

**Assessment of Soil Properties and Ground Water Quality in  
Satwas Tehsil of Dewas District, Madhya Pradesh**



**THESIS**

**Submitted to the**

**Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya,**

**Gwalior (MP) - 474002**

**In partial fulfilment of the requirement for the Degree of  
MASTER OF SCIENCE**

**In**

**AGRICULTURE (SOIL SCIENCE AND AGRICULTURAL  
CHEMISTRY) 2020**

**By POOJA RATHORE**

**Department of Soil Science and Agricultural Chemistry**

**Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior**

**College of Agriculture, Indore (M.P.)– 452001**

## CERTIFICATE – I

This is to certify that the thesis entitled “**Assessment of soil properties and ground water quality in Satwas Tehsil of Dewas District, Madhya Pradesh**” submitted in partial fulfilment of the requirements for the **DEGREE OF MASTER OF SCIENCE IN AGRICULTURE (Soil Science and Agricultural Chemistry)** of **Rajmata Vijayaraje Scindia Krishi Vishwa vidyalaya, Gwalior**, is a record of the bonafide research work carried out by **Pooja Rathore, I.D. No. 18121306** under my guidance and supervision. The subject of the thesis has been approved by the student's advisory committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of investigation has been acknowledged by the scholar.

**Chairman of the advisory  
committee**

**Place: Indore**

**(Dr. K.S. Bangar)**

**Date:**

### **MEMBERS OF THE STUDENT'S ADVISORY COMMITTEE**

Chairman: **Dr. K.S. Bangar** .....

Member: **Dr. A. K. Sharma** .....

Member: **Dr. U.R. Khandkar** .....

## CERTIFICATE – II

This is to certify that the thesis entitled “**Assessment of soil properties and ground water quality in Satwas Tehsil of Dewas District, Madhya Pradesh.**”, submitted by **Miss Pooja Rathore, I.D.N. 18121306** to the **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.)** in partial fulfilment of the requirements for the Degree of master of science in the agriculture (**Soil Science & Agricultural Chemistry, College of Agriculture , Indore**) has been accepted after evaluation by the External Examiner and approved by the Student’s Advisory Committee after an oral examination of the same .

**Chairman of the advisory  
committee**

**(Dr. K.S. Bangar)**

**Place: Indore**

**Date:**

### **MEMBERS OF THE STUDENT’S ADVISORY COMMITTEE**

Chairman: **Dr. K.S. Bangar** .....

Member: **Dr. A. K. Sharma** .....

Member: **Dr. U.R. Khandkar** .....

Head of the Department: **Dr. K.S. Bangar** .....

Dean of the collage .....

Director of Instructions .....

## ACKNOWLEDGEMENT

*First and foremost, I have to thank my research supervisor, **Dr. K.S. Bangar Professor**, Department of Soil Science & Agricultural Chemistry, College of Agriculture, Indore, without their assistance and dedicated involvement in every step throughout the process, this manuscript / thesis would have never been accomplished. I would like to thank you very much for your support and understanding over these past two years.*

*My sincere thanks to the members of my advisory committee **Dr. U.R. Khandkar**, Professor, Department of Soil Science and Agricultural Chemistry, **Dr. A. K. Sharma**, Professor & Head of the Section, Department of Agronomy, College of Agriculture, Indore.*

*I would like to offer special thanks to head of the section **Dr. K.S. Bangar**, Professor, Department of Soil Science and Agricultural Chemistry. I extend my sincere gratitude to **Dr. S.K. Rao**, Hon'ble Vice Chancellor, **Dr. A.K. Singh**, Director of Instruction, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior and **Dr. A. K. Sharma**, Dean College of Agriculture, Indore for providing necessary facilities during the investigation. I heartfelt thanks to **Dr. S.C. Tiwari**, **Dr. S.K.Sharma** , **Dr. Aashish Upadhyay**, **Shri Sanjay Dubey** and **Dr. Anusuiya Panda** for supporting me.*

*I owe an everlasting depth of gratitude to my father **Shri. Rakesh Rathore** and my mother **Shrimati. Pushpa Rathore** for their support and encouragement. I also want to express my profound feelings for my elder brother **Praveen Rathore** and my sister **Dolli Rathore** who have piloted me up to this stage and whose love, devotion, blessing and care throughout my life enabled me to achieve this seemingly invincible goal.*

*Getting through my dissertation required more than academic support, and I have many, many people to thank for listening to and, at times, having to tolerate me over the past two years. I cannot begin to express my gratitude and appreciation for their friendship. Miss **Neha Rahangdale**, **Sangeeta Mandloi**, **Pooja Patidar**, **Maya Waskale**, **Shweta Kushwah**, **Shivani Sharma**, have been unwavering in their personal and professional support during the time I spent at the University. For many memorable evenings out and in, I must thank everyone above as well as **Ram Mulewa**, **Rajnandini Verma** I would also like to thank who opened both her home and heart to me when I first arrived in the city.*

Place: Indore

Pooja Rathore

Date:

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## LIST OF ABBREVIATION

<b>Symbol</b>	<b>Legends</b>
&	And
@	At the rate of
°C	Degree Celsius
C.D.	Critical Difference
cm	Centimetre
dS/m	Decisiemens per metre
d.f.	Degree of Freedom
<i>et al.</i>	And others
etc	and the rest
Fig.	Figure (s)
gm	Gram
ha	Hectare
me L <sup>-1</sup>	Milli equivalent per litre
EC	Electric conductivity
i.e.	That is
K	Potassium
kg/ha	Kilogram per hectare
L	Litre
m	Metre (s)
N	Nitrogen
S.No.	Serial number
NS	Non-significant
P	Phosphorus
OC	Organic carbon
mmolL <sup>-1</sup>	Milli mol per litre
RH	Relative humidity
RSC	Residual sodium carbonate
CEC	Cation Exchange Capacity
ESP	Exchangeable sodium percentage
Viz.	Namely
%	Percent
±	Plus, or Minus
SAR	Sodium absorption ratio
HCO <sub>3</sub> <sup>-</sup>	Bicarbonate
µg	Micro gram
SO <sub>4</sub> <sup>-</sup>	Sulphate
mg	Milligram
Ca <sup>2+</sup>	Calcium

Mg <sup>2+</sup>	Magnesium
Na <sup>+</sup>	Sodium
CO <sub>3</sub> <sup>-</sup>	Carbonate
r	Correlation coefficient

## CHAPTER - I

### INTRODUCTION

Soil is a reservoir of nutrients and plays a pivotal role in supporting the growth of crops and other vegetation maintaining the earth's environment clean. It also acts as a source and sink for atmospheric gases (Sharma *et al.*, 2011). Out of the total geographical area of 329 Mha of our country, about 265 Mha is suitable for crop production and about 175 Mha is affected by soil related constraints and are classified as waste land. There are 17 essential nutrients which are required for plant growth. Study of macro and micro nutrients is important to agricultural chemist for plants growth and soil management. In achieving better crop yield the farmers should be made aware about the status of soil constituents, chemistry of water available, nutrient supply to the crop, climatic conditions etc (Brady, 1990). Indian soils are principally poor in fertility, as these have steadily been depleted of their limited nutrient resources due to continuous cultivation from many centuries without protecting soil fertility.

Soil fertility is governed by macro nutrient and control the growth and yields of crops. It is determined by the presence or absence of nutrients i.e. macro and micronutrients. The sustainable productivity of a soil mainly depends upon its ability to supply essential nutrients to the growing plants. Soil fertility fluctuates throughout the growing season each year due to alteration in the quantity and availability of mineral nutrients by the addition of fertilizers, manure, compost, mulch, and lime in addition to leaching. Hence, evaluation of fertility status of the soils of an area or a region is an important aspect in the context of sustainable agriculture. Soil testing assess the current fertility status and provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for maximizing crop yields and to maintain the optimum fertility in soil year after year. The site specific nutrient management practices reduce the cost of cultivation and environmental pollution due to the imbalanced application of chemical fertilizers. For proper soil management, the farmer should know what amendments are necessary to optimize the productivity of soil for specific crops. Plants and animals must have water to survive. Among all available

sources of water, groundwater is most decentralized and dependable source of water for millions rural and urban families. It accounts for nearly 80 percent of the rural domestic water needs and 50 per cent of the urban water needs in India (Dinesh *et al.*, 2005).

Groundwater is ultimate, most suitable fresh water, resource with nearly balanced concentration of the salt for human consumption (Tiwari *et al.*, 2010) the large volume of water that covers the surface of the earth, only 1% is inland fresh and easily available for human use.

The qualities groundwater resources vary naturally and widely depending on climate, season, geology of bedrock as well as anthropogenic activities (Ramesh and Soorya, 2012).

Groundwater quality is as important as its quantity, and therefore it is essential to consider in depth the holistic approach towards its management. Ground water quality is relatively more important than surface water as it is less susceptible to contamination/pollution and is suitable for different purposes. The quality or physico-chemical characteristics of groundwater is highly dependent on anthropogenic activities like agriculture, mining, urban settlements, etc., as well as natural processes like rock–water interaction, geological formations, and aerobic/anaerobic conditions of the aquifers (Subramani *et al.*, 2005). On the earth 97.2 % of water is salty and 2.8 % is fresh water from which about 20 % constitutes ground water (Rajesh Kumar, 2011).

Ground water which affects soil and crop yield. By poor agricultural management & water logging soil become degraded by salinization. Looking to the above facts the present will be taken up to know the property of the soil and the ground water quality in Satwas tehsil of Dewas district Madhya Pradesh.

Satwas tehsil is one of the important tehsil located in the Dewas district of Madhya Pradesh (India). The total area of Satwas is 979 km<sup>2</sup> including 938 km<sup>2</sup> rural area and 40.2 km<sup>2</sup> urban area. It is located at latitude of 22° 31' 48" N and longitude of 76° 40' 48" E. There are 150 villages and 40 panchayats in Satwas Tehsil. It has an average elevation of 303 m. The climate of Satwas tehsil as well as Dewas district is tropical, characterized by hot summer and

well distributed rainfall during the southwest monsoon season. Monsoon arrives generally in the end of June. Normal annual rainfall of the district is 40.2 inch per year. Tube well or bore well is the major source of irrigation in Satwas tehsil. A detailed soil survey and ground water in the tehsil is carried out village-wise during 2019-20. The work is done under All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture and Soil testing Laboratory, College of Agriculture Indore, Madhya Pradesh. The present study entitled “**Assessment of soil properties and ground water quality of Satwas Tehsil of Dewas District, Madhya Pradesh**” is carried out with the following objectives:

1. To know the soil fertility status of Satwas tehsil.
2. To know the chemical properties of soil.
3. To classify the soil as per the degree of salinity / sodicity.
4. To categorize the water quality with respect to irrigation.

