fertility of soils of Markapur mandal of Prakasam region, Andhra Pradesh for sustainable land use planning. The study revealed that the available N content in all the physiographic divisions of the Mandal ranged from 87.8 to 6.3 kg/ha. Available P varied from 8.7 to 28.4 kg/ha and exchangeable potassium 62.7 to 257.6 kg/ ha.

Dhumgond *et al.* (2017) researched the hill zone acid soils of Hassan and Chikkamagalur districts in Karnataka and reported that the available Nitrogen and Phosphorus content were medium and Potassium status was higher in both depths and cropping systems. However, surface soil had considerably higher available N, P, and K content (453.7 ± 65.2 N kg/ha, 32.7 ± 8.4 P_2O_5 kg/ha and 467.7 ± 149.1 K2O kg/ha) under paddy, areca, and coffee cropping systems, respectively. When compared to areca and paddy, the coffee system had higher N, P, and K values (426.5 ± 58.2 N kg/ha, 31.1 ± 7.1 P_2O_5 kg/ha and 452.1 ± 110.5 K_2O kg/ha, respectively). The recycling of biomass can explain the medium status of available N and P and the higher status of K in acid soils (leaf-litter and residue and addition of manures).

Mauriya (2013) analysed the soils of Narendra Deva University of Agrieulture and Technology, Kumarganj, Faizabad, Uttar Pradesh and found that the soils were having low nitrogen (148 kg ha), medium phosphorus (20 Kg ha) and medium potassium (195 kg K ha).

Kashiwar *et al.* (2018) evaluated the soil fertility status of Rajiv Gandhi South Campus (BHU), Mirzapur, Uttar Pradesh by Using GIS. Total 260 soil samples were collected from depth of 0 – 15 cm and study revealed that available N, P and K were varied from 160-241.5, 8.24-11.79 and 70.1-128.25 kg/ha , respectively.

Secondary Macro- nutrients in soil

Singh *et al.* (2017) examined the soils of the Lahar block in the Bhind district of Madhya Pradesh and reported that the secondary nutrient sulphur, calcium and magnesium status in the soil varied from 16.58 to 28.68, 4.50 to 9.05, and 2.73-6.99 kg/ha, respectively. Based on Ramamoorthy and Bajaj suggested assessments (1969), Sulphur was categorised 40% as medium (10-20 kg/ha) and 60% as high (>20 kg/ha), and adequate calcium and magnesium (100%). It's possible that this was due to the formation of a favourable soil climate.

Khadka *et al.* (2016) studied soil fertility status of National Maize Research Program, Rampur, Chitwan, Nepal. A total of 98 soil samples were taken randomly at depths ranging from 0 to 20 cm and analysed for various parameters like texture, pH, OM, N, P, K, Ca, Mg, S, Zn, Fe, Cu, Mn and B. According to findings extractable calcium (1012.11±87.96 ppm) and available sulphur (10.08±0.76 ppm) were found low. Similarly extractable magnesium (135.47±22.04 ppm) was found medium.

Jayaprakash *et al.* (2012) studied macro nutrient status in non-traditional areca growing soil of Karnataka and found that exchangeable calcium ranged from 1.8 to 4.2 cmol (P+) kg. The range of exchangeable magnesium in soil profiles was 0.89 to 3.5 cmol (P+) kg. The available sulphur in different soil profiles ranged from 8 to 18.5 ppm, with the surface horizon having the highest concentration. It gradually decreased as the depth of the soil was increased.

Garanayak *et al.* (2018) studied GPS based Soil Profile with micronutrient analysis of Soils of Ganjam district, Odisha. 2 pedons are studied during dry season one each from up and medium and It was obseverd that Ca and Mg content increased downwards from 4.4 to 5.6 Cmol(p+)/kg & 2.18 to 2.98 Cmol(p+)/kg and Sulphur content decreased downwards and varied from 3.1 to 8.2 mg/kg compared to those of pedon2 were 14.4 to 22.52 Cmol(p+)/kg Ca, 4.32 to 9.40 Cmol(p+)/kg Mg & 6.99 to 11.29 mg/kg S. The difference in properties between two pedons was primarily due to the parent material in pedon1 being lateritic and basaltic.

Triphati *et al.* (2015) studied soil physico-chemical properties influenced by wheat residue burning in Ashrawad khurd village of Indore (MP) India. Soil samples were collected before and after burning of crop residues at depth of 0-10 cm and analysed in lab. The results revealed that exchangeable calcium and magnesium content were reduced after burning wheat residue. Before burning of wheat residue exchangeable calcium and magnesium were 28.05 mg/L and 10.94 mg/L respectively, and after burning, it were observed 26.05 mg/L and 08.51 mg/L respectively.

Chaudhari (2013) analysed the soil physico-chemical properties in Jalagon District, Maharashtra. Soil samples were taken during the summer season from 8 different villages for this study. According to the findings, the percentage of calcium in soil samples ranged from 0.94 to 3.38 percent by weight, with the normal range being 0.98-2.45 percent by weight. Sample S6 had a percentage of Ca of 3.38 percent by weight, which is abnormal. According to the study, the percentage of magnesium in soil samples ranged from 0.91 to 2.65 percent by weight, whereas the normal percentage of magnesium is 1.20 to 2.00 percent by weight. Sample S8 had a percentage of Mg of 2.65 percent by weight, which is abnormal.

Khadka *et al.* (2018) assessed Soil Fertility and Mapping of Regional Agricultural Research Station, Parwanipur, Bara, Nepal. Total 76 soil samples were collected at the depth of 0-20 cm for analysis and Arc-GIS 10.1 was used for soil fertility mapping. Results showed that available calcium was 1674.6±46.3ppm and available magnesium was 175.43± 8.93ppm, both were medium as per nutrient index value. Analysed soil samples were found low in available Sulphur (0.8± 0.1 ppm).

Physical and chemical properties of water

pH, EC and TDS

Yadav *et al.* (2012) studied the physico-chemical properties of selected ground water samples of Agra, Uttar Pradesh. Water samples were collected from 12 sampling sites from Feb. to May 2011. The results showed that the range of physico-chemical parameters like pH varied from 7.2-7.7 , The highest pH was observed as 7.7 at sampling location S4 and S12 and lowest was 7.2 at S2, S7 and S10. The samples are found to be within the allowable range as compared to WHO and IS 10500-91 standard values. EC ranged from 1580 to 5200 mmhos/cm, EC was found in all analysed samples to be higher than the WHO cap. The presence of a significant amount of dissolved inorganic substances in ionised form was suggested by high EC values. TDS values ranged from 1020-4950 mg/L, TDS levels of more than 500 mg/L are not considered safe for drinking water sources (Jain, 2002).

Okoro *et al.* (2012) conducted a research to determine the effects of industrial activities on ground water quality in industrial and non- industrial area in Ilorin Town. The research showed that pH values ranged from 6.5 to 8.5 and suggested that they were suitable for domestic use. EC values ranged from 48 to 320 µS/cm. Sites 1 and 3 had the highest conductivity of 285 to 320µS/cm, which was above the appropriate limit. This might be due to industrial activity in the region.

Dixit *et al.* (2015) studied the quality of pond water of Bilaspur District, Chhattishgarh, India. Pond water samples were collected from 27 villages of bilaspur and analysed for physico-chemical parameters. The study revealed that the pH values varied from 6.50 to 9.69, the EC values ranged from 118.7 - 206.6 mmhos/cm and the TDS varied from 165.5 to 254.8 ppm.

Mehta *et al.* (2014) examined the hydro geochemistry of ground water in the Sanganer Tehsil of Jaipur district, Rajesthan. During the pre-monsoon season, 40 samples were collected from wells, tube-wells, and hand pumps for this analysis. According to the findings, the pH of water samples ranged from 8.87-7.25, suggesting that the water is alkaline in nature, and showed a negative association with all other parameters. The EC of water samples ranged from 4850 to 530 mhos/cm and all samples were higher than the permissible limit.

Shivhare *et al.* (2017) studied the effect of nallahs on ground water quality in Indore city of Madhya Pradesh. Water samples were collected from 18 groundwater sources and study was carried out for assessment of 21 parameters. It was observed that pH value varied from 6.5 – 8.5, EC ranged from 734 - 1843.4 µ mhos/cm and TDS varied from 425 to 1350 mg/L. According to other analysed data, the standard of groundwater in Indore city has degraded to the point where it is unfit for drinking and irrigation.

Reda (2016) studied of drinking water quality of Arbaminch town. Water samples were obtained from three sampling locations in this study: Secha, Sikela, and Arbaminch University. The pH of three sampling sites, Secha, Sikela, and Arbaminch University, was 7.34, 7.13, and 7.76, respectively, indicated that all samples were within WHO permissible ranges, while the EC of three sampling sites, Secha, Sikela, and Arbaminch University, was 211.8, 210.0, and 230.5 µS cm^{-1}, indicated that all samples were within permissible ranges.

Chakarde and Shrivastava (2018) conducted a study on the Narmada River in the Hoshangabad region at various sampling stations to determine any seasonal changes in physical and chemical water parameters (affecting water quality). They observed that the pH values varied from 7 to 8.7, this might be due to the high buffering capacity of the river system. TDS of the water sample ranged from 97- 500 ppm. TDS and conductivity are correlated; as TDS rises, conductivity rises with it (McNeely *et al*., 1979).

Reddy *et al.* (2012) examined the groundwater quality of Bhaskar Rao Kunta watershed, Nalgonda District of Telangana for its suitability for irrigation. During the pre- and post-monsoon seasons in June and December 2009, 20 groundwater samples were taken from deeper bore wells. The results showed that pH values ranged from 8 to 9 in the pre-monsoon and post-monsoon seasons, respectively. Except for 25% of the samples (sample nos. 10, 14, 19, and 20) crossing the permissible limit in pre-monsoon, 75 percent and 100 percent of the samples displayed a pH value within the permissible limit of 6.5 to 8.5 (BIS 1998). In the pre-monsoon and post-monsoon seasons, EC varied from 650 to 1497 µS/cm and 650 to 1526 µS/cm, respectively. EC was found to be within the acceptable limit of 3000 µS/cm in 100% of the samples (BIS 1998). TDS values ranged widely from 321 to 729 mg/L to 325 to 730mg/L in pre and post-monsoon seasons respectively. During the pre- and post-monsoon seasons, TDS levels ranged from 321 to 729 mg/L to 325 to 730 mg/L. All of the samples had TDS levels below the acceptable limit of 2000 mg/L. (BIS 1998). A higher TDS indicates that the water contains more cations and anions. The highest correlation was found between EC and TDS with a correlation coefficient of 0.98.

Brindha and Elango (2011) conducted an experiment to evaluate the hydro-chemical characteristics of groundwater in Madhuranthakam, Tamil Nadu. Study revealed that the pH and EC values of irrigation water in the study area were varied from 7.2-8.2 and 200-1900 μScm^{-1}, respectively, with an average value of 7.69 and 807.6 μScm^{-1}.

Anions (Cl^- , CO_3^{2-} and HCO_3^-)

Kant *et al.* (2015) assessed the ground water quality of Lahar block of Bhind district, Madhya Pradesh, India. Total 40 water samples were collected from tube well and analysed water quality. The study revealed that chloride concentrations in water samples ranged from 1.90 to 15.30 Meq/L, carbonate concentrations ranged from 0.0 to 1.1 Meq/L, and bicarbonate concentrations ranged from 2.10 to 8.30 Meq/L.

Aher and Gaikwad (2017) conducted an experiment to evaluate the irrigation groundwater quality in the Nandgaon block of Maharashtra's Nashik district. For the analysis, water samples were taken from 52 dug wells used for irrigation. The study showed that chloride concentration of analysed samples varied from 36-304 mg/L with an average value of 98.77 mg/L and bicarbonate concentrations ranged from 88-676 mg/L with a mean of 229.62 mg/L.

Khan and Jhariya (2018) studied hydro-geochemistry and assess groundwater quality for drinking and irrigation purpose in Raipur district, Chhattisgarh. During the pre-monsoon season, a total of 100 groundwater samples were collected and analysed using standard methods. The study revealed that chloride concentration varied from 10 to 270 mg/L. Bicarbonate and carbonate ions was the primary sources of alkalinity in water. The action of carbon dioxide on basic materials in the soil causes these concentrations in water. Bicarbonate concentrations in the studied region varied from 18.3 to 439.2 mg/L, while carbonate concentrations ranged from 6.6 to 84.4 mg/L. The dominant anions were HCO_3>Cl>CO_3> SO_4>Fe>F>NH_3.

Nag and Das (2014) evaluated the quality of ground water for irrigation in SuriI and II blocks, Birbhum district, West Bengal, between the post-monsoon and pre-monsoon seasons of 2012 and 2013. In the post-monsoon era, the Bicarbonate ion ranges from 48.80 to 1073.60 mg L^{-1}, and in the pre-monsoon period, it ranges from 48.8 to 292.8 mg L^{-1}. In the research area, chloride concentrations in groundwater samples ranged from 15.0 to 124.96 mg L^{-1}in post-monsoon conditions and from 15.0 to 274.9 mg L^{-1}in pre-monsoon conditions. Water with too much chloride has a poor taste, and the chloride ion combines with Na (which comes from the weathering of granitic terrains) to form NaCl, which is salty and unfit for irrigation and drinking.

Kumar and Kumar (2013) conducted an experiment to assess the current status of physico-chemical contaminants and their sources in groundwater in Goramachia, Jhansi, UP, India. Groundwater samples from mining and residential areas were obtained in six separate locations and analysed. Chloride levels in the mining and residential areas of Goramachia ranged from 39 to 19 mg/L. In the residential area, it was found between the ranges of 39-19 mg/L, while in the mining area of Goramachia, it was found between the ranges of 35-34 mg/L, while the two samples taken in the months of January and May were undetectable.

Tabbal and Zboon (2012) analysed the groundwater for irrigation and drinking in Jordan's northern area and observing that HCO_3 levels in water samples ranged from 1.11 to 7.42 meq/L. Irrigation water with CO_2 concentrations greater than 0.1 meq/L and HCO_3 concentrations greater than 10 Meq/L is usually not recommended. Both of the samples are far below the permitted limit. As a result, all water samples collected in the research area can be used for long-term irrigation (Ayers and Westcot, 1994). The highest chloride concentration measured was 65.92 Meq/L, while the lowest was 0.564 Meq/L. It was discovered that EC and TDS have a strong positive relationship with Cl and a strong negative relationship with HCO3. Cl and EC were found to have the highest positively correlated values (r = 0.989).

Tiwari and Singh (2014) carried out hydro geochemical investigation and groundwater quality assessment of Pratapgarh District, Uttar Pradesh. A total of 55 groundwater samples were collected to assess water quality for irrigation and domestic uses. HCO_3 concentrations in groundwater samples ranged from 207 mg/L to 654 mg/L (on average 395 mg/L) and account for 65 percent of total anions in equivalent units. The main source of HCO_3 in groundwater is weathering of carbonate and/or alumino-silicate minerals, with a secondary contribution from CO_2 gas dissolution. In addition, the dissolution of carbonates and the weathering of silicate minerals may also create bicarbonate (Njitchoua and Ngounou, 1997). The chloride concentration in Pratapgarh district groundwater ranged from 4.8 to 743 mg/L, with an average of 158 mg/L. Groundwater chloride (Cl^-) may come from both natural and anthropogenic sources. The main lithogenic sources of chloride in groundwater are atmospheric precipitation, salt deposit dissolution, and weathering of halite and evaporite.

Cations (Na^+, K^+, Ca^{2+} and Mg^{2+})

Shashi *et al.* (2015) examined the quality of ground water in the Lahar block of Madhya Pradesh's Bhind district and reported that potassium levels ranged from 0.00 to 0.70 meq L^{-1}. The sodium concentrations ranged from 1.50 to 42.70 meq L^{-1}. Calcium and magnesium levels ranged from 2.5 to 32.0 meq L^{-1}. The pH value has a non-significant negative correlation (r=-0.121) with K^+.

Srinivasamoorthy *et al.* (2011) conducted a study to know groundwater quality in Salem district of Tamilnadu for determining its fitness for drinking and irrigation proposes. It was observed in study that calcium concentration in ground water samples were varied from 3.0 to 130 0 mg/L, potassium concentration ranged from 10 to 384 0 mg/L and sodium concentration from 33 0 to 8340 mg/L. The large quantity of major cations in the groundwater samples were in the order of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$.

Vasanthavigar *et al.* (2012) conducted a study on groundwater quality to determining its suitability for agricultural purposes in sub basin of Thirumanimuttar in Tamil Nadu. The results showed that concentration of Ca^{2+} in the water samples varied 16 – 0.228 0 mg/L, Mg^{2+} varied from 10.5-158.40 mg/L, Na^+ ranged from 0.80-1497.0 mg/L and K^+ varied from 0.80-497.0 mg/L. The order of concentration of major cations is $Na^+ > Ca^{2+} > Mg^{2+} > K^+$.