## CHAPTER - II

### REVIEW OF LITERATURE

The comprehensive review of literature is the most essential part of any scientific study. This chapter contains various scientific literatures with respect to soil properties and ground water quality performed in past in India and abroad in relation to **“Assessment of soil properties and ground water quality of Satwas Tehsil of Dewas District, Madhya Pradesh”**

#### A. Soil fertility and available nutrients

Bahuguna *et al.* (2012) reported the soil fertility status at eight different sites of Kedarnath Wildlife Sanctuary (KWLS) of Garhwali Himalaya, India. They found the mean available phosphorus content varied from 13.02 kg ha<sup>-1</sup> to 16.28 kg ha<sup>-1</sup> with estimated mean exchangeable potassium content varies from 145.60 kg ha<sup>-1</sup> to 216.16 kg ha<sup>-1</sup> in soils of eight sites.

A study is conducted by Kaleeswari (2012) for assessing the soils of Melmalayanur block of Villupuram district, Tamil Nadu, (India). They obtained the available sulphur content varies from 1.25 to 198.75 mg kg<sup>-1</sup>, an average value 48.64 mg kg<sup>-1</sup> and the deficiency of S is found in 1.17 % area and 66.97 % area is found in high status available sulphur.

Ganorkar and Chinchmalatpure (2013) investigated the soil fertility status in Amravati district. They obtained the pH of soil ranged from 7.80-8.46, OC content in soil ranged from 1.25-1.69 %, available N ranged from 219-298 kg ha<sup>-1</sup>, available P ranged from 18.5-25 kg ha<sup>-1</sup> and available K ranged from 445 - 648 kg ha<sup>-1</sup> in soils of Amravati district.

A study is conducted by Sarmah *et al.* (2013) in soils of Assam, India for evaluating soil fertility status. They found that available nitrogen 296.18 kg ha<sup>-1</sup>, available P 82.80 kg ha<sup>-1</sup> and available K 52.57 kg ha<sup>-1</sup> in soil of Assam.

Padmavathi *et al.* (2014) studied the soil fertility status in soils of Coimbatore district. They found the available N varied between 102 to 394 kg

ha<sup>-1</sup>, and the available P varied from 5.30 to 75.10 while available K ranged from 102 to 789 kg ha<sup>-1</sup>. They studied that the available N is obtained to be low in 86.41 percent of soil samples; phosphorus is medium, while K found to be high in 56.55 percent soil samples.

Chauhan *et al.* (2015) investigated the macro nutrient in soils of Taluka Ghora Bari district Thatta. They found that the 77 % of soil samples are poor in total nitrogen, 51 % are deficient in available phosphorus, while exchangeable potassium are good in soils.

Sharma *et al.* (2015) studied the soil fertility status in vertisols of Nignoti village. They found available N varied between 114 to 300 kg ha<sup>-1</sup> with a mean of 213.4 kg ha<sup>-1</sup> and Available P ranged from 6 to 30.4 kg ha<sup>-1</sup> with an average value of 17.3 kg ha<sup>-1</sup>. 22.47 % soil samples are classified as low fertility class in available P and 64.8 % in medium fertility class. 97.6 % soil samples are found high in available K. Available S varied from 5.02 to 35.66 kg ha<sup>-1</sup> in various soil samples.

A study is conducted by Mustafa *et al.* (2016) in six pedons of the Kheragarah Tehsil of Agra district Uttar Pradesh, India. They observed the major nutrient content in soil as 72.0 to 220.0 kg ha<sup>-1</sup>, 3.7–15.0 kg ha<sup>-1</sup>, and 153.0 - 361.6 kg ha<sup>-1</sup> in available N, available P and available K respectively. These values indicate that the soils are low, low to high, and medium to high in available N, available P and available K respectively.

Shinde *et al.* (2016) analyzed the soils for knowing the soil fertility status in 2015-2016 at Agriculture College Farm, Nandurbar under Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dhule. They found the available N varied between 125 to 238 kg ha<sup>-1</sup>, available P ranged between 7.49 to 32.42 kg ha<sup>-1</sup> and K varied from 336 to 459 kg ha<sup>-1</sup>. Available N are very low in Soils of Agriculture College farm, Nandurbar, available P are low to high and available K are very high.

Sharma *et al.* (2017) reported about the chemical properties of soil in Ralyawan village of Jhabua district of Madhya Pradesh, India. They stated that

soil are low, ranged from 152 to 298 kg ha<sup>-1</sup> with a mean value of 236 kg ha<sup>-1</sup>. , low to medium ranged from 7.15 to 38.8 kg ha<sup>-1</sup> with a mean value of 16.4 kg ha<sup>-1</sup>, and medium to high level , varied between 179 to 826 kg ha<sup>-1</sup> with an average value of 418 kg ha<sup>-1</sup> in available nitrogen ,available phosphorus and available potassium respectively. They reported that the available nitrogen status is low in soil of Ralyawan village and the pH ranged between 7 to 8 with an average value of 7.5 and 0.17 to 0.86 dS m<sup>-1</sup> electrical conductivity of soil water suspension is reported . Soils are low to medium in organic carbon status is states in Ralyawan village of Jhabua district of Madhya Pradesh, India.

Kashiwar *et al.* (2018) studied the soil available nutrients. They recorded that the available nitrogen 160-241.5 kg ha<sup>-1</sup>, phosphorus 8.24-11.79 kg ha<sup>-1</sup> potassium 70.1- 128.25 kg ha<sup>-1</sup> and sulphur are ranged from, 6.7-10.25 kg ha<sup>-1</sup>.

Swain *et al.* (2019) reported that the available nitrogen content, available Bray's phosphorus content, and available soil potassium content in these soils are obtained to be ranged from 50.0 to 225.0 kg ha<sup>-1</sup>, 11.3 to 2326.5 kg ha<sup>-1</sup>. 37.6 to 458.3 kg ha<sup>-1</sup> respectively. Sulphur varied from 2.17 to 11.02 mg kg<sup>-1</sup> is found in soil. All the maps are found in lower range, while in upland soils all the parameters are found in higher values.

## **B. Chemical properties of soil**

An investigation is carried out by Meena *et al.* (2006) investigated the soil chemical properties in Tonk district of Rajasthan. They recorded that the 63 % soil samples is low (< 0.50 %) in organic carbon content ,21 % soil samples is medium (0.50 to 0.75 %) and 16 % soil samples in high (>0.75 %) in organic carbon content in soils.

Rajeswar *et al.* (2009) investigated the soil chemical properties in Garikapadu of Krishna District of Andhra-Pradesh. They reported that the electrical conductivity values varied from 0.10 to 0.32 dS m<sup>-1</sup>.

Parihar *et al.* (2013) studied about the soils of Guava orchard Satpura hills of Madhya Pradesh. They reported that the soil is neutral to alkaline in nature, soils pH ranged from 7.0 to 9.

Shivanna *et al.* (2014) conducted study to evaluate the soil fertility status of selected command areas of three lakes- Eachanur, V.Mallenahalli and Halkurke in Tiptur taluka. The variables tested included pH, EC, OC, N, P, and K. The study revealed that the pH of the soil samples ranged from 7.07 to 7.87 and is on slightly alkaline side but within the limit of 6.5-8.5 which is optimum for crops. EC values ranged from 0.26 dS m<sup>-1</sup> to 0.485 dS m<sup>-1</sup> and are within the limit of 0.8 dSm<sup>-1</sup> indicating low salinity status of the soils. OC content ranged from 0.50 % to 0.67 % and all the samples are of medium rating.

An experiment is conducted by Sharma *et al.* (2015) for investigating chemical properties of soil in Vertisols of Nignoti village. They stated that, pH of soil ranged between 7.0 to 8.0, and EC varied between 0.11 to 1.09 dS m<sup>-1</sup> and OC ranged between 0.23 % to 0.80 % these value indicate that the soil is low to medium in soil organic carbon status.

Behera *et al.* (2016) investigated about the chemical properties of soil of south Goa and north Goa. They recorded that the soils are acidic to neutral in nature. EC and OC ranged widely in both the soil layers.

Kashiwar *et al.* (2018) studied about the chemical properties of soil in Agricultural Farm of Rajiv Gandhi South Campus (Banaras Hindu University), Barkachha, Mirzapur, Uttar Pradesh, India. They studied about the 260 soil samples; study showed that the pH ranged from 5.9 to 6.5 with an average value of 6.14, these value indicate that the soil is slightly acidic in nature, and E.C. ranged from 0.25-0.76 dS m<sup>-1</sup> with an average value of 0.53, OC ranged from 0.26-0.75 % in soils.

## **Irrigation water quality related with pH**

A study is carried out by Sarkar and Hassan (2006) in basin of Bangladesh for evaluating the ground water quality. They found the pH of basin water varied from 7.75 to 8.09 with a mean value 7.97 which is acceptable pH range for irrigation suitability.

Vasanthavigar *et al.* (2010) studied the ground water quality in sub basin of Thirumanimuttar in Tamil Nadu for evaluating water suitability for crop production and domestic purposes. They concluded that the pH of ground water ranging from 6.78 to 9.22 with a mean value of 7.37, which is neutral to alkaline in nature in study area.

Jadhav *et al.* (2012) asserted the Borewell water quality for suitability for drinking and domestic purposes. The study is carried out in Ajara Tahsil during April 2011. The pH values ranged from 6.5 to 8.4. All samples are within the permissible limit. The pH value of about 10 are exceptional and may reflect contamination by strong bases such as NaOH and  $\text{Ca(OH)}_2$ .

Sarala *et al.* (2012) investigated the ground water quality in Jawaharnagar, Hyderabad (A.P.). They observed that the pH of the groundwater samples in the study area ranged from 6.76 - 7.81 and 6.65 - 7.62 during post and pre-monsoon respectively. The groundwater in this area is generally acidic in nature due to granitic rock formation. The total alkalinity values in the study area are within the permissible limit and ranging from 240-480  $\text{mg l}^{-1}$  during post monsoon period and 230-460  $\text{mg l}^{-1}$  in pre-monsoon period.

Ashfaq and Ahmad (2014) investigated the ground water quality in Aligarh, Uttar Pradesh India. The pH values of the study area are within the permissible limits of WHO standards (6.5- 8.5). The value of pH is found to lie between 6.4 - 8.1.

A study is carried out by Apraj *et al.* (2017) for assessing the ground water quality for irrigation in Palghar and Dahanu Tehsils of Coastal Konkan.

They concluded that the pH values of irrigation water samples are ranged from 7.14 to 8.38 with an average value of 7.63 from Palghar Tehsil and the pH of irrigation water samples from Dahanu tahsil ranged from 6.81 to 8.43 with a mean of 7.48 Kaithal district in Haryana. They concluded the pH of water samples ranged from 7.36 to 9.80 with an average of 8.1.

### **Irrigation water quality related with EC**

A study is carried out by Sarkar and Hassan (2006) for evaluating the groundwater quality in basin of Bangladesh. They found that the EC of basin water varied from 0.64 to 1.06 dS m<sup>-1</sup> which is suitable for irrigation purpose.

Jadhav *et al.* (2012) studied the ground water quality in Ajara tehsil (Maharashtra) . They observed the Electrical conductance values ranged from 0.12 to 1.22 dS m<sup>-1</sup> and indicate the presence of some ionic matters in water. All the values are within the permissible limit.

Sarala *et al.* (2012) investigated the ground water quality in Jawaharnagar, Hyderabad (A.P.). They concluded that the Electrical conductivity values varied from 615-1950 dS m<sup>-1</sup> and 583-1898 dS m<sup>-1</sup> during post and pre-monsoon respectively.

Reddy (2013) investigated the quality of groundwater in Bhaskar Rao Kunta watershed in Nalgonda District of Telangana state, India. He observed that the EC values ranged from 650 and 1497 (μS cm<sup>-1</sup>) with a mean value of 975 (μS cm<sup>-1</sup>). He found that the 80 % of the samples lies under medium to high salinity.

Singh *et al.* (2014) assessed the ground water quality in the Ranchi district of Jharkhand. They observed that the EC range lies between 238 and 1357 μS cm<sup>-1</sup> in which a mean value of 666 μS cm<sup>-1</sup> which is higher than the acceptable limit.

Choudhary *et al.* (2016) determined the ground water quality in the part of central India. The result showed that the electric conductivity of the central India is very high and varied between 785 - 4589 μS cm<sup>-1</sup>.

Apraj *et al.* (2017) evaluated the groundwater quality for agricultural purpose in the villages of Palghar and Dahanu tehsils of Coastal Konkan. They observed that the water is slightly saline. The EC in Palghar tahsil lies between 0.31 to 1.28 (dS m<sup>-1</sup>) with an average value 0.68 (dS m<sup>-1</sup>) and EC ranges between 0.44 to 0.45 (dS m<sup>-1</sup>) with an average 0.79 (dS m<sup>-1</sup>) in Dahanu tehsils .

### **Irrigation water quality in relation to total cations**

Jadhav *et al.* (2012) studied the ground water quality in Ajara tehsil (Maharashtra). Total hardness of water sample ranged from 40 to 480 mg L<sup>-1</sup> indicated that out of 51 samples, 3 samples (S 35, S 46 and S 51) are fall under very hard category above 300 mg L<sup>-1</sup> , calcium hardness values ranged from 8.02 to 72.18 mg L<sup>-1</sup>. All samples are within the permissible limit. Magnesium hardness values ranged from 6.16 to 86.42 mg L<sup>-1</sup> and are within the permissible limit of 50 to 150 mg L<sup>-1</sup> (WHO).

Sarala *et al.* (2012) investigated the ground water quality in Jawaharnagar Hyderabad (A.P.) and observed that the calcium concentration in water samples collected from the study area ranged from 176-376 mg L<sup>-1</sup> and 166-426 mg L<sup>-1</sup> in post and pre monsoon seasons. So, all the samples exceeded the permissible limit and the magnesium level in the water samples ranged from 66-280 mg L<sup>-1</sup> and 64-278 mg L<sup>-1</sup> in post and pre monsoon seasons. Most of the locations exceeded the permissible limit.

An investigation is carried out by Apraj *et al.* (2017) to assessing groundwater quality for suitability of irrigation in the areas of Palghar and Dahanu tehsils of Coastal Konkan. They concluded that the concentration of Na<sup>+</sup> in water samples from Palghar tahsil ranged between 4.98 to 109.26 me L<sup>-1</sup> with an average value of 31.92 me L<sup>-1</sup> and that from Dahanu tahsil 6.14 to 104.70 me L<sup>-1</sup> with an average value of 29.12 me L<sup>-1</sup>. The results showed that Ca<sup>2+</sup> is dominant in water among all the cations followed by Na<sup>+</sup>, Mg<sup>2+</sup> and K<sup>+</sup>.

The study is carried out by Rao (2018) for assessing groundwater samples in Prakasam district of Andhra Pradesh. He obtained the

concentration of  $\text{Ca}^{2+}$  ranged from 55 and 90  $\text{mg L}^{-1}$  with an average of 65.67  $\text{mg L}^{-1}$  and  $\text{Mg}^{2+}$  between 42 to 105  $\text{mg L}^{-1}$  with an average of 76.87  $\text{mg L}^{-1}$ , concentration of  $\text{Na}^+$  between 185 to 823  $\text{mg L}^{-1}$  with an average of 444.73  $\text{mg L}^{-1}$  and concentration of  $\text{K}^+$  found to be low, which varied between 12 to 121 with an average of 54.33  $\text{mg L}^{-1}$  in samples of ground water.

### **Irrigation water quality in relation to total anions**

Sarkar and Hassan (2006) evaluated the quality of groundwater in basin of Bangladesh. The results showed that concentration of anions such as  $\text{HCO}_3^-$  ranged between 6.25 to 11.50 (8.07), and  $\text{Cl}^-$  between 2.38 to 7.75 (5.13)  $\text{me L}^{-1}$  in water samples.

Jadhav *et al.* (2012) studied the ground water quality in Ajara tehsil Maharashtra and observed that the chloride in excess ( $250 \text{ mg L}^{-1}$ ) impart a salty taste to water and people are not accustomed to high chlorides may be subjected to laxative effects. Chloride values ranged from 25.56 to 178.92  $\text{mg L}^{-1}$ . All the samples are within the permissible limit.

Sarala *et al.* (2012) investigated the ground water quality in Jawaharnagar Hyderabad (A.P.) and observed that the concentration of nitrite content in all the samples ranged from 0.0005-0.1  $\text{mg L}^{-1}$  and 0.0005-0.15  $\text{mg L}^{-1}$  during post and pre monsoon seasons and the nitrate concentration is ranged between 0.3-14.6  $\text{mg L}^{-1}$  and 0.5-12.2  $\text{mg L}^{-1}$  in post and pre monsoon seasons. Sulphate concentration is ranged from 25- 100  $\text{mg L}^{-1}$  and 23-123  $\text{mg L}^{-1}$  during post and pre monsoon seasons. In the study area the sulphate levels are within the permissible limit of 200  $\text{mg L}^{-1}$ . The chloride concentration in the study area varied from 40-230  $\text{mg L}^{-1}$  and 38- 358  $\text{mg L}^{-1}$  during post and pre monsoon periods.

Vasanthavigar *et al.* (2012) investigated the groundwater quality in sub basin of Thirumanimuttar (Tamil Nadu) for irrigation suitability. The abundance of major anion concentration in order as  $\text{HCO}_3^- > \text{Cl}^- > \text{NO}_3^-$ . They found the concentration of anions in water samples as  $\text{HCO}_3^-$  73.22 - 893.84,  $\text{Cl}^-$  86.85 - 1,602.27 and  $\text{SO}_4^{2-}$  0.01 - 126.8.

Apraj *et al.* (2017) studied quality of groundwater for irrigation in the areas of Palghar and Dahanu tehsils of Coastal Konkan. The results showed that the concentration of carbonate varied from 0.0 to 6.0 me L<sup>-1</sup> with a mean value of 1.02 me L<sup>-1</sup> from Palghar tehsil, while in Dahanu tehsil, it is varied from 0.0 to 6.0 me L<sup>-1</sup> with a mean value of 2.50 me L<sup>-1</sup>. There are no carbonate contents in majority of water samples. The order of anions in samples is Cl<sup>-</sup> > HCO<sub>3</sub><sup>-</sup> > SO<sub>4</sub><sup>2-</sup> > CO<sub>3</sub><sup>2-</sup>.

The study is carried out by Rao (2018) for assessing groundwater samples in Prakasam district of Andhra Pradesh. He found the total anions like bicarbonate, chloride, sulphate. The concentration of HCO<sub>3</sub><sup>-</sup> is found between 480–1025 mg L<sup>-1</sup> with an average value of 731.33 mg L<sup>-1</sup>, Cl<sup>-</sup> from 215 and 1060 mg L<sup>-1</sup> with an average value of 568.83 mg L<sup>-1</sup> and SO<sub>4</sub><sup>2-</sup> content is found to be 22–125 mg L<sup>-1</sup> with a mean of 71.47 mg L<sup>-1</sup> in samples of water.

### **Irrigation water quality in relation to SAR**

Singh *et al.* (2014) investigated the quality of ground water in the township of Ranchi district of Jharkhand. They obtained the SAR varied between 0.6 to 2.0 (mmol L<sup>-1</sup>)<sup>1/2</sup> (average. 1.0 (mmol L<sup>-1</sup>)<sup>1/2</sup>). These SAR values were good for agricultural purpose.

Elmabrok and Libda (2015) analyzed the quality of ground water in Alagilat Area, the results showed that SAR ranges from 2.41 to 15.42 (mmol L<sup>-1</sup>)<sup>1/2</sup> with a mean value of 4.84 (mmol L<sup>-1</sup>)<sup>1/2</sup> and SAR content to be within the safe limit and it is acceptable for irrigation use.

Singh *et al.* (2017) analyzed the groundwater quality in Gulha block of Kaithal district in Haryana India. They concluded the SAR which varied between 2.55 to 14.39 (mmol L<sup>-1</sup>)<sup>1/2</sup> with an average value of 6.12 (mmol L<sup>-1</sup>)<sup>1/2</sup> in water samples.

A study is conducted by Apraj *et al.* (2017) for assessing the groundwater quality for irrigation in the areas of Palghar and Dahanu Tehsils

of Coastal Konkan. They concluded that the SAR ranged between 2.63 to 20.49  $(\text{mmol L}^{-1})^{1/2}$  with an average value of 10.53  $(\text{mmol L}^{-1})^{1/2}$  in Palghar tehsil and in Dahanu tehsil the same ranged from 3.11 to 17.22  $(\text{mmol L}^{-1})^{1/2}$  with an average value of 10.17  $(\text{mmol L}^{-1})^{1/2}$ . Among all water samples 61% samples are classified under C1 class which is suitable for irrigation and 39% water samples are moderately suitable and classified under C2 class.