Singh *et al.* (2014) studied ground water quality in the Ranchi district of Jharkhand state. The study revealed that concentration of Ca^{2+} in the water samples ranged from 21.8 to 164 mg/L, Na^+ ranged from 14.2 to 752 mg /L, Mg^{2+} varied from

9.8 to 46 mg/L, and K^+ varied from 1.9 to 19.3 mg/L. In water samples, the abundance of cations was $Ca^{2+} > Na^+ > Mg^{2+} > K^+$.

Mendonsa and Vishnu (2019) examined five freshwater lakes in and around Mumbai, India. From September 2018 to March 2019, five lakes were chosen for sampling: Karnala Lake, Kala Talao Lake, Shivaji Talao Lake, Adharwadi Lake, and Jagannath Kasinath Salvi Talao Lake. The findings showed that in March, hardness (i.e. calcium and magnesium concentrations) varied from 96.1 to 28.05 mg/L, while in September, hardness varied from 88.17 to 24.04 mg/L.

Venkateswarana and Deepa (2015) evaluated the quality of ground water in the Vaniyar watershed of Dharmapuri district Tamil Nadu. During the pre-monsoon and post-monsoon seasons, total 60 groundwater samples were taken in a systematic manner. Their study concluded that the concentration of major cations in water samples such as Ca^{2+}, Na^+,Mg^{2+} and K^+ ranged from 1.25 – 17.02 mg/L, 1.04 - 15.75 mg/L , 1.90 - 14.72 mg/L, and 0.26 to 0.92 mg/L respectively.

Kumar *et al.* (2016) studied the shallow hard rock aquifer in Pudunagaram, Palakkad district, Kerala, to assess ground water quality. A total of 60 ground water samples were obtained during the post-monsoon and pre-monsoon seasons for this analysis. According to the result, calcium concentrations in water samples varied from 219-5 mg/L during the post-monsoon period and 776-20 mg/L during the pre-monsoon season. The sodium concentrations were 88.2-51.5 mg/L during the post-monsoon and 388-10.8 mg/L during the pre-monsoon.

Irrigation Water Quality Parameters (SAR, RSC, SSP, PI and KR)

Kant *et al.* (2015) conducted a study to evaluate the ground water quality of Lahar block, Bhind district, Madhya Pradesh. A total of 40 water samples were taken from the tube well and the water quality was assessed. The results showed that the SAR values ranged from 0.87 to 28.22, indicating that 82.50 percent of the region is suitable for irrigation and 17.50 percent of the area has a high to very high SAR for irrigation. Kelly's ratios ranged from 0.14 to 8.05, while SSP values varied between 8.95 and 12.56.

Aher and Gaikwad (2017) analysed the irrigation groundwater quality in Nandgaon block of Nashik district, Maharashtra. Water samples were taken from 52 dug wells irrigation water in an area of Nandgaon and it was observed that all the samples had SAR values less than 10 , it mean fall in excellent (S1= SAR <10) category and indicated that these groundwater supply are appropriate for irrigation purpose with no danger of exchangeable sodium. SSP varied from 0.57 to 9.57 nmeq/L, with average value 3.62 meq/L. SSP values less than 50 indicate good water quality, while SSP values greater than 50 indicate that the water is hazardous for irrigation (USDA, 1954). The groundwater is secure for irrigation purposes based on these requirements. The groundwater's PI value varies from 32.10 to 95.18, with an average of 63.18. PI values greater than 75 mean that the irrigation water is of high quality. If the PI values are between 25 and 75, it means that the water is of good quality for irrigation. However, PI values of 25 indicate that the water is unsuitable for irrigation. Kellys Ratio values in the research area ranged from 0.09 to 2.66. These results show that the majority of the KR for groundwater samples (83 percent) are within the acceptable limit of 1.0 and are appropriate for irrigation.

Guettaf *et al.* (2017) investigated the water quality of the Seybouse River in northeast Algeria between April and August 2010, and January and April 2011. In Seybouse River, the measured value of SAR varied from 1.44 to 6.94. There was an important association between irrigation water SAR values and the degree to which sodium was adsorbed by soil. RSC values in Seybouse River groundwater samples ranged from -9.60 to1.60 meq/L.

Khan and Jhariya (2018) conducted a research on hydro-geochemistry and groundwater quality in Raipur district of Chhattisgarh. During the pre-monsoon season, a total of 100 groundwater samples used for drinking and irrigation purpose were collected and analysed using standard methods. The study showed that in the groundwater samples, SAR value ranged from 0.44 - 2.9 and mean value was 1.4. Since the sodium adsorption ratio (SAR) is less than ten, it is ideal for irrigation. SAR represents sodium absorption by soil particles, which can increase with the amount of soluble sodium in the soil, posing an alkali hazard in the soil and obstructing crop production (Islam and Shamshad, 2009). The permeability index (PI) of most groundwater samples were fell into class II (25–75%), with just a few groundwater samples falling into class III (25%) indicating that groundwater was suitable for irrigation.

Kathane and Aher (2015) carried out a study to determine groundwater quality for domestic and agricultural functions in PTW-1 Watershed of Buldhana District, Vidharbha region, India. Samples were collected from 25 different locations during post-monsoon session. The study revealed that all analyzed samples fall in excellent S1 (SAR<10 meq/L) class, indicating that these groundwater supply are suitable for agricultural use. SSP varied from 0.61 to 4.30 meq/L, SSP < 60 meq/L characterize safe water while it was unsafe if > 60 meq/L. As per these criteria the groundwater is safe for agricultural purpose. RSC ranged from -11.95 to -2.37 meq/L with an average of -4.45 meq/L specify that the calculated RSC in general groundwater is suitable for irrigation Uses. PI ranged from 28.77 -43.60 meq/L with a mean of 36.09 meq/L, PI values fallen in between 25 and 75 meq/L, means it was good quality of water for irrigation.

Chapter III

MATERIALS AND METHODS

The materials and methods used in "**Assessment of Soil Fertility and Underground Water Quality of different Villages of Depalpur block of Indore district, Madhya Pradesh**" were discussed in this chapter. The information related to field survey of the town, collection of soil and water samples, and their analysis in Soil Science - Soil and Water Conservation Laboratory of Rajiv Gandhi South Campus, Barkachha, Banaras Hindu University are presented under the different sections and sub-section.

3.1 General description of Site

3.1.1 Geographic location

Depalpur is one of the four blocks of the Indore district, and is situated in rural Madhya Pradesh. It is located at an average elevation of 533 metres i.e.1748 feet above the mean sea level and it is located at 22.85°N 75.55°E. According to Census 2011 data the sub-district code of Depalpur tehsil is 03540. There are 3 towns, 147 villages, 42,763 houses, 38783 families and has a population of 2, 28,101 peoples in Depalpur block. Total area of Depalpur block is 797 km^2 in which 787.50 km^2 comes under rural area and 9.10 km^2 comes under urban area.

3.1.2 Weather and climate

The climate of Depalpur block and Indore district is distinguished by hot summers and evenly distributed rainfall during the southwest monsoon season. Monsoon season begins in the middle of June and lasts until the end of July. The district is located on the Malwa plateau and has a sub-tropical, semi-arid climate with lows of 4°C and 21°C and highs of 29°C and 43°C in the winter and summer seasons, respectively. The month of January is the coldest, and the temperature reaches its highest point in May. The area's average annual rainfall is 952.2 mm. The majority of the annual rainfall falls between mid-June and mid-September; winder rains are rare and unpredictable; and the South West Monsoon is responsible for the majority of precipitation.

Table 3.1.2a: Climate data of depalpur block

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature in °C	19	21.9	26.5	31.3	32.7	29.4	25.2	24.4	25	25.3	23	19.9
Avg. Temperature (Min.) in °C	12.4	15	19.2	24	26.2	25.1	23	22.4	21.8	19.8	17.1	13.5
Average Max temperature in °C	25.7	28.8	33.6	38.2	39.2	34.3	28.1	27.1	28.9	31	29.1	26.5
Average precipitation (mm)	5	6	5	3	9	152	356	307	144	28	11	7
Humidity (%)	44	37	25	20	29	56	82	85	78	51	43	44

(Source: Climate-data.org.)

3.1.3 Soils and Agriculture

The district's major soil types are medium black, shallow black, mixed red, and skeletal. It is made up of broad undulating plans of black cotton soil with flat-topped hills. The medium black soils range in thickness from 0.46 to 0.90 metres and are high in lime and lime nodules. Since the subsoil and partially disintegrated rock underneath allow for easy drainage, these medium black soils can be freely irrigated. The main crops of district are soybean and wheat.The Indore district is part of the Malwa plateau. The total land area is 381100 ha, with a net cultivated area of 252424 ha. Irrigation covers 166552 hectares of the total cultivated land. The major cropping patterns of Indore district are as follows:

Table 3.1.3a: Cropping pattern of Indore

Irrigated	Un-Irrigated
Soybean – Potato – Wheat	Soybean – Wheat
Soybean – Potato	Soybean – Gram
Soybean – Garlic	Maize– Wheat
Soybean – Wheat	Maize – Gram

3.1.4 Experimental site

Forty representative surface soil samples were collected from farmer’s field and simultaneously forty irrigation water samples were also collected from six different villages (Pitawali, Mendakwas, Palsoda, Chittoda, Kadoda and Kai) of Depalpur block of Indore district, Madhya Pradesh.

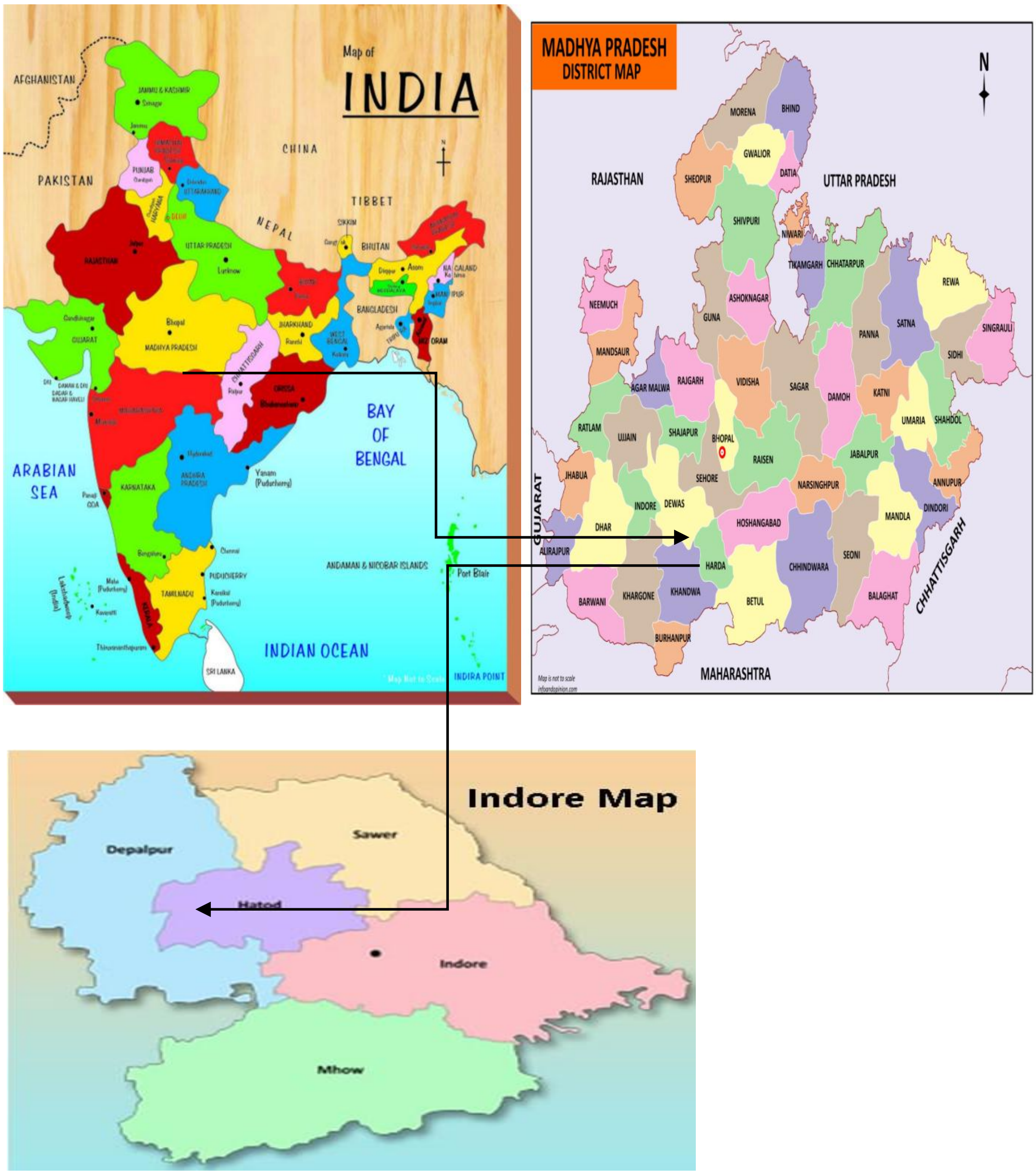


Figure 3.1.1a Location map

3.2 Method of soil sampling and processing

3.2.1 Collection of soil sample

Altogether 40 surface soil of the Undisturbed land of different villages of Depalpur block were sampled randomly to a depth of 0-15 cm in 'V' shape by the help of Spade from 40 different sites of different geomorphologic locations viz, upland, middle and lowland. The soil samples were mixed systematically and about one kilogram of composite samples was taken from each site. The Geographical locations of the sampling sites are represented in table 3.2.1.

Table 3.2.1a: Description of Soil sampling sites

Name of Village	Sample No.	Name Of Farmers	Location			Cropping System	
			Latitude	Longitude	Altitude (m)	Kharif	Rabi
Pitawali	S1	Mansingh Kumar Ji	22° 57' 18.297" N	75° 32' 37.441" E	449	Soybean	Wheat
	S2	Ratansingh Bisi Ji	22° 56' 39.718" N	75° 32' 34.195" E	455	Soybean	Chick pea
	S3	Jitendra Chouhan Ji	22° 56' 39.602" N	75° 32' 59.021" E	453	Soybean	Wheat
	S4	Kamal Panwar Ji	22° 56' 54.432" N	75° 33' 20.777" E	461	Maize	Gram
	S5	Dilip Prajapat Ji	22° 57' 28.288" N	75° 33' 3.473" E	456	Soybean	Wheat
	S6	Vikram Patel Ji	22° 57' 51.375" N	75° 32' 46.632" E	446	Soybean	Chick pea
	S7	Om Tanvar Ji	22° 57' 55.709" N	75° 33' 27.182" E	468	Maize	Wheat
	S8	Madansingh Patel Ji	22° 58' 1.373" N	75° 33' 41.040" E	460	Soybean	Wheat
Mendakwas	S9	Hariram Pipada Ji	22° 57' 53.564" N	75° 32' 17.313" E	434	Soybean	Wheat
	S10	Banesingh Tawar Ji	22° 57' 36.111" N	75° 31' 40.267" E	450	Maize	Gram
	S11	Nathu Choudhari Ji	22° 58' 6.563" N	75° 31' 51.554" E	458	Soybean	Wheat
	S12	Bhagat Panwar Ji	22° 57' 58.742" N	75° 31' 54.625" E	441	Soybean	Wheat
	S13	Maniram Kumhar Ji	22° 58' 9.034" N	75° 31' 26.815" E	460	Soybean	Wheat
	S14	Ganpat Seth Ji	22° 57' 28.353" N	75° 31' 22.029" E	455	Soybean	Chick pea
	S15	Ganga Bai Ji	22° 57' 8.263" N	75° 31' 56.369" E	454	Soybean	Wheat
	S16	Omprakash Khatod Ji	22° 56' 49.516" N	75° 32' 6.239" E	451	Soybean	Pea
Palsoda	S17	Bhagwan Patel Ji	22° 58' 27.558" N	75° 32' 7.209" E	439	Soybean	Wheat
	S18	Sunil Rathore Ji	22° 58' 19.894" N	75° 32' 26.967" E	448	Soybean	Wheat
	S19	Goverdhan Singh Ji	22° 58' 33.784" N	75° 32' 34.445" E	450	Soybean	Wheat
	S20	Ramprasad Parmar Ji	22° 58' 21.174" N	75° 32' 50.031" E	451	Soybean	Wheat
Chittoda	S21	Mukesh Rathore Ji	22° 58' 33.963" N	75° 33' 8.492" E	450	Soybean	Wheat
	S22	Hariram Patel Ji	22° 58' 20.002" N	75° 33' 28.791" E	453	Maize	Wheat
	S23	Ramkishan Jadhav Ji	22° 58' 5.727" N	75° 33' 21.190" E	457	Soybean	Wheat
	S24	Mulchand Dhayal Ji	22° 58' 9.235" N	75° 32' 19.809" E	457	Soybean	Wheat
Kadoda	S25	Babulal Rathore Ji	22° 57' 36.385" N	75° 34' 8.248" E	463	Soybean	Wheat
	S26	Dinesh Rathore Ji	22° 57' 15.807" N	75° 34' 40.857" E	452	Soybean	Wheat
	S27	Prahlad Chouhan Ji	22° 56' 54.495" N	75° 34' 48.674" E	452	Bajra	Gram
	S28	Pappu Kelwa Ji	22° 56' 39.016" N	75° 35' 2.474" E	455	Soybean	Wheat
	S29	Ghanshyam Rathore Ji	22° 57' 21.417" N	75° 35' 4.688" E	453	Soybean	Wheat
	S30	Nihal Singh Ji	22° 56' 59.936" N	75° 34' 25.546" E	452	Soybean	Chick pea
	S31	Shyam patel Ji	22° 56' 44.592" N	75° 34' 12.448" E	455	Soybean	Wheat
	S32	Pawan Rathore Ji	22° 56' 51.940" N	75° 33' 54.998" E	458	Soybean	Wheat
Kai	S33	Kamal Tanwar Ji	22° 56' 28.398" N	75° 34' 34.680" E	452	Maize	Wheat
	S34	Shivnarayan sankhla Ji	22° 55' 27.221" N	75° 32' 55.557" E	465	Soybean	Wheat
	S35	Parmanand Jadav Ji	22° 55' 54.979" N	75° 33' 9.015" E	463	Soybean	Wheat
	S36	Mukesh Sen Ji	22° 55' 20.334" N	75° 33' 30.539" E	461	Soybean	Pea
	S37	Jitendra Thakur Ji	22° 55' 31.311" N	75° 33' 51.790" E	460	Soybean	Wheat
	S38	Dinesh Badvaya Ji	22° 56' 4.971" N	75°33' 34.229" E	444	Soybean	Wheat
	S39	Shriram Jadav Ji	22° 56' 23.626" N	75° 33' 12.381" E	454	Soybean	Wheat
	S40	Sitaram Rathore Ji	22° 56' 16.106" N	75° 33' 55.374" E	449	Soybean	Wheat

3.2.2 Processing of soil sampling

Surface soil samples were collected and air dried in a room temperature before being transported to the laboratory. These soil samples were crushed, powdered, and grinded with a wooden roller before sieving with a 2.0 mm sieve. Finally, a representative sample of 1 kg was preserved in a labeled polythene bag for further laboratory study.