### **Irrigation water quality in relation to RSC**

Elmabrok and Libda (2015) studied the quality of ground water in Alagilat Area, Libya and found that the irrigation water samples are within the safe limit for agriculture use. They obtained the RSC values varied between 250.82 to 0.66  $(\text{me L}^{-1})$  with a mean value of -33.73  $(\text{me L}^{-1})$  in irrigation water samples.

Bhatt (2016) assessed the groundwater quality in Gohana block of Sonapat, Haryana. They obtained the RSC contain in ground water varied from 0 to 9.2  $\text{me L}^{-1}$  and maximum samples are moderately suitable for agricultural purpose.

A study is conducted by Apraj *et al.* (2017) for studying about the groundwater quality for irrigation in the areas of Palghar and Dahanu tehsils of Coastal Konkan. They obtained the RSC values in water samples in Palghar tehsil ranged from 0 to 3.80 with a mean value of 0.74 and in Dahanu tehsil ranged from 0 to 4.8 with a mean value of 1.96.

### **Correlation among different parameters of water quality**

Bhoopathi *et al.* (2014) studied the ground water quality in Nacharam area of Ranga reddy district, Andhra Pradesh. They obtained the correlation between,  $\text{Na}^+$  and  $\text{K}^+$  is 1.0, pH and EC is -0.01, EC and  $\text{Ca}^{2+}$  is -0.13.

Khan *et al.* (2012) asserted a correlation on the ground water quality parameters of Vaiyampatti Village, Tiruchirappalli District. The data obtained in the range of 0.003 to 0.870 for all water quality parameters and found a weak correlations are obtained between pH and chloride ( $r = -0.533$ ).

A study is carried out by Choudhary *et al.* (2016) for assessing the quality of ground water in the part of central India and they found that the correlation between  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  is -0.01,  $\text{K}^+$  and  $\text{Ca}^{2+}$  is -0.05,  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  is 0.93 in water samples.

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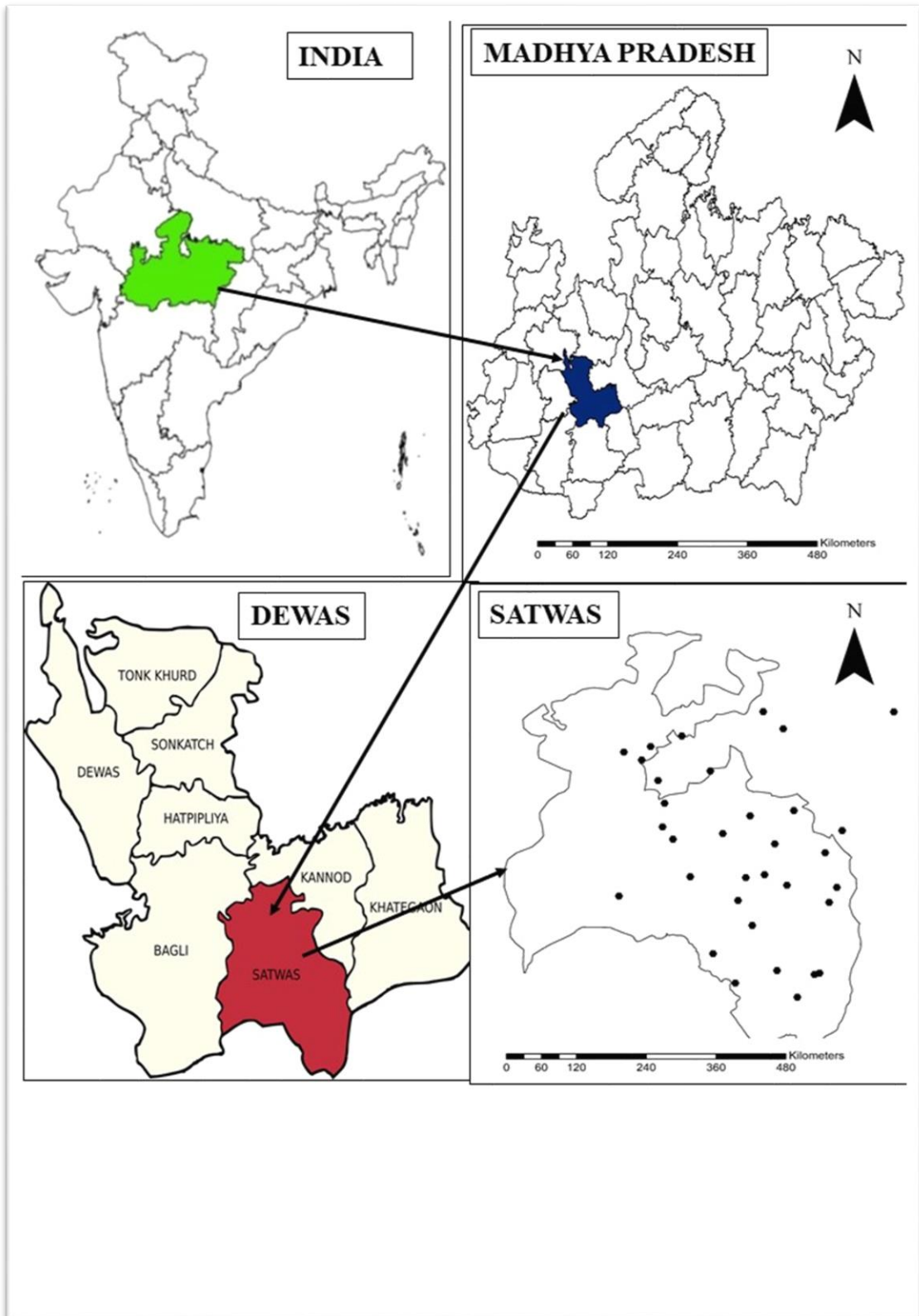
## CHAPTER - III

### MATERIAL & METHODS

The chapter material and methods included the determination of soil fertility status and ground water quality by various methods with respect to present study entitled “**Assessment of soil properties and ground water quality of Satwas tehsil of Dewas district, Madhya Pradesh**”.

#### **3.2 Collection of soil sample and preparation:**

Soil samples (33 number) are collected from different locations by using Global positioning system (GPS) from different villages of Satwas tehsil, come under Dewas district (MP). Field is divided into different homogenous units based on the visual observation. Drive the auger to a plough depth of 15 cm and draw the soil sample. Reduce the bulk of sample to about half to one kilogram by quartering or compartmentalization. Collect the sample in a clean cloth or polythene. Powder the soil sample by breaking the clods to its ultimate soil particle using a wooden mallet. Collected soil samples passing through 2 mm sieve and stored in a polythene bag with proper labeling for laboratory analysis. General information about the study area and location of the soil and water samples are presented in Fig.1 and Table 3.1



**Fig. 1: Location of study area in Satwas tehsil of Dewas district, M.P.**

**Table 3.1: General information about Soil and water samples (open wells/tube wells, hand pumps) and farmers rating, in Satwas tehsil of Dewas district**

Sample No.	Village	Location <sup>oo</sup>	Source	Depth (m)	Crops grown	Farmer's rating	Years
1.	Hardi	22° 38' 09.8"N & 76° 49' 13.2"E	W	10	Wheat, Gram, Soybean	Good	15
2.	Bekalya	22° 36' 20.9"N & 76° 35' 44.8"E	W	10	Wheat, Gram, Vegetables	Good	25
3.	Gaja Khedi	22° 35' 39.7"N & 76° 33' 46.4"E	W	10	Wheat, Gram, Vegetables	Good	10
4.	Jinwani	22° 35' 16.9"N & 76° 32' 04.5"E	W	10	Wheat, Gram, Vegetables, Maize	Good	30
5.	Kanta Phod	22° 34' 49.9"N & 76° 33' 13.9"E	W	15	Wheat, Gram, Soybean	Good	20
6.	Salamatpura	22° 33' 37.8"N & 76° 34' 18.7"E	TW	100	Wheat, Gram, Soybean	Good	13
7.	Badgaon	22° 32' 16.5"N & 76° 34' 46.3"E	TW	175	Wheat, Gram, Soybean	Good	2
8.	Ektera	22° 30' 50.7"N & 76° 34' 41.3"E	W	10	Wheat, Gram, Soybean	Good	25
9.	Surmanya	22° 26' 36.5"N & 76° 32' 02.5"E	TW	140	Maize Soybean	Good	10
10.	Pura	22° 30' 07.3"N & 76° 35' 22.7"E	TW	115	Soybean, Maize	Good	5
11.	Sindharni	22° 27' 53.7"N & 76° 36' 33.1"E	TW	100	Soybean, Maize	Good	5
12.	Balya	22° 30' 33.0"N & 76° 38' 32.6"E	W	10	Soybean, Gram	Good	40
13.	Satwas	22° 31' 39.7"N & 76° 40' 15.3"E	W	10	Soybean, Gram, Sorghum	Good	40
14.	Palasi	22° 34' 17.6"N & 76° 37' 37.7"E	W	10	Soybean, Gram	Good	5
15.	Kothada	22° 36' 57.6"N & 76° 42' 12.4"E	W	10	Soybean, Gram	Good	3
16.	Dagra Kheda	22° 37' 57.3"N & 76° 40' 53.9"E	W	10	Soybean, Gram , Wheat	Good	10
17.	Pagri	22° 32' 03.3"N & 76° 43' 02.4"E	TW	255	Soybean, Wheat	Good	1
18.	Kher Kheda	22° 30' 56.1"N & 76° 46' 09.1"E	TW	40	Soybean, Wheat	Good	15
19.	Mansuriya	22 ° 29' 34.3"N & 76° 46' 06.4"E	TW	70	Soybean, Gram , Wheat	Good	3
20.	Khapras	22° 27' 30.2"N & 76° 45' 54.9"E	TW	45	Soybean, Gram, Moong	Good	10
21.	Narayan Pura	22° 26' 35.5"N & 76° 45' 27.2"E	TW	115	Soybean, Gram	Good	20
22.	Gola Gudan	22° 27' 33.1"N & 76° 42' 44.2"E	TW	50	Soybean, Wheat, Gram	Good	20
23.	Gada Gaon	22° 28' 08.7"N & 76° 41' 17.3"E	TW	45	Soybean, Wheat, Gram, vegetables	Good	5
24.	Nimasa	22° 27' 56.2"N & 76° 40' 05.8"E	TW	100	Maize, Gram	Good	3

Sample No.	Village	Location	Source	Depth (m)	Crops grown	Farmer's rating	Years
25.	Panpat	22° 26' 32.9"N & 76° 39' 38.5"E	TW	100	Soybean, Wheat, Gram	Good	6
26.	Bhat Vardi	22° 25' 04.3"N & 76° 40' 35.8"E	TW	70	Soybean, Wheat, Gram	Good	11
27.	Beda Khal	22° 23' 18.5"N & 76° 38' 08.9"E	TW	45	Soybean, Wheat, Gram , Maize	Good	12
28.	Bhamar	22° 21' 34.5"N & 76° 39' 37.4"E	TW	35	Soybean, Wheat, Gram , Maize	Good	15
29.	Dhasau	22° 22' 24.0"N & 76° 42' 15.6"E	TW	70	Soybean, Wheat, Gram , Maize	Good	24
30.	Nimlay	22° 20' 49.9"N & 76° 43' 36.3"E	TW	35	Soybean, Maize, Vegetables	Good	50
31.	Banasa	22° 22' 13.7"N & 76° 44' 39.1"E	TW	120	Soybean, Maize	Good	24
32.	Kothda	22° 22' 19.0"N & 76° 44' 58.5"E	TW	11	Soybean, Gram , Maize	Good	11
33.	Borkhedi	22° 30' 01.1"N & 76° 41' 53.0"E	W	10	Soybean, Wheat, Gram	Good	3

### **3.3 Methods for chemical properties:**

#### **3.3.1 Determination of pH in soil:**

The pH is defined as the reciprocal of the common logarithm of the hydrogen ion ( $H^+$ ) activity, which is product of the hydrogen ion concentration and the hydrogen ion activity. The pH is determined by glass electrode or pH meter (Richards, 1954). Weigh and place 10 gm of soil into the glass beaker. Add 20 ml (1: 2) of distilled water to the soil sample. Stir the solution to obtain soil slurry and then cover with watch glass. The sample must stand for a minimum of one hour, stirring every 10 to 15 minutes. Standardize the pH meter by means of the standard solutions provided. Place the electrodes into the soil slurry solution. Read and record the pH value to the nearest tenth of a whole number.

#### **3.3.2 Determination of electrical conductivity (EC):**

The electrical conductivity indicates the amount of soluble (salt) ions in soil. The EC is a measurement of the conductivity of the soil solution; the measurement should be made under a controlled mixture of water to soil (2:1). It is expressed in  $dS\ m^{-1}$  at  $25^{\circ}C$ . The EC of soil suspension is determined with the help of conductivity meter (Richards, 1954).

#### **3.3.3 Determination of organic carbon:**

Analysis of soil organic carbon is done by Walkley and Black's rapid titration method (1934). Transfer 2.5 gm air dried soil into a 500 ml conical flask. Add 10 ml 1N  $K_2Cr_2O_7$  solution and 20 ml concentrated  $H_2SO_4$ . Swirl the content of the flask 2 or 3 times and allow the flask to stand for 30 min. for the reaction to complete. Add 200 ml distilled water to the flask to dilute the suspension, and then add 10 ml of orthophosphoric acid or 1 ml of diphenylamine indicator. A deep violet color will appear. Titrate it with 0.5 N ferrous ammonium sulphate, till the color changes from violet to blue and finally bright green. Note the volume of the ferrous ammonium sulphate used in titration. Carry out a blank titration (without soil), the same way.

$$\text{Organic carbon\% in soil} = [(X-Y) \div 2] \text{ ml} \times 0.003 \times 100 \div 2 = R$$

Where, X= blank titration reading.

Y= sample reading, W= Weight of soil used

\* Assume that organic matter contains 58% carbon, thus the organic matter content of the soil will be calculated as -

$$\text{Organic matter in soil (\%)} = R \times 1.724$$

#### **3.3.4. Available Nitrogen**

Available nitrogen is determined by Alkaline permanganate method (Subbiah and Asija, 1956). 20 gm of soil samples are taken in one litre flask and, then added 100 ml of 0.32 %  $\text{KMnO}_4$  and 2.5 % NaOH each. The flask is immediately connected to distillation assembly and heated. The distilled ammonia is collected in 0.1N  $\text{H}_2\text{SO}_4$  using methyl red indicator. The excess of sulphuric acid is titrated against 0.1N NaOH. Results have been expressed in  $\text{N kg h}^{-1}$ .

#### **3.3.5. Available phosphorus**

Available P is determined by Olsen's method (Olsen *et al.*, 1954).

##### **Extraction**

Add 50 ml of the bicarbonate extractant to a 100 ml conical flask containing 2.5 gm of soil sample. Add 1 gm of activated carbon. Shake for 30 minutes on the mechanical shaker and filter.

##### **Development of colour**

Take 5 ml of the filtered soil extract with a bulb pipette in a 25 ml measuring flask; deliver 5 ml of the molybdate reagent with an automatic pipette, dilute to about 20 ml with distilled water, shake and add 1 ml of the dilute  $\text{SnCl}_2$  solution with a bulb pipette. Fill to the 25 ml mark and shake thoroughly. Read the blue colour after 10 minutes on the spectrophotometer at 660 nm after setting the instrument to zero with the blank prepared similarly but without the soil.

### 3.3.6. Available K

Potassium (K) present in the soil is extracted with neutral ammonium acetate of 1 molarity (Jackson 1976). This is considered as plant-available K in the soils. It is estimated with the help of a flame photometer.

**Extraction:** Add 25 ml of the ammonium acetate extractant to a conical flask fixed in a wooden rack containing 5 gm of soil sample. Shake for 5 minutes and filter. Determine the K in the filtrate with the flame photometer. Preparation of the standard curve: Set up the flame photometer by atomizing 0 and 20  $\mu\text{g Kml}^{-1}$  solutions alternatively to readings of 0 and 100. Atomize intermediate working standard solutions and record the readings. Plot these readings against the respective K contents and connect the points with a straight line to obtain a standard curve.

### 3.3.7. Exchangeable cations

It is usually determined in a neutral normal ammonium acetate extract of soil. Extraction is carried out by shaking the soil–extractant mixture, followed by filtration or centrifugation. Calcium and Mg are determined either by the EDTA titration method or by using an AAS after the removal of ammonium acetate and OM. Appreciable amounts of soluble Ca and Mg may be present in soils. Hence, these water-soluble cations are estimated in the 1:2 soil–water extract and deducted from ammonium acetate extractable Ca and Mg (as ammonium acetate also extracts water-soluble cations) in order to obtain exchangeable Ca and Mg. Generally, to obtain the soil–water extract, 25 g soil and 50 ml of water suspension is shaken for 30 minutes on a mechanical shaker and filtered. The method of estimation in the water extract (water-soluble cations) and ammonium acetate extract (exchangeable cations) is same. The EDTA titration method developed by Cheng and Bray (1951) is preferred on account of its accuracy, simplicity and speed.

Mg in solution can be titrated with 0.01 N EDTA using EBT dye as indicator at pH 10 in the presence of ammonium chloride and ammonium hydroxide buffer. At the end point, the colour changes from wine-red to blue or green.

**Table: 3.2 Methods used in determination of chemical properties of Soil**

S.No.	Soil Characteristics	Methods
1.	Soil pH	Richards (1954)
2.	EC (dS m <sup>-1</sup> )	Richards (1954)
3.	Organic Carbon %	Walkley and Black, (1934)
4.	Available N (kg ha <sup>-1</sup> )	Alkaline Permanganate method (Subbiah and Asija, 1956)
5.	Available P (kg ha <sup>-1</sup> )	Olsen's method (Olsen <i>et al.</i> , 1954)
6.	Available K (kg ha <sup>-1</sup> )	Flame photometer, 1976 (Jackson)

**Table 3.3 The nutrient availability classes as per the criteria**

Nutrients	Low	Medium	High
N (kg ha <sup>-1</sup> )	<250	250-400	>400
P (kg ha <sup>-1</sup> )	<10	10-20	>20
K (kg ha <sup>-1</sup> )	<250	250-400	>400

**3. Methods for analyzing Chemical properties of irrigation water:****3.1 Collection of ground water samples****3.2 Methods of analysis****3.3 Methods of reporting****3.1 Collection of groundwater sample**

The groundwater samples (33 number) are collected from different villages of Satwas tehsil of Dewas district. The locations is recorded using GPS (Global positioning system). The water is collected in the post monsoon period during march, April 2019 in a 500 ml cleaned polyethylene bottle by using established methodology. The bottle is rinsed thrice with the sampling

water prior to collection and filled up to the mouth with the water. Collected samples are brought to the laboratory of Salt Affected Soils Project, College of Agriculture, Indore for determination of groundwater quality parameters using specialized methods.

### **3.2 Methods of analysis**

#### **3.2.1 Determination of pH**

Pour a 40 ml  $\pm$  5 ml sample into the glass beaker. Standardize the pH meter by means of the standard solutions provided. Immerse the electrodes of the pH meter into the water sample. Read and record the pH value to the nearest tenth of a whole number as per the method suggested by Richards, (1954).

#### **3.2.2 Determination of EC**

The electric current in water is conducted by the ions present in it, so when the concentration of ions increases, conductivity augments as well. The salt content of the soil can be estimated roughly from an electrical-conductivity measurement in water. Scale of conductivity (Deci Siemens per meter at 25° C.) The symbol "EC" is used to represent electrical conductivity. The EC values are measured in using a conductivity (EC) meter (Richards, 1954).

#### **3.2.3 Determination of total cations**

Calcium, magnesium, sodium, potassium etc are the main cations which is present in ground water. Concentrations of total cations in irrigation water affect its suitability for crop. Determination of cation ( $\text{Na}^+$  and  $\text{K}^+$ ) is estimated by the flame photometer. The cations ( $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ ) are estimated by volumetric titration method given by Richards (1954).

#### **3.2.4 Determination of total anions**

Major anions present in ground water are carbonates, bicarbonates, chloride, sulphate etc and affects the irrigation water quality. Total anions in water are determined by volumetric titration method (Richards, 1954).

### 3.2.5 Determination of Sodium Absorption Ratio (SAR)

SAR that expresses the relative activity of sodium ions in the exchange reactions with the soil.

This ratio measures the relative concentration of sodium to calcium and magnesium. It determines the suitability of ground water for irrigation as alkali hazard for crop. Calculation of SAR with the help of following formula (Richards, 1954)

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

On the basis of sodium hazard irrigation water is classified as, Low - S1 [ $< 10$ ], medium -S2 [ $10 - 18$ ], high- S3 [ $18 - 26$ ] and very high -S4 [ $>26$ ].