3.3 Analysis of soil samples

The soil samples were analyzed for various physical and chemical parameters. The physical parameters include bulk density (BD), particle density (PD), porosity and water holding capacity (WHC) whereas chemical parameters include pH, electrical conductivity (EC), organic carbon (OC), primary macronutrients(N,P,K), secondary macronutrients (Ca, Mg, S) and micronutrients (Fe, Mn, Zn and Cu).Reagents and solutions used in soil analysis are given below-

Table 3.3a: Reagents and solutions utilized in soil Testing

SOIL PARAMETERS	REAGENTS AND SOLUTIONS
pH	▪ Buffer solutions of 4.0, 7.0 and9.2 ▪ Suspension of soil and distilled water in a 1:2.5 ratio
EC	▪ Suspension of soil and distilled water in a 1:2.5 ratio
Nitrogen	▪ 2.5% Sodiumhydroxide ▪ Mixed indicator (0.1 of bromocrosol green and 100mlethanol) ▪ 2.5% Boricacid ▪ 0.32% Potassiumchromate
Phosphorous	**Acidic Medium** ▪ Bray’s reagent (0.03N ammonium fluoride + 0.025NHCL)

	▪ Ascorbicacid ▪ Molybdate tartrate solution (ammonium molybdate + antimony potassium tartrate + H_2SO_4) **Basic Medium** ▪ O.5N Sodium bicarbonate solution ▪ Dacro-g-60 charcoal ▪ Ammonium molybdate solution ▪ Ascorbic acid ▪ Antimony potassium tartrate solution ▪ 2.5M Sulphuric acid ▪ P-nitro phenol indicator
Potassium	▪ Standard potassium chloride solutions ▪ 1N Ammonium acetate solution
Calcium and Magnesium	▪ Ammonium acetate solution ▪ Aqua regia (HCL + HNO3) ▪ Erichrome black-T indicator ▪ EDTA (ethylene diamine tetra acetic acid) ▪ Muroxide indicator ▪ 4N NaOH buffer solution ▪ Ammonium chloride – ammonium hydroxide buffer solution
Organic Carbon	**Walkley and Black Rapid Titration Method** ▪ 1N potassium dichromate ▪ 0.5N ferrous ammonium sulphate ▪ Diphenylamine indicator ▪ Concentrated H2SO4 (sp.gr.1.84) ▪ Orthophosphoric acid or sodium fluoride
Sulphur	▪ 0.15% of calcium chloride ▪ Barium chloride crystals ▪ 0.25g of gum acacia ▪ Standard potassium sulphate solutions

3.3.1 Determination of Bulk density (BD)

The bulk density of the soil was determined using a Pycnometer, as suggested by Black (1965).

Procedure

On an electric balance, the clean dry pycnometer was taken and weighed. With the help of a spatula, soil was filled upto the brim of the pycnometer. The weight of the pycnometer with soil was then measured. The soil was then extracted from the pycnometer. A burette was filled with water, and water was dropped into the same pycnometer from burette until the pycnometer was completely filled with water. The reading will indicate the actual volume of the pycnometer. Then using this formula, the bulk density of the samples was calculated -

$$BD\ (g/cm^3) = \frac{Mass of soil}{Volume of soil}$$

3.3.2 Determination of Particle density (PD)

The particle density of the soil samples were analyzed using pycnometer (Black, 1965). **Procedure -**Using the weighing balance, the weight of a clean and dry pycnometer was taken first, followed by the weight of a pycnometer + water.Then 10 g of soil and 15 ml of water were combined in a beaker and boiled for a few minutes to expel the air. The boiled contents were then shifted to the pycnometer, which was then filled to the brim with water and weighed it on electric balance along with the cork. Particle density was determined based on these values.

Calculation

$$PD\ (g/cm^3) = \frac{10}{(W2+10)-W3}$$

- Mass of empty, clean, dry pycnometer (g) = W1
- Mass of pycnometer + water (g) = W2

- Mass of pycnometer + water + soil (g) = W3
- Mass of soil = 10g

3.3.3 Determination of Porosity

Porosity was determined by using Bulk density (BD) and Particle density (PD) values of the soil. The formula used to calculate porosity (%) was represented as

$$\text{Porosity (\%)} = \left[1- \frac{\text{BulkDensity}}{\text{ParticleDensity}}\right] \times 100$$

3.3.4 Determination of Water holding capacity (WHC)

The water holding capacity of the soils was determined using Piper's method (1966).

Procedure

A keen box was taken, and filter paper with the same diameter as the keen box was attached to the inner base of the box and weighed. The soil was placed in the keen box above the filter paper. The soil was added by tapping the box 20 times. After filling the soil, the upper surface was made nearly horizontal with a knife. The soil-filled box was then placed in a Petri dish filled with water and left for an hour after that the keen box containing the wet soil was placed in the oven @ 105˚C for 24hrs to dry. The weight of the box was taken with dry soil, and eventually, a filter paper of the same size as the keen box was submerged in water for one hour and weighted before and after wetting.

Calculation

$$\text{Saturation \%} = \frac{\text{Wet wt.} - \text{Dry wt.}}{\text{Dry wt.}} \times 100$$

3.3.5 Soil reaction (pH) determination

The pH of the soil was calculated using a pH metre after preparing a 1:2.5 (10g soil + 25ml distilled water) soil water suspension (Jackson, 1973).

Table 3.3.5a: Soils are rated based on their pH value:

Classes	Limit
Strongly acidic	< 5
Moderately acidic	5.6 – 6.5
Neutral	6.6 – 7.3
Alkaline	> 7.3

3.3.6 Electrical Conductivity (EC) determination

The soluble salt content was calculated by preparing a 1:2.5 soil water suspension and allowing it to settle until a clear supernatant formed. The electrical conductivity was calculated with an EC meter and is indicated in dSm^{-1} units (Jackson, 1973).

Table 3.3.6a: Soils are classified based on their EC values

Classes	EC (dSm^{-1})
All crops	<0.7
Most crops	0.7-2.0
Salt tolerant	2.0-10.0
Most halophytes	10-32
No crops (sea water)	>32

3.3.7 Determination of Organic Carbon (OC)

The organic carbon was calculated using the wet oxidation method proposed by Walkley and Black (1934).

Procedure

1g of soil sample was placed in a conical flask, followed by 10 ml of potassium dichromate (1 N $K_2Cr_2O_7$) solution. After adding 20 ml of sulphuric acid

(H_2SO_4) to the sample, the colour changed to green, indicating the presence of organic matter, and it was left for 30 minutes to oxidise. After that, 200 ml of distilled water and 0.5-1 ml of diphenylamine indicator were applied to the samples. When the colour changed to purple, the titration was repeated with ferrous ammonium sulphate until the colour changed to green and the titrated value was reported.A blank titration was also performed.

Calculation:

$$\% \text{ Organic Carbon (OC)} = N \times \frac{(B-C)}{wt.of soil} \times 0.003 \times 100$$

% organic matter (OM) = Organic Carbon (OC) × 1.724 (Van Bemmelen factor)

Where,

B = Volume of 0.5N ferrous ammonium sulphate (FAS) solution required to neutralize 10 ml of 1N of $K_2Cr_2O_7$ i.e. blank titration.

C = Volume of 0.5N ferrous ammonium sulphate (FAS) solution used for titration of soil sample.

N = Normality of $K_2Cr_2O_7$

3.3.8 Determination of Available Nitrogen (N)

The available nitrogen in soil was determined using a Semi-automatic Kjeldahl Nitrogen Analyzer (Kjeldahl Distiller) given by Subbiah and Asija (1956).

Procedure

5 g of soil sample was transferred to a distillation tube, and 5 ml of distilled water was used to wash out the adhering soil particles at the cylinder's neck. The semi-auto-analyser distillation tube was then set up, and 20 ml of pH 4 boric acid was taken in a 250 ml conical flask, and the outlet tube was inserted in the conical flask

containing boric acid. When the button on the instrument was pressed, 25 ml of sodium hydroxide solution was applied to the distillation tube. The distillation timer was set to 9 minutes.

Calculation

$$\text{Available N (kg/ha)} = \frac{(S-V)\times 0.02\times 14\times 2.24\times 10^{6}}{1000\times 5}$$

Where,

S = Sample titration reading

V = Blank titration reading

3.3.9 Determination of Available Phosphorous (P)

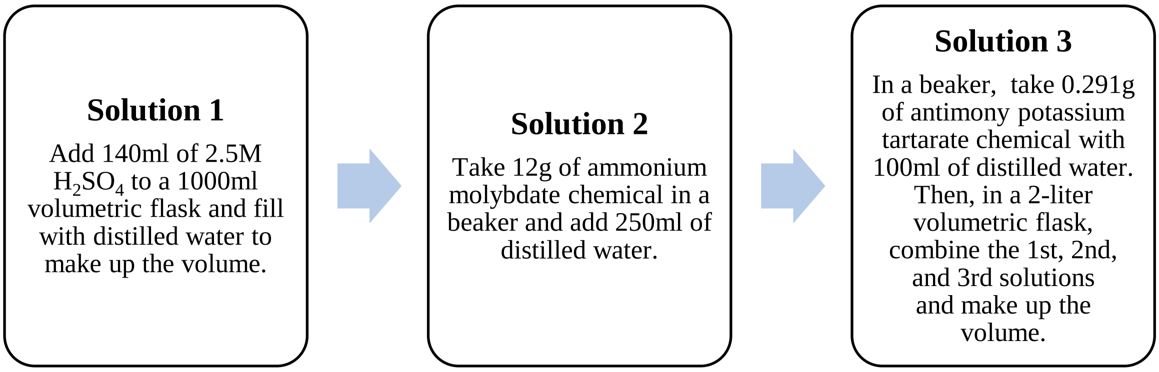
Soil phosphorus in the soil samples were evaluated by Olsen's (1954) method as soil samples were having pH more than 5.5. If pH is less than 5.5 than Bray's method is followed.

Olsen's method of P estimation

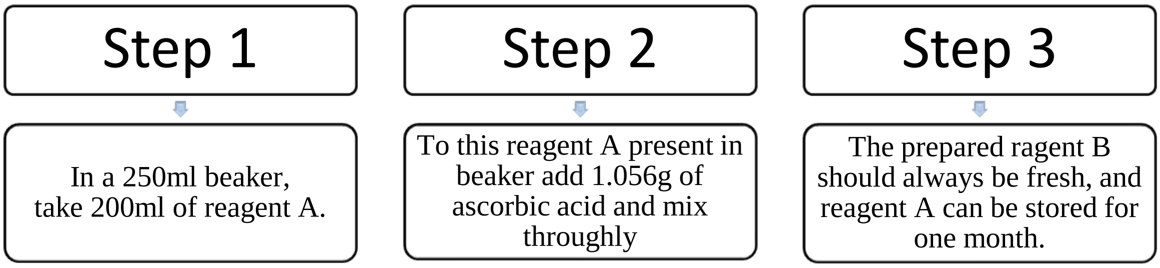
Procedure

First, reagents A and B were prepared. 2.5 g of soil was taken in a conical flask, and 50 ml of Olsen's reagent (0.5 M $NaHCO_3$) and a pinch of activated charcoal were added. The contents were shaken in a shaker for 30 minutes before being filtered through Whatman no. 1 filter paper. A 10 ml aliquot of this filtrate was placed in a 25 ml volumetric flask, and 2-3 drops of nitro phenol indicator were added drop by drop until the colour changed to yellow.After changing the colour to yellow, 2.5 ml of 2.5M H_2SO_4 was added drop by drop until the yellow colour was gone. Then 8 ml of reagent B (Murphey Riley colour reagent) was added, followed by 25 ml of distilled water. After 15 minutes, spectrophotometer readings at 730 nm were taken. Standard concentrations of 0, 1, 2, 3, 4, and 5 ppm were also prepared. A blank was also performed. Using regular prepared standard solutions, a calibration curve was plotted.

Preparation of reagent A



Preparation of reagent B (Murphey Riley colour reagent)



Calculation

$$\text{Available P (kg/ha)} = \frac{R \times \text{Volume of extractant} \times 2.24 \times 10^6}{\text{Volume of aliquot} \times 2.24 \times \text{wt of soil}}$$

Where

R = µg P in the aliquot (obtained from standard curve).

3.3.10 Determination of Available Potassium (K)

The available potassium in soil samples was extracted with a neutral normal ammonium acetate extractant and measured with a flame photometer (Schollenberger and Simon, 1945).

Procedure

5 g of soil sample was placed in a 100 ml conical flask, and 25 ml of extractant was added and shaken for 5 minutes. After shaking, the contents were immediately filtered into a beaker using Whatman no. 1 filter paper. A flame photometer was used to measure the potassium concentration in the filtrate. From a 1000 ppm potassium chloride solution, standards of 50 and 100 ppm were prepared (KCl). The standard reading was taken first, followed by the sample reading.

Calculation

Dilution factor = $\frac{25}{5}$= 5 times

Reading of the flame photometer for the test sample = C

Available Potassium (kg/ha) = C × 5 × 2.24

3.3.11 Analysis of Exchangeable Calcium

The exchangeable calcium in soil was evaluated by use of neutral normal ammonium acetate solution which was given by Jackson, 1973.

Procedure

5 g of soil sample was put in a 100 ml conical flask, and 25 ml of extractant was added to it. The contents were then shaken in a rotatory shaker for 5 minutes and filtered with Whatman no. 1 filter paper and calcium was determined after pre-treatment. Along with pre-treatment, 5 ml of sample was pipetted into a conical flask and diluted to a volume of 25 ml with distilled water. The sample was then treated with 5 drops of 4N sodium hydroxide buffer solution and 50 mg of Muroxide indicator. The sample was titrated with 0.01N EDTA until the colour changed from orange red to purple, and the titrated value was recorded.

Calculation

Amount of Ca (Meq/L) $=\frac{R\times Normality of EDTA\times 1000}{Aliquot(ml) taken}$

Amount of Ca (Meq/100g) = $\frac{100}{Soil\ weight(g)}\times\frac{Extract\ volume(ml)}{100}\times$Amount of Ca (meq/L)

Where,

R= Volume (ml) of standard EDTA used in titration

3.3.12 Analysis of Exchangeable Calcium + Magnesium

The analysis of exchangeable Calcium + Magnesium in soil was done by use of neutral normal ammonium acetate solution (Jackson, 1973).

Procedure

5 g of soil sample was put in a 100 ml conical flask, and 25 ml of extractant was added to it. The contents were then shaken in a rotatory shaker for 5 minutes and filtered with Whatman no. 1 filter paper and calcium was determined after pre-treatment. Along with pre-treatment, 5 ml of sample was pipetted into a conical flask and diluted to a volume of 25 ml with distilled water. The sample was then treated with 10 drops of ammonium chloride-ammonium hydroxide buffer solution and 4 drops of Erichrome black-T indicator. The sample was titrated with 0.01N EDTA until the colour changed from wine red to blue, and at that point the titrated value was recorded. To calculate the magnesium content of a soil sample, the calcium + magnesium content of the soil sample was subtracted from the calcium content of the soil sample.