### 3.2.6 Determination of Residual Sodium Carbonate (RSC)

RSC determines the hazardous effect of carbonate and bicarbonate on water quality. It is evaluated by the following equation according to where ions concentrations are expressed in  $mmol L^{-1}$ . Generally, when water has excess concentration of bicarbonate there will be tendency for calcium and magnesium to precipitate as carbonates. Calculation of RSC with the help of following formula (Richards, 1954).

$$RSC = [(CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})]$$

Classification of irrigation water based on quality of water. RSC of water as  $<1.25 me L^{-1}$  - good,  $1.25-2.5 me L^{-1}$  fair,  $>2.5 me L^{-1}$  poor quality and unsuitable for irrigation.

### 3.3 Method of reporting

The results of the analysis of water samples are grouped as per the classification suggested by Richards (1954) as given in Table 3.4 and Minhas *et al.* (1998) of CSSRI, Karnal Haryana (Table 3.5).

**Table 3.4. Classes of ground water quality as per Richards (1954)**

Salinity classes (dS m <sup>-1</sup> )		Sodium hazards (SAR) (mmol L <sup>-1</sup> ) <sup>1/2</sup>	
C1	<0.250	S1	<10
C2	0.250-0.750	S2	10-18
C3	0.750-2.250	S3	18- 26
C4	>2.250	S4	>26

**Table 3.5: Criteria of ground water quality as per the Minhas *et al.* (1998) of CSSRI, Karnal (Haryana)**

S.N o.	Water quality	EC (dS m <sup>-1</sup> )	SAR (mmol L <sup>-1</sup> ) <sup>1/2</sup>	RSC (me L <sup>-1</sup> )
<b>A.</b>	<b>Good</b>	<2	<10	<2.5
<b>B.</b>	<b>Saline water</b>			
1.	Marginally Saline	2- 4	<10	<2.5
2.	Saline	>4	<10	<2.5
3.	High SAR Saline	>4	>10	<2.5
<b>C.</b>	<b>Alkali waters</b>			
1.	Alkali	<4	<10	2.5-4.0
2.	Alkali	<4	<10	>4.0
3.	Highly Alkali	variable Marginally	>10	>4.0

## CHAPTER - IV

### RESULTS

This section deals with the results obtained from research on subject entitled “**Assessment of soil properties and ground water quality of Satwas tehsil of Dewas district, Madhya Pradesh**”. The results are presented in following heads.

#### **Results of ground water samples of Satwas tehsil of Dewas district**

##### **4.1 Number of ground water samples and soil samples:**

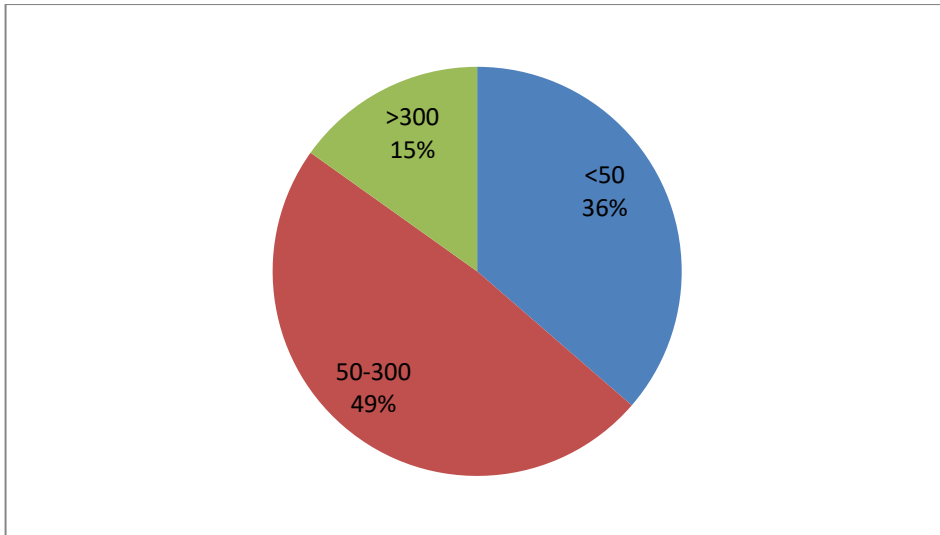
Study of soil and ground water samples of Satwas tehsil is carried out during experimental session 2019 and total 66 samples are collected village wise with GPS locations.

##### **4.2 Depth of wells / tube wells:**

According to the depth of wells and tube wells (Table 4.1), ground water samples of Satwas tehsil are categorized. The depth of wells/ tubewell of Satwas tehsil are less than 50 m and constituted 36.4 % of the total wells/tube wells. About 48.5 % of wells/tubewells samples of the Satwas tehsil are declared 50-300 m depth and regarding 15.1 % samples are >300 m depth. The general information about the location of samples in Satwas tehsil of Dewas district is presented in Table 3.1.

**Table 4.1: Allocation of ground water samples Satwas tehsil accordance with the depth of wells / tubewells:**

<b>S.No.</b>	<b>Well / Tube well depth (m)</b>	<b>No. of samples</b>	<b>% samples</b>
1.	< 50	12	36.4
2.	50-300	16	48.5
3.	>300	5	15.1



**Fig. 4.1: Percent distribution of ground water samples according to depth of wells / tubewells (m)**

**Table 4.2: pH, EC of ground water samples of Satwas tehsil of Dewas district**

<b>S.No.</b>	<b>Name of village</b>	<b>pH</b>	<b>EC (dS m<sup>-1</sup>)</b>
1.	Hardi	7.1	0.74
2.	Bekalya	7.2	0.71
3.	Gaja Khedi	7.5	0.8
4.	Jinwani	7.5	0.92
5.	Kanta Phod	7.4	0.82
6.	Salamatpura	7.6	0.98
7.	Badgaon	7.7	1.13
8.	Ektera	8.7	0.70
9.	Surmanya	8.0	0.59
10.	Pura	7.6	0.73
11.	Sindharni	7.2	0.65
12.	Balya	7.1	0.90
13.	Satwas	7.7	0.81
14.	Palasi	7.4	0.92
15.	Kothada	7.7	0.69
16.	Dagra Kheda	7.9	0.98
17.	Pagri	7.8	0.81
18.	Kher Kheda	7.3	1.29
19.	Mansuriya	7.4	1.27
20.	Khapras	7.3	1.04
21.	Narayan Pura	7.7	0.98
22.	Gola Gudan	7.5	0.82
23.	Gada Gaon	7.3	0.24
24.	Nimasa	7.2	0.91
25.	Pan Pat	7.4	0.31
26.	Bhat Vardi	7.4	0.90
27.	Beda Khal	7.3	0.89
28.	Bhamar	7.6	0.98
29.	Dhasaur	7.5	0.80
30.	Nimlay	7.2	1.98
31.	Banasa	7.6	0.93
32.	Kothda	7.3	1.14
33.	Borkhedi	7.7	0.84

**Table 4.3: Cations present in ground water samples of Satwas tehsil of Dewas district**

S.No.	Name of village	Cations ( me L <sup>-1</sup> )			
		Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>
1.	Hardi	4.6	2.4	1.18	0.12
2.	Bekalya	3.2	1.6	2.0	0.02
3.	Gaja Khedi	3.2	1.2	1.75	0.29
4.	Jinwani	3.6	1.2	1.67	0.01
5.	Kanta Phod	2.8	2.0	2.06	0.02
6.	Salamatpura	3.4	1.8	3.2	0.06
7.	Badgaon	4.6	2.4	2.15	0.05
8.	Ektera	3.2	1.2	2.92	0.06
9.	Surmanya	2.8	1.4	0.97	0.03
10.	Pura	2.8	1.4	1.2	0.03
11.	Sindharni	3.2	1.2	0.57	0.03
12.	Balya	2.2	1.2	3.5	0.06
13.	Satwas	2.0	1.2	3.09	0.05
14.	Palasi	4.4	2.2	2.25	0.05
15.	Kothada	2.4	2.0	1.45	0.02
16.	Dagra Kheda	4.2	1.4	2.56	0.01
17.	Pagri	3.8	1.8	2.5	0.01
18.	Kher Kheda	6.6	3.6	1.98	0.55
19.	Mansuriya	5.4	3.6	3.51	0.24
20.	Khapras	5.2	3.4	1.98	0.02
21.	Narayan Pura	5.6	2.2	1.93	0.01
22.	Gola Gudan	4.2	2.4	1.5	0.01
23.	Gada Gaon	0.6	0.2	1.63	0.01
24.	Nimasa	5.4	2.8	0.97	0.03
25.	Panpat	0.4	0.2	2.23	0.17
26.	Bhat Vardi	4.4	3.2	1.38	0.01
27.	Beda Khal	5.8	2.8	0.43	0.01
28.	Bhamar	4.8	2.8	2.28	0.02
29.	Dhasaur	4.0	2.4	1.63	0.01
30.	Nimlay	10.8	6.4	2.71	0.05
31.	Banasa	3.6	2.8	2.9	0.01
32.	Kothda	6.0	3.6	2.01	0.00
33.	Borkhedi	3.6	2.8	2.05	0.01

**Table 4.4: Anions present in ground water samples of Satwas tehsil of Dewas district**

S.No.	Name of village	Anions (me L <sup>-1</sup> )			
		CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>
1.	Hardi	0	2.0	3.6	2.4
2.	Bekalya	0	2.8	2.2	1.8
3.	Gaja Khedi	0	2.8	2.8	0.8
4.	Jinwani	0	2.2	2.6	1.6
5.	Kanta Phod	0	2.2	2.8	1.8
6.	Salamatpura	0	2.2	2.8	3.4
7.	Badgaon	0	2.6	2.8	4.0
8.	Ektera	0	2.6	2.4	2.2
9.	Surmanya	0	2.6	2.4	0.6
10.	Pura	0	2.4	1.8	1.6
11.	Sindharni	0	1.8	1.8	1.4
12.	Balya	0	3.8	2.0	1.2
13.	Satwas	0	3.4	2.0	0.8
14.	Palasi	0	3.8	2.2	2.8
15.	Kothada	0	2.8	1.8	1.2
16.	Dagra Kheda	0	2.2	1.8	4.2
17.	Pagri	0	2.8	2.2	3.2
18.	Kher Kheda	0	2.6	4.2	5.6
19.	Mansuriya	0	3.2	4.6	4.8
20.	Khapras	0	2.4	2.8	4.8
21.	Narayan Pura	0	3.2	2.8	3.8
22.	Gola Gudan	0	3.4	2.0	2.8
23.	Gada Gaon	0	0.8	0.4	1.2
24.	Nimasa	0	3.4	3.6	2.2
25.	Panpat	0	0.6	1.2	1.2
26.	Bhat Vardi	0	3.2	2.2	3.6
27.	Beda Khal	0	3.6	2.0	3.4
28.	Bhamar	0	3.2	2.2	4.4
29.	Dhasau	0	4.0	2.2	1.8
30.	Nimlay	0	6.8	7.2	5.8
31.	Banasa	0	3.6	3.2	2.6
32.	Kothda	0	3.6	2.6	5.2
33.	Borkhedi	0	2.2	2.2	4