Calculation

Amount of Ca + Mg (Meq/L) = $\frac{\mathrm{R\times Normality\ of\ EDTA\times 1000}}{\mathrm{Aliquot(ml)\ taken}}$

$$\text{Amount of Ca + Mg (Meq/100g)} = \frac{100}{Soilweight(g)} \times \frac{Extractvolume(ml)}{100} \times \text{Ca + Mg (Meq/ L)}$$

$$\text{Amount of Mg (Meq/L)} = \text{Ca + Mg (Meq/L)} - \text{Ca (Meq/L)}$$

Where,

R= Volume (ml) of standard EDTA used in titration

Pre-treatment to determine exchangeable Calcium and Calcium + Magnesium in soil

1.Transfer ammonium acetate extractant to 250ml beaker and evaporate the content on water bath. → 2. Wash the walls of the beaker with a small amount of water and let it evaporate again. → 3. Add 3ml of hydrochloric acid and1ml of nitric acid and. → 4. After evaporation, dissolve the residue in 20ml 0.1N acetic acid. → 5. Filter into a 50ml volumetric flask using Whatman no. 1 filter paper and dilute the volume.

3.3.13 Analysis of Available Sulphur

Sulphur was analysed in the soil samples by Turbidimetric method (Chesnin and Yien, 1950).

Procedure

10 g of soil was taken and 50 ml of 0.15 percent calcium chloride extractant was added to the samples. The materials were then shaken for 30 minutes in a shaker before being filtered through Whatman no. 1 filter paper. Then, 10-20 ml of filtrate was transferred to a 25 ml volumetric flask, along with 2 ml of gum acacia solution to maintain the contents, and the volume was made up. The contents were then shaken in a shaker for 10 minutes, and spectrophotometer readings at 340 nm were taken. From

100 ppm potassium, working standards of 0.25, 0.5, 1.0, 2.5, and 5.0 were also prepared. The following formula was used to calculate the available Sulphur (mg/Kg):

Calculation

$$\text{Available Sulphur (mg/Kg)} = R \times \frac{50}{10} \times \frac{1}{10}$$

Where,

R stands for S content in µg as read on X-axis

Table 3.3b: Rating chart of different analysed soil nutrients

Nutrients	Low	Medium	High
Organic carbon (%)	<0.5	0.5-0.75	>0.75
Available N (kg/ha)	<280	280-560	>560
Available P (kg/ha)	<12.5	12.5-25	>25
Available K (kg/ha)	<135	135-335	>335
Available S (mg/kg)	<10	10-20	>20
	Deficient	**Sufficient**	
Magnesium(meq/100g)	<1.5	>1.5	-
Calcium (meq/100g)	<1.0	>1.0	-

3.4 Methodology for soil nutrients status determination

Individual soil samples were classified into three fertility classes based on their nutrient index values calculated from soil test summaries, with the percentage distribution divided into low, medium, and high categories. According to Muhret al. (1963), the nutrient index is calculated using the following formula:

$$\text{Nutrient Index (N.I.)} = \frac{[\text{\% in high category x 3 + \% in medium category x 2 + \% in low category x 1}]}{100}$$

In this percent assessment, a nutrient index less than 1.5 denotes low fertility, while one between 1.5 and 2.5 denotes medium fertility. A value of 2.5 or higher (maximum 3.00) indicates a high fertility class for that nutrient (Ghosh and Hasan, 1976). Individual soil test values were classified into three classes based on above-mentioned limits, (Ramamoorthy and Bajaj, 1969).

Table 3.4a: Rating Chart of Nutrient Index

S.No.	Nutrient Index	Value	Interpretation
1	Low	<1.67	Low fertility status of thearea
2	Medium	1.67-2.33	Medium fertility status of thearea
3	High	2.33	High fertility status of thearea

3.5 Collection of Ground Water Samples

Total of 40 ground water samples were collected from 6 different villages of Depalpur block of Indore district. Water samples were collected in plastic bottles and were symbolised. 2-3 drops of toluene was added in the samples to prevent the growth of microbes. The brief description of water samples were given below in table.

Table 3.5a: Description of Water sampling sites

Name of Village	Sample No.	Name of Farmers	Location			Irrigation Source
			Latitude	Longitude	Altitude (m)	
Pitawali	S1	Munna singh Ji	22° 57' 20.384" N	75° 32' 33.587" E	460	Bore well
	S2	Bhawarlal Ji	22° 57' 34.165" N	75° 32' 52.715" E	450	Bore well
	S3	Ratan bisi Ji	22° 56' 43.610" N	75° 32' 48.846" E	447	Bore well
	S4	Ram lal Ji	22° 56' 33.742" N	75° 32' 58.335" E	466	Bore well
	S5	Gajraj Singh Ji	22° 56' 57.759" N	75° 33' 8.029" E	450	Bore well
	S6	Mansingh Ji	22° 57' 44.123" N	75° 33' 35.442" E	451	Bore well
	S7	Mangu Ji	22° 57' 28.467" N	75° 33' 6.230" E	432	Bore well
	S8	Kundan Ji	22° 57' 47.660" N	75° 33' 15.841" E	455	Bore well
Mendakwas	S9	Rahul Suner Ji	22° 58' 5.433" N	75° 31' 49.858" E	446	Bore well
	S10	Bhagat Solanki ji	22° 57' 57.484" N	75° 32' 4.718" E	450	Bore well
	S11	Satyanarayan Ji	22° 57' 42.674" N	75° 32' 12.248" E	457	Bore well
	S12	Shyam Patel ji	22° 58' 4.976" N	75° 31' 31.356" E	456	Bore well
	S13	Kailash Ji	22° 57' 28.521" N	75° 31' 28.389" E	454	Bore well
	S14	Meharwan Ji	22° 57' 15.020" N	75° 31' 27.846" E	453	Bore well
	S15	Mahesh dabi Ji	22° 57' 9.254" N	75° 31' 46.531" E	454	Bore well
	S16	jitendra Chouhan ji	22° 57' 46.521" N	75° 31' 43.612" E	454	Bore well
Palsoda	S17	Vikash Patel Ji	22° 58' 31.953" N	75° 32' 30.577" E	442	Bore well
	S18	dasharath Rathore Ji	22° 58' 27.618" N	75° 32' 52.365" E	448	Bore well
	S19	Ganpat Ji	22° 58' 37.149" N	75° 32' 12.618" E	441	Bore well
	S20	Yashwant Dayal Ji	22° 58' 29.018" N	75° 32' 17.844" E	448	Bore well
Chittoda	S21	Dharmendra ji	22° 58' 10.570" N	75° 33' 8.492" E	448	Bore well
	S22	Bharat Patel ji	22° 58' 15.978" N	75° 32' 34.372" E	449	Bore well
	S23	Shriram Rathore Ji	22° 58' 12.762' N	75° 32' 56.490" E	461	Bore well
	S24	Pira Singh Ji	22° 58' 11.815" N	75° 33' 30.818" E	447	Bore well
Kadoda	S25	Dinesh Rathor Ji	22° 57' 34.187" N	75° 34' 43.247" E	454	Bore well
	S26	Babulal Ji	22° 57' 14.934" N	75° 35' 2.594" E	413	Bore well
	S27	Ishawar Patel Ji	22° 57' 2.175" N	75° 35' 14.504" E	458	Bore well
	S28	Dheeraj Chouhan Ji	22° 57' 23.187" N	75° 34' 8.978" E	459	Bore well
	S29	Vishal Rathore Ji	22° 57' 13.065" N	75° 34' 40.182" E	456	Bore well
	S30	Ganshyam Ji	22° 56' 56.340" N	75° 34' 45.615" E	464	Bore well
	S31	Gulab Singh Ji	22° 56' 39.942" N	75° 34' 44.509" E	455	Bore well
	S32	Pratap Singh ji	22° 56' 52.837" N	75° 34' 15.153" E	457	Bore well
Kai	S33	Arun Rathore Ji	22° 55' 37.213" N	75° 32' 55.811" E	466	Bore well
	S34	Dinesh Badwaya Ji	22° 56' 5.936" N	75° 33' 25.363" E	463	Bore well
	S35	Lakhan Patel Ji	22° 56' 12.037" N	75° 32' 54.147" E	460	Bore well
	S36	Shrawan Rathore Ji	22° 55' 56.496" N	75° 33' 37.045" E	460	Bore well
	S37	Anil Patel Ji	22° 56' 3.570" N	75° 33' 53.701" E	457	Bore well
	S38	Sohan Ji	22° 55' 30.999" N	75° 33' 52.339" E	464	Bore well
	S39	Hariom Ji	22° 55' 40.359" N	75° 33' 26.510" E	463	Bore well
	S40	Amar Singh Ji	22° 55' 53.840" N	75° 33' 7.716" E	453	Bore well

3.6 Analysis of water samples

The collected water samples were tested in a laboratory for chemical and water quality parameters such as pH, EC, sodium, potassium, bicarbonate, chloride, calcium, magnesium, SAR, RSC, SSP, PI, and KR using standard methods defined by APHA in 1992. Reagents and solutions used in water analysis are given below-

Table 3.6a: Reagents and solutions utilized in water testing

WATER PARAMETERS	**REAGENTS AND SOLUTIONS**
pH	▪ Buffer solution of pH 4.0, 7.0 and9.2
EC	▪ 0.01N KCLsolution
CO_3 and HCO_3	▪ 0.05N Standard sulphuric acid ▪ Methyl redindicator ▪ Phenolphthaleinindicator
Calcium and Magnesium	▪ 0.01N EDTAsolution ▪ Muroxideindicator ▪ Sodium diethyl dithio carbamatecrystals ▪ 4N NaOH buffersolution ▪ Erichrome black-Tindicator ▪ Ammonium chloride-ammonium hydroxidebuffer
Sodium	▪ Standard sodium chloridesolution
Chloride	▪ 0.02N Silver nitratesolution ▪ 0.02N Sodium chloridesolution ▪ Potassium chromateindicator
Potassium	▪ Standard potassium chloridesolution

3.6.1 Measurement of Water Reaction (pH)

For analysis of water pH suitable quantity of water sample was taken in 50 ml beaker and measured using pH meter as described by APHA, 1992.

3.6.2 Measurement of Electrical Conductivity (EC)

To determine the EC of water, a suitable amount of water was taken in a 50 ml beaker and calculated using an EC metre as defined by APHA in 1992, and the results were expressed in dS/m.

3.6.3 Measurement of Chloride (Cl^-)

Chloride in water samples was measured by Mohr's titration method (APHA, 1992).

Procedure

In a conical flask, 5 ml of water sample was pipetted out and diluted with 25 ml of distilled water. The samples were then treated with 5-6 drops of potassium chromate indicator (K_2CrO_4), which changed the initial colour to dark yellow. It was then titrated with 0.02N silver nitrate solution until the final colour was brick red.

Calculation:

$$Cl^- \text{ meq/L} = \frac{Normality\ of\ AgNO_3 \times vol.\ of\ AgNO_3 \times 1000}{ml\ of\ aliquot\ used}$$

$$Cl^- \text{ meq/L} = \frac{Normality\ of\ AgNO_3 \times vol.\ of\ AgNO_3 \times 1000}{ml\ of\ aliquot\ used} \times Eq.wt.of Cl^- (35.5)$$

3.6.4 Measurement of Carbonates ($CO3^{2-}$) and Bicarbonates (HCO_3^-)

A basic acidimetric titration method was used to evaluate carbonates and bicarbonates in water samples (APHA, 1992).

Procedure

5 ml sample of water was pipetted into a conical flask and diluted to a volume of 25 ml with distilled water. Then 2 drops of phenolphthalein indicator were added to the samples, the colour did not change to pink, indicating that carbonates were not present in the water samples. So, 2 drops of methyl orange indicator were added to the

same water samples, and the initial colour changed to yellow. It was then titrated with 0.01N sulphuric acid until the final colour changed to rose red, and the burette volume was recorded.

Calculation

$$CO_3^{2-}\ (meq/L) = \frac{Normality of H_2\,SO_4 \times vol. of H_2\,SO_4 \times 1000}{ml\ of\ aliquot\ taken}$$

$$CO_3^{2-}\ (mg/l) = \frac{Normality of H_2\,SO_4 \times vol. of H_2\,SO_4 \times 1000}{ml\ of\ aliquot\ taken} \times Eq.wt.\ of\ CO_3^{2-} (30)$$

$$HCO_3^-\ (meq/L) = \frac{Normality of H_2\,SO_4 \times vol. of H_2\,SO_4 \times 1000}{ml\ of\ aliquot\ taken}$$

$$HCO_3^-\ (mg/l) = \frac{Normality of H_2\,SO_4 \times vol. of H_2\,SO_4 \times 1000}{ml\ of\ aliquot\ taken} \times Eq.\ wt\ of\ HCO_2^{3-}\ (61)$$

3.6.5 Measurement of Calcium (Ca^{2+}) and Magnesium (Mg^{2+})

The complexometric titration method was used to assess calcium and magnesium levels in water samples.

Procedure

In a conical flask, 5 ml of water sample was diluted with 25 ml of distilled water. Then, to avoid contact with other metal ions, 1 ml of ammonium hydroxide-ammonium chloride buffer solution was added, along with a pinch of carbamate crystals. After that, 2-3 drops of Erichrome Black-T indicator were added; the initial colour was pink. It was titrated with 0.01N EDTA solution until the final colour appeared to be blue.

Calculation

$$Ca^{2+}\ and\ Mg^{2+}\ (meq/L) = \frac{Normality of EDTA \times vol. of EDTA \times 1000}{ml\ of\ water\ sample\ taken}$$

$$Ca^{2+}\ and\ Mg^{2+}\ (mg/L) = \frac{Normality of EDTA \times vol. of EDTA \times 1000}{ml\ of\ water\ sample\ taken} \times Eq.\ wt.\ of\ Ca^{2+}\ and\ Mg^{2+}$$

3.6.6 Measurement of Calcium (Ca^{2+})

Calcium in water samples was analysed by using Complexometric titration method.

Procedure

In a conical flask, 5 ml of water was taken and diluted with 25 ml of distilled water. Then a pinch of carbamate crystals and 5 ml of sodium hydroxide buffer solution were applied to avoid contact with other metal ions. The initial colour was changed to pink by adding 40 mg of mixed Muroxide indicator (0.5g Muroxide + 40g potassium sulphate). With 0.01N EDTA solution, it was titrated until the final colour purple emerged.

Calculation

$$Ca^{2+}(meq/L) = \frac{Normality of EDTA \times vol. of EDTA \times 1000}{ml\ of\ water\ sample\ taken}$$

$$Ca^{2+}(mg/L) = \frac{Normality of EDTA \times vol. of EDTA \times 1000}{ml\ of\ water\ sample\ taken} \times \text{Eq. wt. of } Ca^{2+}(20)$$

3.6.7 Measurement of Sodium (Na+) and potassium (K^+)

Since sodium and potassium are water soluble, they were easily measured using the flame photometer method using NaCl and KCl as standards, respectively (APHA, 1992).

Table 3.6b: Rating chart of different Analyzed water parameters

Parameters	Suitable	Moderately suitable	Not suitable
pH	6.5 – 8.4	0 – 5.0	>9.5
EC(dS/m)	<0.3	3.0 – 7.0	>7.0
HCO_3^-(meq/L)	>1.25	1.25 – 8.5	8.5
Cl^-(meq/L)	<4.0	4.0 – 10.0	>10.0
Na^+(meq/L)	<3.0	3.0 – 9.0	>9.0

(Source: FAO.org)

3.7 Irrigation Water Quality Index (IWQI)

Irrigation water quality is highly dependent upon both the type and quantity of salts dissolved in it. The primary parameters of water quality are mainly determined through irrigation water quality index. The irrigation water quality varies from location to location, in regions, countries etc. The important factors which determine the water quality are salinity and alkanity conditions of the irrigated area. Water quality is the most important component in respect to sustainable use of water for irrigated agriculture. The basic criteria for evaluating the water quality for irrigation purpose are: Relative proportion of sodium to other Cations expressed as Sodium Absorption Ratio (SAR), Total salt concentration expressed by electrical conductivity, bicarbonate content, Residual Sodium Carbonate (RSC), Permeability index (PI), Soluble sodium percentage, Kelly's ratio (KR).

Computation of WQI

WQI is generally calculated by following method:

1. Calculation of quality rating for selected water parameters

$$Qi = \frac{(VA-VI)}{(VS-VI} \times 100$$

Where,

Qi = Quality rating of ith parameter for a total of n water quality parameters.

VA = Actual value of the water quality parameter obtained from laboratory analysis

VB = Ideal value of that quality parameter can be obtained from the standard table by BIS.

VI for pH = 7 and for other parameters it is equating to zero and DO V ideal = 14.6 mg / L

Vs = Recommended BIS standard of the water quality parameter.