**Table 4.5: RSC, SAR and Categories of ground water samples of Satwas tehsil of Dewas district**

<b>S.No.</b>	<b>Name of village</b>	<b>RSC</b>	<b>SAR</b>	<b>Categories (CSSRI, Karnal)</b>
1.	Hardi	Nil	0.22	A
2.	Bekalya	Nil	0.46	A
3.	Gaja Khedi	Nil	0.42	A
4.	Jinwani	Nil	0.38	A
5.	Kanta Phod	Nil	0.47	A
6.	Salamatpura	Nil	0.70	A
7.	Badgaon	Nil	0.41	A
8.	Ektera	Nil	0.70	A
9.	Surmanya	Nil	0.24	A
10.	Pura	Nil	0.29	A
11.	Sindharni	Nil	0.14	A
12.	Balya	Nil	0.95	A
13.	Satwas	Nil	0.86	A
14.	Palasi	Nil	0.44	A
15.	Kothada	Nil	0.35	A
16.	Dagra Kheda	Nil	0.54	A
17.	Pagri	Nil	0.53	A
18.	Kher Kheda	Nil	0.31	A
19.	Mansuriya	Nil	0.59	A
20.	Khapras	Nil	0.34	A
21.	Narayan Pura	Nil	0.35	A
22.	Gola Gudan	Nil	0.29	A
23.	Gada Gaon	Nil	0.91	A
24.	Nimasa	Nil	0.17	A
25.	Panpat	Nil	1.44	A
26.	Bhat Vardi	Nil	0.25	A
27.	Beda Khal	Nil	0.07	A
28.	Bhamar	Nil	0.41	A
29.	Dhasau	Nil	0.32	A
30.	Nimlay	Nil	0.33	A
31.	Banasa	Nil	0.57	A
32.	Kothda	Nil	0.32	A
33.	Borkhedi	Nil	0.41	A

**Table 4.6: Maximum, minimum, mean and SD value of ground water of Satwas tehsil of Dewas district**

S.No.	pH	EC dSm <sup>-1</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>	SAR (mmol L <sup>-1</sup> ) <sup>1/2</sup>
			me L <sup>-1</sup>							
<b>Maximum</b>	8.70	1.98	6.80	7.2	5.8	10.8	6.40	3.51	0.55	1.44
<b>Minimum</b>	7.12	0.24	0.60	0.4	0.40	0.40	0.20	0.43	0.00	0.07
<b>Mean</b>	7.50	0.88	2.88	2.58	4.02	4.02	2.20	2.0	0.06	0.46
<b>SD</b>	0.30	0.28	1.03	1.13	1.48	1.84	1.16	0.76	0.10	0.26

The chemical analysis of each water sample, range and means of different water quality parameter of Satwas tehsil are represented in Table 4.2 – 4.6. The pH values varied from 7.12 to 8.70 with a mean of 7.50 (Table 4.6). The lowest pH in water samples is recorded in villages Hardi and Balya (pH 7.12) at serial number 01 and 12, and highest value of pH is observed in village Ektera (pH 8.70) at sample number 08 (Table 4.2). The EC values varied from 0.24 to 1.98 with a mean of 0.88 dS m<sup>-1</sup> (Table 4.2). The highest value of EC (1.98 dS m<sup>-1</sup>) is observed in village Nimlay at sample number 30. The lowest salt content (EC 0.24 dS m<sup>-1</sup>) in water samples is recorded in village Gadagaon and at sample number 23. The SAR confined from 0.07 to 1.44 (mmolL<sup>-1</sup>)<sup>1/2</sup> with a mean value of 0.46 (mmolL<sup>-1</sup>)<sup>1/2</sup>. The lowest SAR value of 0.07 (mmolL<sup>-1</sup>)<sup>1/2</sup> is recorded in village Bedakhal at sample number 25 and highest value of SAR 1.44 (mmolL<sup>-1</sup>)<sup>1/2</sup> in village Panpat at sample number 27 (Table 4.6).

The cation concentration in ground water samples of Satwas tehsil is presented in Table 4.3. The calcium concentration in the samples had a wide range (0.40 to 10.8 me L<sup>-1</sup>) followed by Mg<sup>2+</sup> (0.20 to 6.4 me L<sup>-1</sup>), Na<sup>+</sup> (0.43 to 3.51 meL<sup>-1</sup>) and K<sup>+</sup> (00 to 0.55 me L<sup>-1</sup>). Mean value of Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup> are, 4.02, 2.20, 2.0 and 0.06 respectively. In case of anion, Cl<sup>-</sup> is the dominant ion with maximum value (7.2 me L<sup>-1</sup>) observed in village Nimlay at serial number 30 (Table 4.4). The highest value of HCO<sub>3</sub><sup>-</sup> (6.8 meL<sup>-1</sup>)

observed in Nimlay village at sample number 30, while the minimum (0.6 me L<sup>-1</sup>) recorded in village at sample number 25. Minimum value of SO<sub>4</sub><sup>-</sup> (0.6 me L<sup>-1</sup>) are recorded in Surmavya village at serial no. 09 and maximum value of SO<sub>4</sub><sup>2-</sup> (5.8 me L<sup>-1</sup>) are observed in Nimalay at serial no 30. The RSC and SAR values presented in Table 4.5 shows that RSC is totally absent in all water samples. The SAR values varied from 0.07 to 1.44 (mmolL<sup>-1</sup>)<sup>1/2</sup>. The lowest value of SAR 0.07 (mmolL<sup>-1</sup>)<sup>1/2</sup> is found in Bedakhal of number 27 sample. The highest value of SAR 1.44 (mmolL<sup>-1</sup>)<sup>1/2</sup> is obtained in Panpat village (number 25 sample) of Satwas tehsil of Dewas district.

**Table 4.7: Ground water classification of Satwas tehsil of Dewas district Minhas *et al.* (1998) of CSSRI, Karnal (Haryana)**

S.No.	Categories	No. of Samples	% samples
1.	A (Good)	33	100 %
2.	B1 ( Marginally Saline)	0	0
3.	B2 (Saline)	0	0
5.	C1 (Marginally Alkali)	0	0
6.	C2 (Alkali)	0	0
7.	C3 (Highly Alkali)	0	0

**Table 4.8: Distribution of ground water samples according to EC (dSm<sup>-1</sup>) and SAR (mmolL<sup>-1</sup>)<sup>1/2</sup> of Satwas tehsil of Dewas district (Richards, 1954)**

	S1 (SAR <10)	S2 (SAR 10-18)	S3 (SAR 18-26)	S4 (SAR >26)	% samples
<b>C1 (&lt;0.25)</b>	01	0	0	0	3.1
<b>C2(0.25-0.75)</b>	08	0	0	0	24.2
<b>C3(0.75-2.25)</b>	24	0	0	0	72.7
<b>C4(&gt;2.25)</b>	-	0	0	0	-

### 4.3 Classes of ground water based on pH

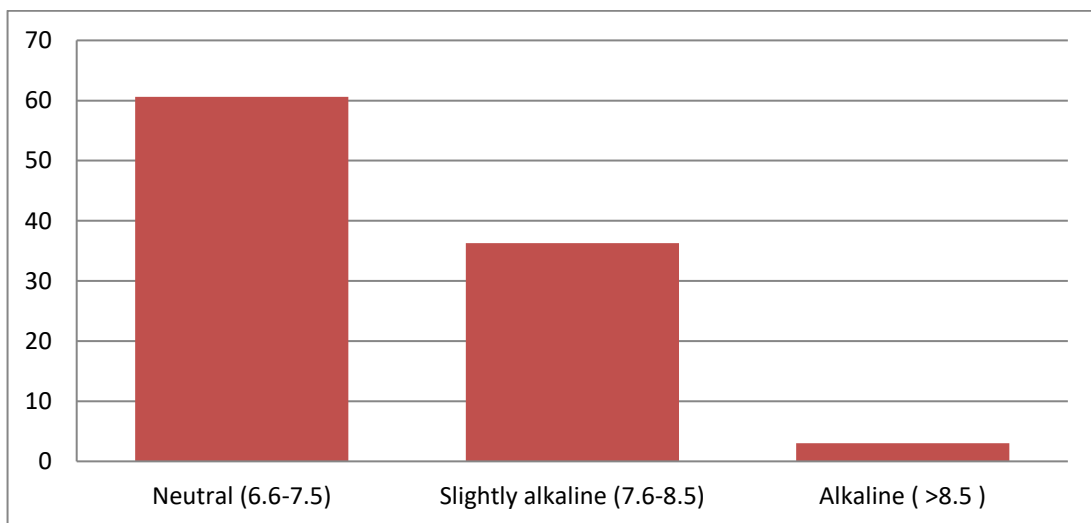
Ground water samples of Satwas tehsil belongs to the < 7.5 pH class. Further, the 60.60 % sample of Satwas tehsil found to be in the pH class 6.6 -7.5. The pH of water of Satwas tehsil ranged from 7.12 to 8.70 with a mean value of 7.50, standard deviation 0.30 (Table 4.9, Fig. 4.2 & 4.3). Out of 33 water samples 20 water samples are neutral in pH and 12 samples are slightly alkaline in nature.