2. Calculation of Unit weight (Wi)

Calculation of unit weight is done by value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following equation:

$$W = \frac{K}{SI}$$

Where,

WI = Unit weight for nth parameter,

K = Proportionality constant assumed as 1,

SI = Standard permissible value for nth parameter

3. Calculation of WQI is done by aggregating the quality rating with unit weight linearly using the following equation

$$WQI = \frac{\sum WIQI}{\sum WI}$$

Where,

QI = Quality rating,

WI = Unit weight

Table 3.7a: The range of WQI, quality status and conceivable usage of water

WQI	**Water quality status**
<50	Excellent
50-100	Good
101-200	Poor
201-300	Very poor
>300	Unsuitable

(*Source: ICAR research bulletin***)**

Table 3.7b: Water quality parameters as per BIS standards(All are in mg/l except pH and EC)

Parameters	BIS Standards
pH	7.5
Electrical Conductivity	0.3
Total Hardness	300
Calcium	75
Magnesium	30
Alkalinity	200
Bicarbonate	300
Sodium	200
Potassium	20
Chloride	250

(Source: BIS 1991)

3.7.1 Sodium Adsorption Ratio (SAR)

SAR is a unit of measure for crop alkali/sodium hazard. SAR is calculated using the formula below, where all ion concentrations are measured in meq/L.

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

Table 3.7.1a: SAR-based classification of irrigation water (Richards)

SAR (Meq/L)	Classes
0-10	Low sodium
10-18	Medium
18-26	High
>29	Very high

3.7.2 Soluble Sodium Percentage (SSP)

Soluble sodium percentage allows the identification of sodium content, which is important when analyzing sodium hazard. High SSP inhibits plant growth and reacts with soil to reduce permeability. The SSP is calculated using the formula below and is expressed in Meq/L (Todd 1980).

$$\text{SSP (Meq/L)} = \frac{(Na^{+}+K^{+})\times 100}{\mathrm{Ca}^{2+}+\mathrm{Mg}^{2+}+Na^{+}+K^{+}}$$

Table 3.7.2a: Irrigation water classification based on SSP (Todd)

SSP	Classes
<20	Excellent
20-40	Good
40-60	Permissible
60-80	Doubtful
>80	Unsuitable

3.7.3 Residual Sodium Carbonate (RSC)

The residual sodium bicarbonate index is used to assess the alkalinity risk in water. When sodium concentrated water is applied to clay soil, it swells and disperses soil particles, reducing the soil's infiltration capacity. The RSC is calculated using Eaton's (1950) formula, and it is expressed in meq L^{-1}.

$$\text{RSC (meq L}^{-1}) = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

Table 3.7.3a Irrigation water classification based on RSC

RSC	Classes
<1.25	Suitable
1.25-2.50	Moderately suitable
>2.50	Not suitable

3.7.4 Kelly's ratio (KR)

The suitability of water for irrigation is also evaluated using Kelly's ratio (Kelly 1953). Kelly's ratio is the ratio of sodium to calcium and sodium to magnesium. Groundwater with a Kelly's ratio greater than one (>1) is considered unsuitable for irrigation, while groundwater with a Kelly's ratio less than one (<1) is considered suitable. Kelly's ratio was measured using the expression below, which is expressed in meq/L.

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

3.7.5 Permeability Index (PI)

Consistent irrigation water use reduces permeability by increasing the presence of sodium, calcium, magnesium, and bicarbonate in the soil (Chandu et al 1995). The permeability index (PI) is used to measure the suitability of water for irrigation purpose when compared with the total ions in meq/L.

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{2+}\ Mg^{2+} + Na^{+}} \times 100$$

Table 3.7.5a: Irrigation water classification based on PI

PI	Classes
>75	Suitable
25-75	Moderately suitable
<25	Not suitable

Table 3.8: Instruments and Apparatus used in Soil and Water Analysis

INSTRUMENTS	USES
pH meter	For measuring soil and water reaction (pH)
EC meter	For measuring salinity in soil and total dissolved salts (TDS) in water
Hot Air Oven	For drying the soil samples for 24hrs @105˚C
Flame Photometer	For measuring the soil and water potassium, sodium & calcium content
Spectrophotometer	For measuring phosphorus content in soil
Water Bath	To evaporate the contents
Shaker	For uniform mixing
Weighing Balance	To measure the chemicals in grams or kilograms
Semi-Auto Nitrogen Analyzer	For estimation of available nitrogen in soil

3.9 Statistical Analysis

The statistical data for soil and water parameters, such as mean, standard deviation, coefficient of variation and range were calculated and correlation coefficient for such parameters were computed using SPSS statistical software. The formulas for calculating statistical data are as follows:

1. Mean = $\frac{Sumofallsamplesvalues}{Totalnumbersofsample}$

2. Range = largest value (L) – smallest value (S)

3. Standard Deviation (SD) = $\sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}}$

Where,

Σx^2 = Sum of all samples values

$(\Sigma x)^2$ = Sum of squares of all samples values

n = Total number of samples

4. Coefficient of Variation (CV) = $\frac{\text{SD}}{\text{Mean}} \times 100$

Using standard statistical methods, the relationship between related soil properties and available cationic micronutrients in soils was estimated. The correlation coefficient was calculated with the following formula: (Shedecon and Cochoram, 1967).

5. $r = \sqrt{\frac{SP(xy)}{[SS(x)][\,SS(y)]}}$

Where,

r = Correlation coefficient

SP (xy) = Sum product of x, y variables

SS (x) = Sum of square of x variable

SS (y) = Sum of square of y variable

Chapter IV

RESULTS AND DISCUSSION

The assessment of soil fertility and underground water quality of different villages of Depalpur block of Indore district, Madhya Pradesh, India" is our prime objective. To accomplish this, 40 soil and 40 water samples were collected randomly from fallow fields of the farmers and the ground water used for cultivation, respectively from different villages of Depalpur block. In this study, attempts were made to determine the quality of soil and water using different quality criteria, and the results were interpreted and a nutrient map was plotted. Possible explanations for variance in the data were discussed with the help of observations, and possible causes identified by appropriate sources were cited to justify the results. The results of the present study are presented under the following headings:-

4.1 Analysis of soil parameters

4.1.1 Physico-chemical properties of soil.

4.1.2 Status of available primary macronutrients in the soil.

4.1.3 Status of available secondary macronutrients in the soil.

4.1.4 Soil nutrient index value (NIV).

4.1.5 Correlation matrix between physico-chemical properties of soil.

4.2 Analysis of water parameters

4.2.1 Physico-chemical parameters of ground water

4.2.2 Status of anions in ground water.

4.2.3 Status of cations in ground water.

4.2.4 Irrigation water quality index (IWQI).

4.2.5 Correlation matrix between physico-chemical properties of ground water.

4.1 Analysis of soil parameters

4.1.1 Physico-Chemical properties of soil

The data on the physico-chemical properties such as BD, PD, WHC, Porosity, pH, EC and OC of soil are given in the Table 4.1.1 and in Appendix 1 and 2.

The data shows that value of bulk density in soil samples varied from 1.24-1.57 g/cm^3 with a mean value of 1.40 g/cm^3. The standard deviation of bulk density was 0.09 and coefficient of variation was 6.40 %. Sample no. 6 and 10 of Pitawali and Mendakwas village founded lowest bulk density, this may be because of the presence of high organic carbon content and sample no. 20 of Palsoda village reported highest bulk density which may be due to high intensive agricultural practises in the field which resulted in soil compaction. Deoli *et al.* (2020) recorded similar incidents in saheshpur block of dehradun. The partical density of soil samples ranged from 2.12-2.81 g/cm^3 with an average value of 2.59 g/cm^3.The standard deviation of partical density is 0.13 and coefficient of variation is 5.06 %. Sample no. 40 of Kai village reported lowest partical density and sample no. 15 and 37 of Mendakwas and Kai village reported highest partical density.

Table 4.1.1: Statistical analysed data on physico-chemical parameters of soil

Soil parameters	**Range**	**Mean**	**S.D±**	**C.V (%)**
Bulk density (Mg/m$^{3)}$	1.24-1.57	1.40	0.09	6.40
Particle density (Mg/m^3)	2.12-2.81	2.59	0.13	5.06
Water holding capacity (%)	38.24-62.85	55.51	4.14	7.46
Porosity (%)	36.02-55.16	46.03	4.46	9.68
pH	7.4-8.9	8.21	0.34	4.09
EC(dS/m)	0.12-0.47	0.21	0.06	26.54
Organic carbon (%)	0-1.99	0.69	0.47	67.89

The porosity percentage of the soil samples ranged from 36.02 to 55.16 % with the mean value of 46.03 %. The standard deviation (S.D.) of porosity % was reported as 4.46 and coefficient of variation was 9.68%. The highest value (55.16%) observed in sample no. 15 of Mendakawas village and lowest value (36.02%) observed in sample no. 38 of Kai village. The findings showed that as soil particles erode, they fill up the pore spaces, raising the bulk density of the soil and decreasing the porosity. Sample no. 38 had a low porosity value because of its high bulk density (1.51 g/cm^3), while sample no. 15 had a high porosity value because of its low bulk density (1.26 g/cm^3).The values of Water holding capacity of the soil samples varied from 38.24 to 62.85 % with the mean value of 55.51 %. The values of S. D. and C. V. for water holding capacity were 4.14 and 7.46, respectively. The lowest water holding capacity (38.24%) was reported in sample no. 20 of Palsoda village, this is due to nill organic carbon content in the soil sample and highest water holding capacity (62.85 %) was observed in sample no. 28 of Kadoda village as there is high organic carbon content in sample. So the results shows that increase in the organic carbon content, higher will be the water holding capacity of the soil.

Values of pH in soil samples varied from 7.4 to 8.9 with a mean of 8.21. The values of S. D. and C. V. for soil pH were 0.34 and 4.09, respectively. The lowest pH value (7.4) was reported in sample no. 4 of Pitawali village whereas highest pH value (8.9) was observed in sample no. 29 of Kadoda village. The results concluded that 100 % of the samples are alkaline in nature. Similar results were reported by Wani *et al. (2014)* and Chaurasia *et al. (2013)* in Gwalior city of Madhya Pradesh and Varanasi of Uttar Pradesh respectively.

Table 4.1.1a: Classification of Soil Samples Based on Their pH Range

Classes	Range	No. of samples	% of samples
Strongly acidic	<5.5	0	0
Moderately acidic	5.6-6.5	0	0
Neutral	6.6-7.3	0	0
Alkaline	>7.3	40	100

(Source: Natural Resource Conservation service)

The Electrical Conductivity of the analyzed soil samples ranged from 0.12 to 0.47 dS/m with a mean value of 0.18 dS/m. The S.D. and C.V. values were observed as 0.06 and 26.54 %, respectively. The lowest EC value (0.18 dS/m) was reported in sample no. 4 of Pitawali village while highest value (0.47 dS/m) was reported in sample no. 33 of Kai village. According to the results it is found that 100 % of the soil samples were in permissible range, suitable for all type of crops as salinity was not a concern in these soils. Similar results were reported by Bharteey and P.K. *(2017)* in soils of the Narayanpur block of the Mirzapur district of Uttar Pradesh.

Table 4.1.1b: Soil Sample's Classification Basedon Different EC Range

Classes	Range	No. of samples	% of samples
All crops	<0.7	100	100%
Most crops	0.7-2.0	0	0%
Salt tolerant crops	2.0-10.0	0	0%
Most halophytes	10-32	0	0%
No crops (sea water)	>32	0	0%

The organic carbon content in soil samples ranged from 0.00 to 1.99 % with a mean value of 0.69. The S.D. and C.V. value of organic carbon were 0.47 and 67.89 % respectively. The lowest organic carbon (0.0%) was reported in sample no. 20 of Palsoda village whereas highest organic carbon (1.99%) was seen in sample no. 6 of Pitawali village. Out of total soil samples in Depalpur block 47.50% of the soil samples were found in high organic carbon content, 5 % of the soil samples were found in low organic carbon content and 47.50 % of the soil samples were found in medium organic carbon content. This clearly shows that the soils of Depalpur block found rich in the organic carbon content. 95% of the soil samples were observed in medium-high organic carbon content, this may be due to low regional temperatures that reduce the decomposition of organic matter and the accumulation on the soil surface by suppressing microbial and enzyme activity. Similar results were observed by Annepu *et al. (2017)* from the soils of Mid Himalayan region of Himachal Pradesh, which varied from 0.15 to 1.98 %.

Table 4.1.1c: Soil Sample's Classification Based on Different Organic Carbon Ranges

Classes	Range	No. of samples	% of samples
Low	<0.25	2	5.00%
Medium	0.25 – 0.50	19	47.50%
High	>0.50	19	47.50%

(Source: Muhr et.al, 1963)

4.1.2 Status of Available Primary Macronutrients in the Soil

Data on primary macronutrients of soil such as N, P and K are given in table 4.1.2 and Appendix 3.

The nitrogen content in soil samples ranged from 159.65 to 398.30 kg/ha with a mean value of 211.90 kg/ha. The value of standard deviation and coefficient of variation of nitrogen were 61.14 and 28.25 % respectively. The lowest nitrogen value (159.65 kg/ha) was reported in sample no. 20 of Palsoda village whereas highest nitrogen value (398.30 kg/ha) was seen in sample no. 10 of Mendakwas village. 80 % of soil samples were found low in nitrogen content, 20 % of soil samples showed medium levels of nitrogen and none of soil sample showed high level of nitrogen content (table 4.1.2a). Thus the low status of available nitrogen was observed in studied area. Similar results were observed by Patidar *et al. (2017)* and *Rajendiran et al. (2018)* in Ralyawan Village Madhya Pradesh and in Alirajpur district of Madhya Pradesh, respectively.

Table 4.1.2a: Soil Sample's Classification Based on Different Nitrogen Range

Classes	Range	No. of samples	% of samples
Low	<280	32	80.00%
Medium	280-560	8	20.00%
High	>560	0	0.00%

(Source: Muhr et.al, 1963)

The phosphorus content in analysed soil samples ranged from 15.43 to 34.85 kg/ha with a mean value of 22.85 kg/hac. The value of S.D. and C.V. of phosphorus were 5.33 and 23.32 % respectively. The lowest phosphorus value (15.43 kg/ha) was seen in sample no. 26 and 36 of Kadoda and Kai villages, respectively whereas highest phosphorus value (34.85 kg/ha) was observed in sample no. 17 of Palsoda village. Out of total soil samples 62.50 % of the samples were found in medium phosphorus range and 37.5 % of the samples were found in high phosphorus range (table 4.1.2b). The results showed that soils of Depalpur block are rich in phosphorus content this may be due to high phosphorus mineral content (Apatite) or due to use of phosphatic fertilizers. Almost similar results were reported by Patidar *et al. (2017)*in Ralyawan Village, Madhya Pradesh.

Table 4.1.2b: Soil Sample's Classification Based on Different Phosphorus Range

Classes	Range	No. of samples	% of samples
Low	<12.5	0	0.00%
Medium	12.5-25	25	62.50%
High	>25	15	37.50%

(Source: Ramamoorthy and Bajaj, 1969)

The potassium content in analyzed soil samples ranged from 280 to 1008 kg/ha with a mean value of 460.29 kg/ha. The S.D. and C.V. of potassium were 119.13 and 25.88 % respectively. The lowest potassium value (280 kg/ha) was reported in sample no. 5 of Pitawali village while highest potassium value (1008 kg/ha) was observed in sample no. 10 of Mendakwas village. Out of total soil samples 7.50 % of the samples were found in medium potassium range while 92.50 % of soil samples were found in high potassium range (table 4.1.2c). The results concluded that soils of studied area were high in potassium content; this might be due to the presence of most of the mica (biotite and muscovite) in finer clay fractions of soils. Almost Similar results were reported by *Patidar et al. (2017)* who studied on major nutrients and chemical properties of vertisols of Ralyawan Village, Madhya Pradesh

Table 4.1.2c: Soil Sample's Classification Based on Different Potassium Range

Classes	Range	No. of samples	% of samples
Low	<135	0	0.00%
Medium	135-335	3	7.50%
High	>335	37	92.50%

(Source: Ramamoorthy and Bajaj, 1969

Table 4.1.2: Statistical Data on Primary Macronutrients of Soils of Depalpur Block

Soil parameters	Range	Mean	SD±	C.V (%)
N **(kg/ha)**	159.65 - 398.3	211.90	61.14	28.25
P **(kg/ha)**	15.43 - 34.85	22.85	5.33	23.32
K **(kg/ha)**	280 - 1008	460.29	119.13	25.88

4.1.3 Status of Available Secondary Macronutrients in the Soil

Data on the secondary macronutrients of soil such as Ca, Mg and S are given in the Table-4.1.3 and in Appendix 4.

Calcium content in soil samples ranged from 10 to 52 Meq/100g with an average value of 37.65 Meq/100g. The S.D. and C.V. value of calcium were 9.16 and 24.33 % respectively. The lowest calcium value (10 Meq/100g) was seen in sample no. 28 of Kadoda village whereas highest calcium value (52 Meq/100g) was seen in sample no. 1 of Pitawali village. 100% of the soil samples were sufficient in calcium whereas 0.00 % of the samples were deficient in calcium (table 4.1.3a).

Table 4.1.3a: Soil Sample’s Classification Based on Different Calcium Range

Classes	Range	No. of samples	% of samples
Low	<1.5	0	0.00%
High	>1.5	40	100%

(Source: Ramamoorthy and Bajaj, 1969)

Magnesium content in soil samples ranged from 22.80 to 132.00 Meq/100g with an average value of 89.26 Meq/100g. The S.D. and C.V. value of calcium were 27.37 and 30.66 % respectively. The lowest magnesium value (22.80 Meq/100g) was seen in sample no. 17 of Palsoda village whereas highest magnesium value (132.00 Meq/100g) was seen in sample no.28 of Kadoda village. 100% of the soil samples were sufficient in magnesium whereas 0 % of the samples were deficient in magnesium (table 4.1.3b).

Table 4.1.3b: Soil Sample’s Classification Based on Different Magnesium Range

Classes	Range	No. of samples	% of samples
Low	<1.0	0	0.00%
High	>1.0	40	100%

(Source: Ramamoorthy and Bajaj, 1969)

Sulphur content in soil samples ranged from 9.50 to 20.5mg/kg with an average value of 14.22 mg/kg. The S.D. and C.V. value of sulphur were 2.42 and 17.02 % respectively. The lowest sulphur value (9.50 mg/kg) was seen in sample no. 30 of Kadoda village whereas highest sulphur value (20.5 mg/kg) was seen in sample no. 20 of Palsoda village. Out of total soil samples, 95 % of samples found in medium range of sulphur content whereas 2.5 % samples in both low and high range of sulphur content (table 4.1.3c).

Table 4.1.3c: Soil Sample's Classification Based on Different Sulphur Range

Classes	Range	No. of samples	% of samples
Low	<10	1	2.50%
Medium	10-20	38	95.00%
High	>20	1	2.50%

(Source: Kanwar, 1976)

Table 4.1.3: Statistical Data on Secondary Macronutrients of Soils of Depalpur Block

Soil parameters	Range	Mean	SD±	C.V (%)
Ca (Meq/100g)	10 to 52	37.65	9.16	24.33
Mg (Meq/100g)	22.8 to132	89.26	27.37	30.66
S (mg/kg)	9.5 to 20.5	14.22	2.42	17.02

4.1.4 Soil Nutrient Index

It was important to obtain a single value for each nutrient in order to compare the levels of soil fertility in one region with those in another. The nutrient index (N.I) value is a measurement of the soil's ability to provide nutrients to plants. Several researchers and national/international organisations, such as ICAR -NBSS&LUP13, Ministry of Agriculture (Govt. of India), FAO, and others, have adopted and updated the nutrient index method developed by (Parker et al. 1951). This index is used to assess the fertility of soils using samples from each of the three classes: low (<1.67), medium (1.67-2.33), and high (>2.33).

Table4.1.4: Nutrient Index Values of Depalpur Block

S.No	Available nutrient	Nutrient index values	Category
1	Nitrogen	1.20	Low
2	Phosphorus	2.37	High
3	Potassium	2.92	High
4	Sulphur	2.00	Medium
5	Organic carbon	2.42	High

4.1.5 Correlation Matrix between Physico-chemical Properties of Soil of Different Villages of Depalpur Tehsil of Indore District, Madhya Pradesh

Table 4.1.5 displays the data of the correlation matrix between soil physico-chemical parameters.

The bulk density of the soil were found negative and highly significantly correlated with Porosity (r = -0.757**), Water Holding Capacity (r = -0.498**), Organic Carbon (r = -0.847**) and Nitrogen (r = -0.773*) of the soil. Similarly result was reported by Ahad *et al.* (2015) in soils of Kandi, Kupwara district (Kashmir valley), India. The BD of soils is negatively non-significant related with Phosphorus (r = -0.113), Potassium (r = -0.303), Calcium(r = -0.132) and Sulphur (r = -0.186) while it is positively non-significantly correlated with pH (r = 0.199), Electrical Conductivity (r = 0.043) and Magnesium (r = 0.236).

The particle density was found positive and strongly significant related with Porosity (r = 0.643**) of soil. It is positively non-significantly related to pH (r = 0.006), Organic Carbon (r = 0.138), Nitrogen (r = 0.133), Phosphorus (r = 0.087) and Sulphur (r = 0.024) of soil while negatively non-significantly related with WHC (r = -0.113), EC (r = -0.077), Potassium (r = -0.268), Calcium (r = -0.197) and Magnesium (r = -0.024) of soil.

The porosity of soil was observed positive and highly significantly correlated with Organic Carbon (r = 0.733**) and Nitrogen (r = 0.679**) of soil. It is positively non-significant with WHC (r = 0.307), Phosphorus (r = 0.157), Potassium (r = 0.061) and Sulphur (r = 0.167) of soil whereas negatively non-significant with pH (r = -0.138), EC (r = -0.82), Calcium (r = -0.024) and Magnesium (r = -0.243) of soil.

The WHC of soil was found positive and strongly significant related with Organic Carbon (r = 0.518**) and Nitrogen (r = 0.506**) of soil. It is positively non-significant related with EC (r = 0.003), Phosphorus (r = 0.069) and Potassium (r = 0.090) of soil while negatively non-significant with pH (r = -0.089), Calcium (r = -0.077), Magnesium (r = -0.111) and Sulphur (r = -0.232) of soil.

The pH of soil was observed positive and strongly significant related with Phosphorus (r = 0.750**) of soil. . It is positively non-significant related with EC (r = 0.028) and Calcium (r = 0.285) of soil whereas it is negatively non-significant with Organic Carbon (r = -0.222), Nitrogen (r = -0.249), Potassium (r = -0.106), Magnesium (r = -0.060) and Sulphur (r = -0.072) of soil. The EC of soil was positivelynon-significant related with OC (r = 0.11), Nitrogen (r = 0.014), Potassium (r = 0.276), Calcium (r = 0.120) and Magnesium (r = 0.044) of soil while it is negatively non-significant with Phosphorus (r = -0.064) and Sulphur (r = -0.035) of soil.

The organic carbon of soil was positively strongly significant with Nitrogen (r = 0.927**) and positively significant with Potassium (r = 359*) of soil. It is positively non-significant related with Phosphorus (r = 0.123), Calcium (r = 0.005) and Sulphur (r = 0.252) of soil while negatively non-significant with Magnesium (r = -0.192) of soil.

The primary macronutrients of soil i.e. Nitrogen in soils of Depalpur block was found positive and strongly significant related to Potassium (r = 0.423**) and significantly related with Sulphur (r = 0.334*) of soil. It is positively non-significant related with Phosphorus (r = 0.139) whereas negatively non-significant with Calcium (r = -0.065) and Magnesium (r = -0.2250 of soil. Phosphorus of soil was positively non-significant related with Calcium (r = 0.280) and Sulphur (r = 0.060) of soil whereas it is negatively non-significant with Potassium (r = -0.180) and Magnesium (r

= -0.278) of soil. Potassium of soil was positively non-significant related with Magnesium (r = 0.62) and Sulphur (r = 0.140) of soil while it is negatively non-significant with Calcium (r = -0.212) of soil.

The secondary macronutrients i.e. Calcium of soil was found negative and non-significantly related to Magnesium (r = -0.214) and Sulphur (r = -0.095) of soil. Magnesium of soil was positively non-significant related with Sulphur (r = 0.720) of soil.

Table 4.1.5: Correlation between soil physico-chemical properties of Depalpur town of Indore district in Madhya Pradesh

	BD	PD	Porosity	WHC	pH	EC	OC	N	P	K	Ca	Mg	S
BD	1												
PD	.009	1											
Porosity	-.757**	.643**	1										
WHC	-.498**	-.113	.307	1									
pH	.199	.006	-.138	-.089	1								
EC	.043	-.077	-.082	.003	.028	1							
OC	-.847**	.138	.733**	.518**	-.222	.011	1						
N	-.773**	.133	.679**	.506**	-.249	.014	.927**	1					
P	-.113	.087	.157	.069	.750**	-.064	.123	.139	1				
K	-.303	-.268	.061	.090	-.106	.276	.359*	.423**	-.180	1			
Ca	-.132	-.197	-.024	-.077	.285	.120	.005	-.065	.280	-.212	1		
Mg	.236	-.073	-.243	-.111	-.060	.044	-.192	-.225	-.278	.062	-.214	1	
S	-.186	.024	.167	-.232	-.072	-.035	.252	.334*	.060	.140	-.095	.072	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

4.2 Analysis of water parameters

4.2.1 Physico-Chemical Parameters of Ground Water

The data on the physical and chemical parameters of ground water of Depalpur block of Indore district, Madhya Pradesh is given in Table 4.2 and in Appendix 5.

In the present study it was found that values of pH in water samples varied from 6.20 to 7.40 with an average value of 6.78. The value of S.D. and C.V. of the samples were 0.33 and 4.83 % respectively. Sample no. 23 of Chittoda village reported highest pH value (7.40) whereas sample no. 37 of Kai village reported lowest pH value (6.20). Out of the total water samples, 32 samples (80 %) were found suitable for irrigation while the rest 20 % of the samples were moderately suitable for irrigation purpose. These results were represented in the Table-4.2.1a. The results shows that the water samples of Depalpur block are good and suitable for irrigation purpose and are slightly acidic to slightly basic in nature.

Table 4.2.1a: Water Sample's Classification Based On Different pH Range

Classes	Range	No. of samples	% of samples
Suitable	6.5-8.4	32	80%
Moderately suitable	0-6.4	8	20%
Not suitable	>8.5	0	0.00%

(Source: WHO)

The electrical conductivity in water samples varied from 0.28 to 4.45 dS/m with an average value of 1.54 ds/m. The S.D. and C.V. value of water samples were 0.71 and 46.06 % respectively. The highest EC value (4.45 ds/m) and lowest EC value (0.28 ds/m) both were reported in Pitawali village of sample no. 6 and 2, respectively. Out of total water samples, 3 samples (7.50 %) are in suitability range for irrigation, 35 samples (87.5 %) are in moderate suitability range for irrigation and only 2 samples (5 %) are not suitable for irrigation. The results showed that water quality in terms of EC in depalpur town is in moderate range for its use for irrigation purpose.

Table 4.2.1b: Water Sample's Classification Based On Different EC Range

Classes	Range (dS/m)	No. of samples	% of samples
Suitable	0.7	3	7.50%
Moderately suitable	0.7 – 3.0	35	87.50%
Not suitable	>3.0	2	5.00%

(Source: FAO.org)

4.2.2 Status of Anions in Ground Water

The data on major anions such as Cl^-, CO_3^{2-} and HCO_3^- of theGround water from different villages of Depalpur block of Indore district, Madhya Pradesh are given in the Table-4.2.2 and Appendix-6.

The chloride (Cl^-) concentration in water samples varied from 4.40 to 23.20 Meq/L with a mean value of 12.75 meq/L. The S.D. and C.V. value of the samples were 3.84 and 30.15 %, respectively. The lowest concentration of Cl^- (4.4 Meq/L) and highest concentration of Cl^- (23.20 Meq/L) both was reported in Mendakwas village of sample no. 13 and 15, respectively. It was found that none of the samples are in suitable range, 7 samples (17.50%) are in moderately suitable range and 33 samples (82.50 %) are in range of not suitable for irrigation purpose. Result showed that chloride concentration is higher in water of Depalpur block. This Chloride (Cl-) in groundwater may come from both natural and anthropogenic sources. Atmospheric precipitation, salt deposit degradation, and weathering of halite and evaporite are the primary lithogenic sources of chloride in groundwater (Tiwari and Singh, *2014).*

Table 4.2.2b: Water Sample's Classification Based On Different Cl^- Range

Classes	Limit	No. of samples	% of samples
Suitable	<4	0	0.00%
Moderately suitable	4 – 10	7	17.50%
Not suitable	>10	33	82.50%

(Source: FAO.org)

The carbonate ($CO3^{2-}$) concentration in water samples of Depalpur town is nil. The concentration of bicarbonate in water samples ranged from 12 to 32 Meq/L with an average value of 21.80 Meq/L. The S.D. and C.V. value of the samples were 4.37 and 20.62 %, respectively. Sample no. 13 of Mendakwas village reported lowest (12 Meq/L) concentration of bicarbonate while Sample no. 31 of Kadoda village reported highest (32 Meq/L) concentration of bicarbonate. According to Ayers and Westcot (1985), carbonate concentrations greater than 0.1 Meq/L and bicarbonate concentrations greater than 10 Meq/L are not recommended for irrigation purposes. The result shows that 100% of the samples are in not suitable range for irrigation purpose. Weathering of carbonate and/or alumino-silicate minerals is the primary source of HCO3 in groundwater, with a secondary contribution from CO_2 gas dissolution. Furthermore, the dissolution of carbonates and the weathering of silicate minerals may result in the formation of bicarbonate (Tiwari and Singh, 2014).

Table 4.2.2a: Water Sample's Classification Based On Different Alkalinity Range

Classes	Range	No. of samples	% of samples
Suitable	1.25	0	0.00%
Moderately suitable	1.25 – 8.50	0	0.00%
Not suitable	>8.50	40	100%

(Source: WHO, 2004)

4.2.3 Status of Cations in Ground Water

The data on major cations such as K^+, Na^+, Ca^{2+} and $Mg^{2+}$of the Ground water from different villages of Depalpur block of Indore district, Madhya Pradesh are given in the Table-4.2.3 and Appendix-7.

Calcium concentration in water samples ranged from 4.60 to 48.60 Meq/L with an average value of 24.24 Meq/L. The value of S.D. and C.V. for calcium was 8.63 and 35.60 %, respectively. The highest (48.60 Meq/L) and Lowest (4.60 Meq/L) concentration of Ca^{2+} were found in sample no. 6 and 2 of Pitawali village respectively. The concentration of calcium plus magnesium in water sample was observed as nil. According to the ICMR (1975) guidelines, the highest desirable limit for total hardness is 6.0 Meq/L. As per this guideline, all of the samples except one (4.60) from the Depalpur block were found to be below 6.0 Meq/L in terms of hardness and are therefore suitable for irrigation.

Potassium values in analysed water samples varied from 0.05 to 0.23 Meq/L with an average value of 0.11 Meq/L. The value of S.D. and C.V. for potassium was 0.04 and 39.93 % respectively. Sample no. 21 and 24 of Palsoda village, sample no. 25 and 31 of Chittoda village and sample no. 34 of Kai village were reported lowest (0.05 Meq/L) potassium value while sample no. 29 of Kai village was observed highest (0.23 Meq/L) potassium value. According to FAO (1994), the range for potassium concentration in water samples is 0-2 Meq/L. According to this result, potassium content is moderately suitable for irrigation purposes in groundwater samples in the city of Depalpur.

Sodium concentration in water samples varied from 0.48 to 3.91 Meq/L with a mean value of 1.33 Meq/L. The value of S.D. and C.V. for sodium was 0.70 and 52.72 %, respectively. The lowest value (0.48 Meq/L) of Na^+ was seen in sample no. 30 of Kadoda village while highest value (3.91 Meq/L) of Na^+ was reported in sample no. 6 of Pitawali village. The result shows that 95 % of water samples were in range of suitable, 5 % in range of moderately suitable while none of sample was in range of not suitable that means water quality of Depalpur block is suitable for irrigation purpose.

Table 4.2.3a: Water sample's classification based on different sodium range

Classes	Range (Meq/L)	No. of samples	% of samples
Suitable	<3	38	95%
Moderately suitable	3 – 9	2	5%
Not suitable	>9	2	0%

(Source: FAO.org)

4.2.4 Irrigation water quality index (IWQI)

The data on IWQI such as SAR, RSC, SSP, PI and KR are given in the Table-4.2 and in Appendix 8.

The range of Irrigation Water Quality Index of samples varied from 144.69 to 754.66 with a mean value of 373.29. The S.D. and C.V. value of samples for IWQI was 118.13 and 31.64 %, respectively. The highest value (754.66) and lowest value (144.69) of IWQI was found in sample no. 6 and 2 of Pitawali village respectively. Out of total number of water samples 77.50 % of the samples are unsuitable for irrigation, 17.50 % of samples are in very poor range for irrigation and 5 % samples are under poor range for irrigation purpose (table 4.2.4a). The presence of high calcium levels, i.e. total hardness, resulted in a high Water Quality Index in the water.

Table 4.2.4a: Water Sample's Classification Based on Different IWQI Range

WQI Range	Status of Water Quality	No. of samples	% of samples
<50	Excellent	0	0.00%
50-100	Good	0	0.00%
100-200	Poor	2	5.00%
200-300	Very poor	7	17.50%
>300	Unsuitable	31	77.50%

(Source: Anbazaghan, 2014)

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio of water samples varied from 0.18 to 0.79Meq/L with a mean value of 0.37Meq/L. The value of S.D. and C.V. for the samples was 0.13 and 33.95 %, respectively. The lowest value (0.18 Meq/L) of SAR seen in sample no. 3 of Pitawali village, sample no. 17 of Palsoda village and Sample no. 23 of Chittoda village while highest value (0.79 Meq/L) of SAR seen in sample no. 6 of Pitawali village. It was noticed that 100 percent of the samples are within allowable limits and belong to class S1, indicating that there is no sodium hazard, and that ground water samples are within a suitable range for irrigation. Similar result was reported by Aher and Gaikwad (2017) in Nandgaon block of Nashik district, Maharashtra.

Table 4.2.4b: Water sample's classification based on different SAR range

Classes	Range(Meq/L)	No. of samples	% of samples
S_1 (Low sodium hazard)	0-10	40	100%
S_2 (Medium sodium hazard)	10-18	0	0%
S_3 (high sodium hazard)	18-26	0	0%
S_4 (Very high sodium hazard)	>26	0	0%

(Source: FAO, 1994)

Soluble Sodium Percentage (SSP)

Soluble sodium percentage of water samples varied from 3.38 to 13.68 % with an average value of 5.63 %. The value of S.D. and C.V. of the samples were 1.69 and 30.5 %, respectively. Sample no. 16 from Mendakwas village had the lowest SSP value (3.38 %), while sample no. 2 from Pitawali village had the highest SSP value (13.68 %). It was observed that 100 percent of the samples are in the acceptable range and fit for irrigation purposes.

Table 4.2.4c: Water sample's classification based on different SSP range

Classes	Range(meq/L)	No. of samples	% of samples
Good	<50	40	100%
Not suitable	>50	0	0%

(Source: Wilcox, 1955)

Residual Sodium Carbonate (RSC)

RSC of water samples varied from -23.80 to 16.20 meq/L with a mean value of -3.06 meq/L. The value of S.D. and C.V. of the samples were 8.72 and -284.75 %, respectively. The lowest RSC value (-23.80 meq/L) was observed in sample no. 29 of Kadoda village whereas highest RSC value (16.20 meq/L) was observed in sample no. 2 of Pitawali village. The result showed that 67.50 % of water sample are in range of suitable, 10 % of samples in range of moderately suitable and 22.50 % of samples in not suitable for irrigation purpose (table 4.2.4d).

Table 4.2.4d: Water Sample's Classification Based on Different RSC Range

Classes	Range(meq/L)	No. of samples	% of samples
Low hazard (**Suitable)**	<1.25	27	67.50%
Medium hazard (**Moderately suitable)**	1.25-2.25	4	10.00%
High hazard (**Not suitable)**	>2.25	9	22.50%

(Source: Doneen's, 1964)

Kelly Ratio (KR)

Kelly's ratio in water sample ranged from 0.03 to 0.14 with a mean value of 0.06. The S.D. and C.V. of the samples were 0.02 and 33.57 %, respectively. The highest KR value (0.14) was seen in sample no. 2 of Pitawali village while lowest KR value was seen in sample no. 3 of Pitawali village, sample no. 16 of Mendakwas village, sample no. 17 of Palsoda village, sample no. 23 of Chittoda village and sample no. 38 of Kai village. It was observed that 100% of the samples are within the allowable range and suitable for irrigation.

Table 4.2.4e: Water sample's classification based on different Kelly's ratio range

Classes	Range	No. of samples	% of samples
Good	<1.0	40	100%
Not suitable	>1.0	0	0%

(Source: Karanth, 1987.)

Permeability Index (PI)

The data of permeability index in water samples varied from 15.76 to 99.25 with an average value of 26.20. The S.D. and C.V. of the samples were 13.27 and 50.65 %, respectively. The highest value (99.25) of PI was reported in sample no. 2 of Pitawali village whereas lowest value (15.76) was reported in sample no. 16 of Mendakwas village. The results revealed that 2.50 % of the samples are within the permissible limit and found excellent, 42.50 % of samples in range of moderately permissible and 55 % of the samples are not within the allowable range and are therefore deemed unsuitable for irrigation.

Table 4.2.4f: Water Sample's Classification Based on Different PI Range

Classes	Range	No. of samples	% of samples
Excellent	>75	1	2.50%
Good	25-75	17	42.50%
Not suitable	<25	22	55.00%

(Source: Doneen's, 1964)

Table 4.2: Statistical Data of Water Parameters

Parameters	Range	Mean	S.D.	C.V.%
pH	6.20-7.40	6.78	0.33	4.83
EC	0.28-4.45	1.54	0.71	46.06
Ca^{2+}	4.60-48.60	24.24	8.63	35.60
K^{2+}	0.05-0.23	0.11	0.04	39.93
Na^{+}	0.48-3.91	1.33	0.70	52.72
Cl^{-}	4.40-23.20	12.75	3.84	30.15
HCO_3	12.0-32.0	21.18	4.37	20.62
SAR	0.18-0.79	0.37	0.13	33.95
PI	15.76-99.25	26.20	13.27	50.65
KR	0.03-0.14	0.06	0.02	33.57
SSP	3.38-13.68	5.63	1.69	30.05
RSC	-23.80-16.20	-3.06	8.71	-284.75
IWQI	144.69-754.66	373.29	118.13	31.64

4.2.5 Correlation Matrix between Physico-Chemical Properties of Water of Different Villages in Depalpur block of Indore district, Madhya Pradesh

Table 4.2.5 displays the data of the correlation matrix between physico-chemical parameters of water.

pH of water samples was found negatively significant correlated with Potassium (r = -0.341*) and Chlorine (r = -0.315*). It is negatively non-significant correlated with EC (r = -0.181), Sodium (r = -0.217), Calcium (r = -0.275), SAR (r = -0.193), KR (r = -0.019) and SSP (r = -0.064) while positively non-significant correlated with Bicarbonate (r = 0.033), PI (r = 0.115) and RSC (r = 0.288). EC of water samples showed strongly positively significant relation with Sodium (r = 0.780**), Potassium (r = 0.533**), Calcium (r = 0.747**), SAR (r = 0.651**) and

Chlorine (r = 0.454**) while it is strongly negatively significant relation with PI (r = -0.468**) and RSC (r = -0.647**). It also showed positively non-significant relationship with Carbonate (r = 0.185), KR (r = 0.005) and SSP (r = 0.011) of water samples.

Sodium content of water samples were strongly positively significant related with Potassium (r = 0.527**), Calcium (r = 0.890**), Chlorine (r = 0.441**) and SAR (r = 0.947**) while strongly negatively significant related with PI (r = -0.409**) and RSC (r = -0.728**) of water samples. It is positively significantly related with KR (r = 0.328*) whereas positively non-significant related with Bicarbonate (r = 0.305) and SSP (r = 0.302) of water samples.

Potassium of water samples showed strongly positively significant relationship with Calcium (r = 0.489**) and SAR (r = 0.448**) of water samples while strongly negatively significant related with RSC (r = -0.463**). It is positively significant with Chlorine (r = 0.360*). Potassium is positively non-significant related to Bicarbonate (r = 0.042), KR (r = 0.109) and SSP (r = 0.302) while it is negatively non-significant related to PI (r = -0.227) of water samples.

Calcium in water samples of Depalpur block was found strongly positively significant correlated with Chlorine (r = 0.547**) and SAR (r = 0.730**) of water samples while it is strongly negatively significant related with PI (r = -0.674**) and RSC (r = -0.873**) of water samples. It is positively non-significant correlated with Bicarbonate (r = 0.234) of water samples whereas negatively non-significant related to KR (r = -0.041) and SSP (r = -0.073) of water samples.

Bicarbonate in water samples was positively non-significant correlated with SAR(r = 0.297), PI (r = 0.063), KR (r = 0.089), SSP (r = 0.103) and RSC (r = 0.270) of water samples while negatively non-significant related to (r = -0.029) of water samples. Chlorine of water was strongly negatively significant related with RSC (r = -0.556**) of water samples. Chlorine was positively significant correlated with SAR (r = 0.390*) and negatively significant related to PI (r = -0.394*). It is positively non-significant correlated with KR (r = 0.041) and negatively non-significant related to SSP (r = -0.003).

SAR value of analyzed water samples was found strongly positively significant correlated with KR (r = 0.596**) and SSP (r = 0.571**) while strongly negatively significant related with RSC (r = -0.574**) of water samples. SAR was negatively non-significant related to PI (r = -0.167) of water samples. PI value of water was strongly positively significant correlated with KR (r = 0.627**), SSP (r = 0.670**) and RSC (r = 0.699**) of water value. KR value of water was observed strongly positively significant correlated with SSP (r = 0.986**) and it is positively non-significant correlate with RSC (r = 0.085) of water samples. SSP of water was positively non-significant related with RSC (r = 0.123) of water samples.

Table 4.2.5: Correlation between water Physico-chemical properties of Depalpur town of Indore district in Madhya Pradesh

	pH	EC	Na	K	Ca+Mg	Co3- +HCO3-	Cl	SAR	PI	KR	SSP	RSC
pH	1											
EC	-.181	1										
Na	-.217	.780**	1									
K	-.341*	.533**	.527**	1								
Ca	-.275	.747**	.890**	.489**	1							
Carbona	.033	.185	.305	.042	.234	1						
Cl	-.315*	.454**	.441**	.360*	.547**	-.029	1					
SAR	-.193	.651**	.947**	.448**	.730**	.297	.390*	1				
PI	.115	-.468**	-.409**	-.227	-.674**	.063	-.394*	-.167	1			
KR	-.019	.005	.328*	.109	-.041	.089	.041	.596**	.627**	1		
SSP	-.064	.011	.302	.150	-.073	.103	-.003	.571**	.670**	.986**	1	
RSC	.288	-.647**	-.728**	-.463**	-.873**	.270	-.556**	-.574**	.699**	.085	.123	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Chapter V

SUMMARY AND CONCLUSION

A study was conducted on the topic "**Assessment of Soil Fertility and Underground Water Quality of different Villages of Depalpur block of Indore district, Madhya Pradesh**" to evaluate soil and water quality. The research was carried out between January and March of 2021. Surface soil samples (0-15cm) and groundwater samples utilized for irrigation were obtained from six distinct villages in the Depalpur tehsil. The obtained water and soil samples were processed and transported to the laboratory for further testing. Using standard procedures, these samples were tested for various physico-chemical parameters. The correlation between various soil and water characteristics was also discovered. The following are the key results of the current investigation:

5.1 Analysis of Soil Parameters of Depalpur Tehsil

- The Bulk density and Particle density of the soil samples varied from 1.24 to 1.57 gm/cm^3& 2.12 to 2.81 gm/cm^3 with a mean value of 1.40 and 2.59 gm/cm^3, respectively.
- The Porosity percentage of analyses soil samples ranged from 36.02 to 55.16 % with an average value of 46.03 %. Water Holding Capacity of soil samples varies between 38.24 to 62.85 % with a mean value of 55.51 %.
- The pH of soil samples was found in alkaline condition and its values ranged from 7.4 to 8.9 with an average value of 8.21. The investigation shows that 100 % of the samples are alkaline in nature.
- The value of Electrical Conductivity varied from 0.12 to 0.47 dS/m with an average value of 0.18 dS/m. The investigation showed that 100 % of the soil samples were found in permissible range, suitable for all type of crops. Salinity was not a concern in these soils.
- The Organic Carbon in soil samples varied from 0-1.99 % with an average value of 0.69 %.The present study shows that the soils of Depalpur town

found high in the organic carbon content as 95% of the soil samples were observed in medium-high organic carbon content.

- The range of available Nitrogen in soil samples varied between 159.65 to 398.30 kg/ha with an average value of 211.90 kg/ha. The present study shows that soil samples are deficient in available nitrogen as 80 % of soil samples were found low in nitrogen content, 20 % of soil samples showed medium levels of nitrogen and none of soil sample showed high level of nitrogen content.
- The range of available Phosphorus in soil samples varied between15.43 to 34.85 kg/ha with an average value of 22.85 kg/hac. The present study shows thatsoils of Depalpur block are rich in phosphorus content as 62.50 % of the samples were in range of medium phosphorus and 37.50 % of the samples were in range of high phosphorus content.
- The range of available Potassium in soil samples varied between 280 to 1008 kg/ha with an average value of 460.29 kg/ha. The present investigation shows thatsoils of Depalpur town were found high in potassium content as 7.50 % of the samples were found in medium potassium range while 92.50 % of soil samples were found in high potassium range.
- The value of exchangeable Calcium in the soil samples ranged from10 to 52 Meq/100g with a mean of 37.65 Meq/100g.The present study shows thatsoils of Depalpur tehsil are rich in calcium content as 100% of the soil samples were in range of high calcium content.
- The value of exchangeable Magnesium in the soil samples ranged from 22.8 to 132 Meq/100g with a mean of 89.26 Meq/100g. The present investigation shows that soils of Depalpur town are sufficient in magnesium as 100% of the soil samples were in range of high magnesium content.
- The value of available Sulphur in the soil samples ranged from 9.50 to 20.50 mg/kg with a mean of 14.22 mg/kg.The present study shows that soils of Depalpur tehsil are good in sulphur content as 38% of samples found in

medium range of sulphur content whereas 2.50 % samples in both low and high range of sulphur content.

5.2 Analysis of Water Parameters of Depalpur Town

- The pH of water samples was found in slightly acidic to slightly alkaline condition and its values ranged from 6.20 to 7.40 with an average of 6.78. The present study shows that the water samples of Depalpur block are good and suitable for irrigation purpose as 80 % of samples were in range of suitable for irrigation while the rest 20 % of the samples were in range of moderately suitable for irrigation purpose.
- The value of Electrical Conductivity of water samples varied from 0.28 to 4.45 dS/m with a mean of 1.54 dS/m. The present investigation showed that water quality in terms of EC is in moderate range for its use for irrigation purpose as 7.50 % of samples are in suitability range for irrigation, 87.50 % of samples are in moderate suitability range for irrigation and only 5 % of samples are not suitable for irrigation.
- The Chlorine concentration is higher in water of Depalpur block as it varied from 4.40 to 23.20 Meq/L with a mean of 12.75 meq/L. The present findings showed that most of water samples are not suitable for irrigation purpose as 17.50% of samples were found in moderately suitable range and 82.50 % of samples in range of not suitable for irrigation purpose.
- The carbonate concentration was found nil while bicarbonate in water samples varied from 12 to 32 Meq/L with a mean of 21.80 Meq/L. The study shows that 100% of the samples are in not suitable range for irrigation purpose.
- The range of Calcium concentration in water samples varied from 4.60 to 48.60 Meq/L with a mean of 24.24 Meq/L while Calcium plus Magnesium was found nil. The present findings showed that all of the samples except one (4.60) from the Depalpur block were found to be below 6.0 Meq/L in terms of hardness and are therefore suitable for irrigation.

- The range of Potassium in water samples varied from 0.05 to 0.23 Meq/L with amean of 0.11 Meq/L. The present study shows that all the water samples were in range of moderately suitable for irrigation purposes.
- The range of Sodium in water samples varied from 0.48 to 3.91 Meq/L with a mean of 1.33 Meq/L. The present findings showed thatwater quality of Depalpur block is suitable for irrigation purpose in term of sodium content as 95 % of water samples were found in range of suitable, 5 % in range of moderately suitable while none of sample was in range of not suitable.
- The range of IWQI of samples ranged from 144.69 to 754.66 with a mean of 373.29.The present investigation showed that 77.5% of the samples are unsuitable for irrigation, 17.50 % of samples are in very poor range for irrigation and 5 % samples are under poor range for irrigation purpose.
- The SAR value in water samples ranged from 0.18 to 0.79 Meq/L with a mean value of 0.37 Meq/L. The study shows that 100 percent of the samples are within allowable limits and belong to class S_1 (0-10 meq/L), indicating that there is no sodium hazard, and that ground water samples are within a suitable range for irrigation. The SSP, RSC, KR and PI value in the water samples ranged from 3.38 to 13.68, from -23.80 to 16.20, 0.03 to 0.14 and 15.76 to 99.25 with a mean of 5.63, -3.06 , 0.06 and 26.20, respectively.

CONCLUSIONS

Soil and water testing is a low-cost method of learning about the ability of soils and water to support crop growth. Growers can make more informed crop input decisions to minimize risk and maximize profitability if they understand what each soil and water test value means.

The soil test results were analyzed using literature to assist farmers in analysing and supplementing lacking nutrients. From the above results it was conclude that soils of Depalpur town were alkaline in nature and there is no crop salinity hazard. Using the soil nutrient index of the study region, it was observed that the soils of the Depalpur block were low in available nitrogen, medium in sulphur and high in potassium. Phosphorus and organic carbon status were found medium to high in soils of studied area. Deficient nutrients can be supplemented to prevent crops from suffering from deficiencies and to optimize the efficiency of other nutrients. Integrated nutrient management holds the key for sustainable soil fertility management.

The present study also conclude that the groundwater which is used for irrigation in different villages of Depalpur block was found slightly acidic to slightly alkaline in nature and suitable for irrigation purpose. Water quality in terms of EC was found moderately suitable for its use. Most of the water samples have shown low sodium hazard and alkalinity of all the water samples have shown unsuitable for irrigation. As per water quality index, 77.50 % of water samples in town were unsuitable for irrigation, 17.50 % of water samples were very poor and 5 % of water samples were poor for irrigation purpose, it means overall water quality of Depalpur town was found very bad.

This conclusion indicates that more work needs to be done to improve the quality of irrigation water, primarily by improving agricultural practices. The knowledge and experience gained via study may be developed in the future to assist farmers in terms of food quality, high yields through soil and water conservation, and improved environmental protection.

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APPENDICES

Appendix 1: Status of Bulk density, Particle density, Porosity and WHC in soil

Sample No.	Bulk density (g/cm3)	Particle density (g/cm3)	Porosity (%)	Water Holding Capacity (%)
S1	1.34	2.61	48.66	58.57
S2	1.37	2.56	46.48	56.99
S3	1.37	2.62	47.71	57.23
S4	1.30	2.60	50.00	58.89
S5	1.53	2.71	43.54	53.24
S6	1.24	2.64	53.03	62.30
S7	1.36	2.55	46.67	56.45
S8	1.28	2.61	50.96	59.99
S9	1.35	2.59	47.88	54.17
S10	1.24	2.46	49.59	61.40
S11	1.33	2.61	49.04	59.34
S12	1.36	2.68	49.25	58.12
S13	1.47	2.49	40.96	52.98
S14	1.49	2.68	44.40	53.67
S15	1.26	2.81	55.16	51.94
S16	1.32	2.76	52.17	58.96
S17	1.29	2.66	51.50	59.23
S18	1.32	2.65	50.19	55.84
S19	1.34	2.59	48.26	54.11
S20	1.57	2.71	42.07	38.24
S21	1.38	2.60	46.92	53.67
S22	1.39	2.69	48.33	54.33
S23	1.32	2.43	45.68	55.76
S24	1.50	2.70	44.44	56.75
S25	1.51	2.55	40.78	53.34
S26	1.48	2.44	39.34	52.56
S27	1.36	2.40	43.33	53.96
S28	1.54	2.62	41.22	62.85
S29	1.37	2.46	44.31	54.58
S30	1.49	2.66	43.98	53.76
S31	1.37	2.69	49.07	55.87
S32	1.38	2.66	48.12	54.23
S33	1.44	2.70	46.67	53.84
S34	1.46	2.55	42.75	51.78
S35	1.49	2.50	40.40	53.67
S36	1.53	2.67	42.70	50.32
S37	1.38	2.81	50.89	56.79
S38	1.51	2.36	36.02	61.11
S39	1.43	2.49	42.57	53.88
S40	1.35	2.12	36.32	55.66
Mean	**1.40**	**2.59**	**46.28**	**55.51**
Range	**1.24-1.57**	**2.36-2.82**	**36.02-55.16**	**38.24-62.85**
SD	**0.09**	**0.11**	**4.22**	**4.14**
CV	**6.45**	**4.14**	**9.13**	**7.46**

Appendix 2: Status of available pH, EC and organic carbon in soil

Sample No.	pH	Electrical Conductivity (ds/m)	Organic Carbon (%)
S1	8.2	0.17	0.89
S2	8.4	0.16	0.74
S3	7.7	0.21	0.76
S4	7.4	0.12	0.93
S5	8.7	0.22	0.29
S6	8.5	0.21	1.99
S7	8.8	0.25	0.74
S8	8.1	0.26	1.36
S9	8.1	0.17	0.63
S10	7.8	0.31	1.95
S11	7.9	0.15	1.06
S12	7.7	0.20	0.78
S13	8.0	0.21	0.40
S14	7.8	0.18	0.45
S15	7.8	0.20	1.65
S16	7.8	0.17	1.17
S17	8.7	0.20	1.50
S18	8.5	0.22	1.09
S19	8.2	0.18	0.64
S20	8.3	0.17	0.00
S21	8.6	0.22	0.48
S22	8.6	0.21	0.50
S23	8.1	0.20	0.60
S24	8.3	0.17	0.37
S25	8.2	0.18	0.35
S26	8.1	0.24	0.35
S27	8.2	0.22	0.48
S28	8.5	0.20	0.04
S29	8.9	0.15	0.50
S30	8.7	0.19	0.31
S31	8.4	0.17	0.49
S32	8.4	0.28	0.42
S33	8.1	0.47	0.38
S34	8.3	0.25	0.30
S35	8.0	0.24	0.37
S36	8.2	0.22	0.46
S37	8.1	0.20	0.70
S38	8.3	0.24	0.37
S39	8.0	0.22	0.42
S40	8.1	0.22	0.59
Mean	**8.21**	**0.21**	**0.69**
Range	**7.4-8.9**	**0.12-0.47**	**0-1.99**
SD	**0.34**	**0.06**	**0.47**
CV	**4.09**	**26.54**	**67.89**

Appendix 3: Status of available primary macronutrient in soil

Sample No.	Nitrogen (kg/hac)	Phosphorus (kg/hac)	Potassium (kg/hac)
S1	230.23	25.32	358.40
S2	210.45	28.32	414.40
S3	219.87	18.32	324.80
S4	240.45	16.87	380.80
S5	170.20	32.38	280.00
S6	310.00	29.00	459.20
S7	220.32	32.00	302.40
S8	310.20	28.66	425.60
S9	193.43	25.87	392.00
S10	398.30	19.43	1008.00
S11	350.45	20.99	526.40
S12	230.32	17.65	369.60
S13	175.40	21.00	436.80
S14	179.20	17.33	425.60
S15	310.21	16.87	560.00
S16	289.32	19.30	515.20
S17	320.32	34.85	436.80
S18	285.00	29.32	459.20
S19	179.21	27.32	380.80
S20	159.65	27.32	459.20
S21	178.21	21.43	546.00
S22	180.22	26.54	548.80
S23	200.00	19.08	459.20
S24	162.21	20.00	392.00
S25	160.20	18.54	369.60
S26	168.44	15.43	416.00
S27	173.23	18.30	459.20
S28	161.21	24.00	403.20
S29	187.22	32.95	593.00
S30	170.00	27.54	470.40
S31	185.22	21.43	414.40
S32	181.21	19.54	604.80
S33	179.65	21.49	459.20
S34	164.37	25.43	436.80
S35	169.00	19.00	492.80
S36	160.34	15.43	436.80
S37	179.40	19.43	347.20
S38	174.00	23.65	492.80
S39	171.21	16.54	605.00
S40	188.30	20.00	549.00
Mean	**211.90**	**22.85**	**460.29**
Range	**159.65-398.30**	**15.43-34.85**	**280-1008**
SD	**61.14**	**5.33**	**119.13**
CV	**28.85**	**23.32**	**25.88**

Appendix 4: Status of available secondary macronutrients in soil

Sample No.	Calcium (me/100g)	Magnesium (me/100g)	Sulphur (mg/kg)
S1	52.00	105.20	11.00
S2	42.60	59.80	13.00
S3	48.20	25.80	11.00
S4	34.80	61.20	13.00
S5	46.00	38.00	14.00
S6	39.80	98.80	15.20
S7	44.00	46.00	14.20
S8	46.80	100.40	17.20
S9	28.60	53.40	15.20
S10	22.80	69.20	17.50
S11	26.80	79.20	18.70
S12	38.60	92.80	13.20
S13	27.80	131.60	12.50
S14	25.20	64.80	11.30
S15	31.40	111.40	14.60
S16	26.80	92.80	13.80
S17	45.60	22.80	15.60
S18	45.00	121.00	16.80
S19	35.00	128.80	19.20
S20	38.60	95.40	20.50
S21	44.00	83.60	14.50
S22	36.40	59.60	13.50
S23	50.60	102.20	14.50
S24	28.20	108.40	13.50
S25	35.40	104.00	18.50
S26	49.60	106.40	15.60
S27	38.60	79.20	15.40
S28	10.00	132.00	12.50
S29	48.00	86.80	10.50
S30	39.20	117.40	9.50
S31	42.00	92.40	14.50
S32	37.00	81.80	13.40
S33	44.00	98.40	12.60
S34	26.40	85.60	12.50
S35	35.60	112.80	13.50
S36	34.00	118.00	14.20
S37	30.60	106.20	13.40
S38	50.60	96.80	11.50
S39	42.80	95.80	13.50
S40	36.60	104.40	14.00
Mean	**37.65**	**89.26**	**14.22**
Range	**10-52**	**22.80-132**	**9.50-20.50**
SD	**9.16**	**27.37**	**2.42**
CV	**24.33**	**30.66**	**17.02**

Appendix 5: Status of available pH and EC in Water

Sample No.	Water pH	Water EC (dS/m^2)
S1	6.6	1.73
S2	6.7	0.28
S3	6.5	1.25
S4	6.8	1.34
S5	6.4	1.29
S6	6.4	4.45
S7	7.2	1.33
S8	6.7	1.45
S9	6.7	1.38
S10	6.7	1.44
S11	6.3	1.41
S12	6.9	2.00
S13	6.9	0.46
S14	6.7	1.87
S15	6.5	1.99
S16	6.6	2.03
S17	6.7	1.30
S18	6.9	1.18
S19	7.1	1.24
S20	6.9	1.30
S21	7.1	1.19
S22	7.3	1.12
S23	7.4	1.39
S24	7.1	1.07
S25	6.9	1.86
S26	7.2	1.55
S27	7.1	1.38
S28	7.1	1.45
S29	6.9	3.27
S30	7.2	0.69
S31	7.1	1.17
S32	7.3	2.39
S33	6.5	1.97
S34	6.4	1.26
S35	6.4	0.98
S36	6.3	1.64
S37	6.2	2.19
S38	6.5	1.55
S39	6.3	0.80
S40	6.8	1.87
Mean	**6.78**	**1.54**
Range	**6.20-7.40**	**0.28-4.45**
SD	**0.33**	**0.71**
CV	**4.83**	**46.06**

Appendix 6: Status of available Cations in water

Sample No.	Calcium + Magnesium (meq/L)	Calcium (meq/L)	Magnesium (meq/L)	Potassum (meq/L)	Sodium (meq/L)
S1	28.60	28.60	0	0.10	1.57
S2	4.60	4.60	0	0.08	0.65
S3	19.00	19.00	0	0.13	0.57
S4	20.20	20.20	0	0.08	1.13
S5	19.20	19.20	0	0.13	1.00
S6	48.60	48.60	0	0.21	3.91
S7	21.60	21.60	0	0.08	1.00
S8	23.40	23.40	0	0.15	1.35
S9	21.20	21.20	0	0.08	1.26
S10	22.00	22.00	0	0.13	1.39
S11	21.80	21.80	0	0.08	1.30
S12	31.20	31.20	0	0.10	1.65
S13	10.80	10.80	0	0.13	0.83
S14	26.60	26.60	0	0.13	1.61
S15	29.60	29.60	0	0.18	1.78
S16	31.20	31.20	0	0.18	0.91
S17	17.40	17.40	0	0.10	0.52
S18	30.60	30.60	0	0.15	1.70
S19	22.60	22.60	0	0.08	1.09
S20	25.20	25.20	0	0.10	1.17
S21	20.20	20.20	0	0.05	1.00
S22	18.40	18.40	0	0.08	1.04
S23	16.60	16.60	0	0.08	0.52
S24	17.40	17.40	0	0.05	0.91
S25	32.80	32.80	0	0.05	2.00
S26	25.20	25.20	0	0.08	1.43
S27	22.60	22.60	0	0.15	1.26
S28	21.00	21.00	0	0.08	1.30
S29	44.60	44.60	0	0.23	3.61
S30	12.80	12.80	0	0.10	0.48
S31	34.60	34.60	0	0.05	1.74
S32	16.00	16.00	0	0.10	0.87
S33	31.60	31.60	0	0.10	1.70
S34	20.00	20.00	0	0.05	1.13
S35	18.40	18.40	0	0.15	0.74
S36	29.20	29.20	0	0.10	1.43
S37	32.40	32.40	0	0.13	1.70
S38	15.00	15.00	0	0.08	0.52
S39	35.60	35.60	0	0.13	1.91
S40	29.80	29.80	0	0.10	1.57
Mean	**24.24**	**24.24**	**0**	**0.11**	**1.33**
Range	**4.60-48.60**	**4.60-48.60**	**0**	**0.05-0.23**	**0.48-3.91**
SD	**8.63**	**8.63**	**0**	**0.04**	**0.70**
CV	**35.60**	**35.60**	**0**	**39.93**	**52.72**

Appendix 7: Status of available anions in water

Sample No.	Chloride (meq/L)	Carbonate (meq/L)	Bicarbonate (meq/L)
S1	14.80	0	17.20
S2	10.40	0	20.80
S3	14.00	0	20.00
S4	12.00	0	17.60
S5	10.80	0	24.80
S6	17.20	0	29.20
S7	15.20	0	16.80
S8	16.00	0	16.00
S9	11.60	0	22.40
S10	13.60	0	28.80
S11	15.60	0	25.20
S12	16.80	0	18.80
S13	4.40	0	12.00
S14	12.00	0	21.20
S15	23.20	0	24.00
S16	18.80	0	17.20
S17	12.40	0	16.00
S18	16.00	0	23.60
S19	12.80	0	22.00
S20	14.40	0	17.20
S21	10.40	0	18.00
S22	12.80	0	20.40
S23	8.80	0	18.40
S24	12.00	0	21.20
S25	12.40	0	23.20
S26	13.60	0	18.80
S27	11.20	0	24.00
S28	14.00	0	30.00
S29	14.40	0	20.80
S30	5.60	0	28.80
S31	7.20	0	32.00
S32	6.40	0	20.80
S33	16.00	0	24.40
S34	13.20	0	18.40
S35	7.60	0	20.00
S36	15.60	0	15.20
S37	14.80	0	19.60
S38	5.60	0	21.60
S39	10.40	0	21.60
S40	16.00	0	19.20
Mean	**12.75**	**0**	**21.18**
Range	**4.40-23.20**	**0**	**12-32**
SD	**3.84**	**0**	**4.37**
CV	**30.15**	**0**	**20.62**

Appendix 8: Status of irrigation water quality parameters and index

Sample No.	SAR	SSP	RSC	KR	PI	IWQI
S1	0.41	5.51	-11.40	0.05	18.94	405.77
S2	0.43	13.68	16.20	0.14	99.25	144.69
S3	0.18	3.52	1.00	0.03	25.75	312.18
S4	0.36	5.64	-2.60	0.06	24.97	317.05
S5	0.32	5.55	5.60	0.05	29.60	323.31
S6	0.79	7.81	-19.40	0.08	17.74	754.66
S7	0.30	4.75	-4.80	0.05	22.56	331.38
S8	0.39	6.03	-7.40	0.06	21.61	350.37
S9	0.39	5.94	1.20	0.06	26.69	338.97
S10	0.42	6.46	6.80	0.06	28.89	370.33
S11	0.40	5.96	3.40	0.06	27.37	359.93
S12	0.42	5.32	-12.40	0.05	18.23	449.92
S13	0.36	8.12	1.20	0.08	36.90	165.27
S14	0.44	6.13	-5.40	0.06	22.03	405.47
S15	0.46	6.22	-5.60	0.06	21.29	463.97
S16	0.23	3.38	-14.00	0.03	15.76	450.50
S17	0.18	3.46	-1.40	0.03	25.23	274.16
S18	0.43	5.70	-7.00	0.06	20.29	452.37
S19	0.32	4.90	-0.60	0.05	24.39	342.66
S20	0.33	4.82	-0.80	0.05	20.18	355.02
S21	0.31	4.95	-2.20	0.05	24.73	306.59
S22	0.34	5.74	2.00	0.06	28.60	301.35
S23	0.18	3.48	1.80	0.03	28.10	263.62
S24	0.31	5.25	3.80	0.05	30.13	290.64
S25	0.49	5.89	-9.60	0.06	19.59	524.20
S26	0.40	5.66	-6.40	0.06	21.67	373.41
S27	0.38	5.89	1.40	0.06	25.82	353.73
S28	0.40	6.17	9.00	0.06	30.40	368.28
S29	0.76	7.93	-23.80	0.08	16.95	656.38
S30	0.19	4.34	16.00	0.04	44.02	243.17
S31	0.42	4.92	-2.60	0.05	20.35	518.02
S32	0.31	5.73	4.80	0.05	32.19	265.49
S33	0.43	5.38	-7.20	0.05	19.93	464.05
S34	0.36	5.58	-1.60	0.06	25.65	314.07
S35	0.24	4.63	1.60	0.04	27.23	279.17
S36	0.38	5.00	-14.00	0.05	17.41	400.02
S37	0.42	5.33	-12.80	0.05	17.96	466.84
S38	0.19	3.84	6.60	0.03	33.30	237.59
S39	0.45	5.42	-14.00	0.05	17.49	505.80
S40	0.41	5.30	-10.60	0.05	18.96	431.03
Mean	**0.37**	**5.63**	**-3.06**	**0.06**	**26.20**	**373.29**
Range	**0.18-0.79**	**3.38-13.68**	**-23.80-16.20**	**0.03-0.14**	**15.76-99.25**	**144.69-754.66**
SD	**0.13**	**1.69**	**8.71**	**0.02**	**13.27**	**118.13**
CV	**33.95**	**30.05**	**-284.75**	**33.57**	**50.65**	**31.64**

Note: SAR=Sodium adsorption ratio, RSC=Residual sodium carbonate, KR=Kelly's ratio, SSP=Soluble sodium percentage, PI=Permeability index, IWQI=Irrigation water quality index.