**Table 4.9: Distribution of ground water samples according to pH of water**

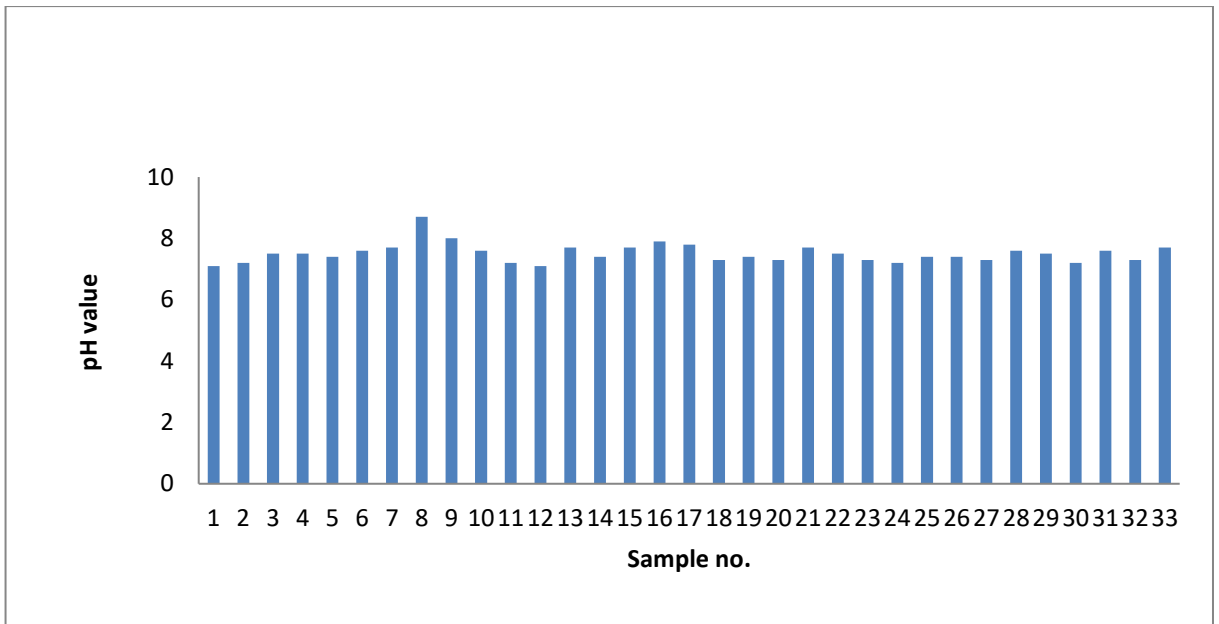
S. No.	Water pH class	No. of Samples	% Samples
1.	Neutral (6.6-7.5)	20	60.6
2.	Slightly alkaline (7.6-8.5)	12	36.3
3.	Alkaline ( >8.5 )	01	3.1

### General statistics

<b>Range</b>	7.12 - 8.70
<b>Mean</b>	7.50
<b>SD</b>	0.30 %



**Fig 4.2: pH range in the ground water sample of Satwas tehsil of Dewas district**



**Fig 4.3: Spatial distribution of pH in the ground water samples of Satwas tehsil of Dewas district**

#### **4.4 Classes of ground water based on electrical conductivity (dS m<sup>-1</sup>)**

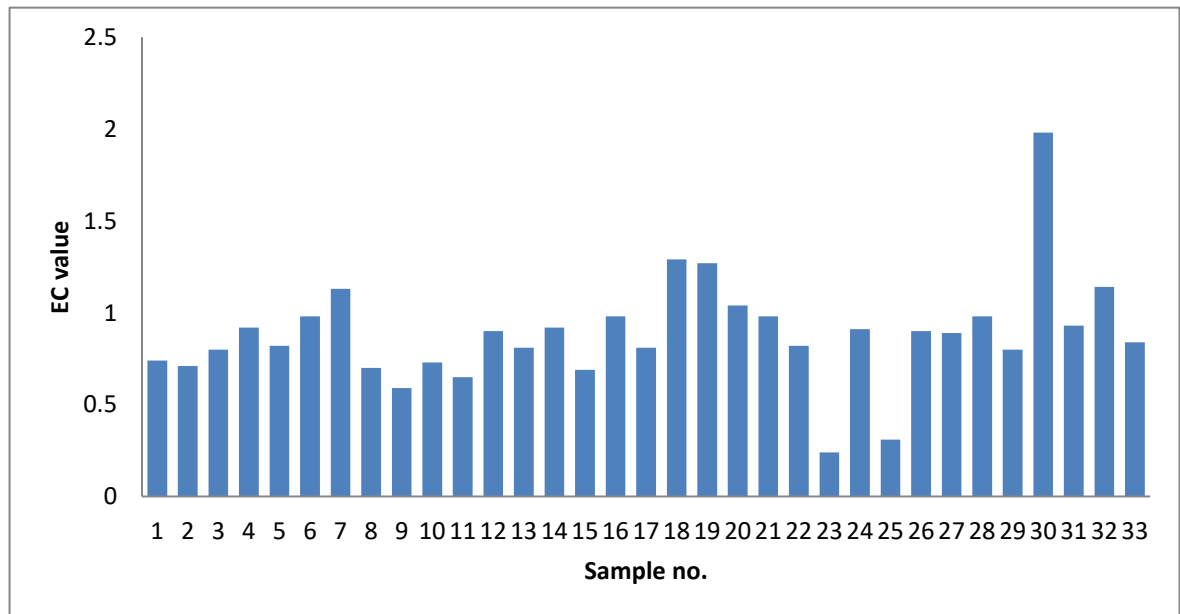
The data with reference to electrical conductivity (EC) of ground water of Satwas tehsil is given in Table 4.3. This parameter of water quality is categorized into four classes (< 0.25, 0.25-0.75, 0.75-2.25 and >2.25 dSm<sup>-1</sup>). The 15.1 % of Satwas tehsil ground water sample belongs to the EC < 0.25 and 75.8 % samples belongs to the 0.25-0.75 class. About 9.1 % water samples of Satwas tehsil fell in the EC range of 0.75-2.25 dS m<sup>-1</sup>. Electrical Conductivity of water ranged from 0.24 to 1.98 dS m<sup>-1</sup> with a mean value of 0.88 dS m<sup>-1</sup>, standard deviation 0.28 (Table 4.10 & Fig. 4.4).

**Table 4.10: Distribution of ground water samples according to electrical conductivity (EC)**

S. No.	EC (dS m <sup>-1</sup> )	No. of Samples	% Samples
1.	< 0.25	05	15.1
2.	0.25-0.75	25	75.8
3.	0.75-2.25	03	9.1

**General statistics**

<b>Range</b>	0.24 to 1.98 dS m <sup>-1</sup>
<b>Mean</b>	0.88 dS m <sup>-1</sup>
<b>SD</b>	0.28 %



**Fig. 4.4: Spatial distribution of EC (dSm<sup>-1</sup>) in the ground water samples of Satwas tehsil of Dewas district**

#### 4.5 Classes of Sodium adsorption ratio (SAR)

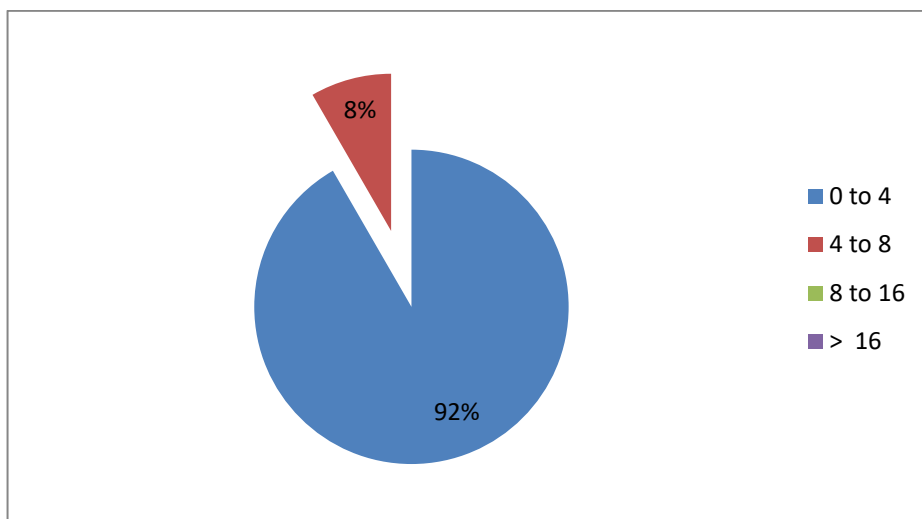
The data depicted in the table 4.6 shows four classes of Sodium Adsorption Ratio (SAR) for ground water quality classification of Satwas tehsil. All the sample of Satwas tehsil fell in the class of SAR <10. As the Satwas tehsil is concerned about 100.0% samples belongs to the SAR class of <10 (Table 4.11 & Fig. 4.5). The SAR ranged from 0.07 to 1.44 (mmol L<sup>-1</sup>)<sup>1/2</sup> with a mean value of 0.46 (mmolL<sup>-1</sup>)<sup>1/2</sup>. The lowest SAR value 0.07 (mmolL<sup>-1</sup>)<sup>1/2</sup> is observed in village Bedakhal and highest value of 1.44 (mmolL<sup>-1</sup>)<sup>1/2</sup> in village Panpat.

**Table 4.11: Distribution of ground water samples according to SAR**

S.No.	Sodium Adsorption Ratio (mmol L <sup>-1</sup> ) <sup>1/2</sup>	No. of samples	% Samples
1.	<10	33	100
2.	10-18	0	Nil
3.	18-26	0	Nil
4.	>26	0	Nil

#### General statistics

Range	0.07 to 1.44 (mmol L <sup>-1</sup> ) <sup>1/2</sup>
Mean	0.46 (mmol L <sup>-1</sup> ) <sup>1/2</sup>
SD	0.26 %



**Fig. 4.5: Distribution of SAR in the ground water samples of Satwas tehsil of Dewas district**

#### **4.6 Classes of Residual Sodium Carbonate (RSC)**

The data with respect to residual sodium carbonate (RSC) of ground water quality of Satwas tehsil presented in Table 4.6. The RSC of water quality is classified into three different classes (<1.25, 1.25-2.5, >2.50 me L<sup>-1</sup>). As far as the Satwas tehsil is concerned 100% sample belongs to the RSC class <1.25 me L<sup>1</sup> (Table 4.12).

**Table 4.12: Distribution of ground water samples according to RSC**

<b>S.No.</b>	<b>Class</b>	<b>RSC (me L<sup>-1</sup>)</b>	<b>No. of Samples</b>	<b>% Samples</b>
1.	Safe	<1.25	33	100
2.	Marginal suitable	1.25-2.5	00	00
3.	Not suitable	>2.5	00	00

#### 4.7 Classes of ground water based on sodium concentration

The data presented in table 4.4 with respect to sodium concentration in water samples are grouped in to four classes (0-5, 5-10, 10-15 and >15 me L<sup>-1</sup>). It is obvious from the data that 100.0% of water samples of Satwas tehsil fall in the class 0-5 me L<sup>-1</sup> of sodium (Table 4.13 & Fig. 4.6).

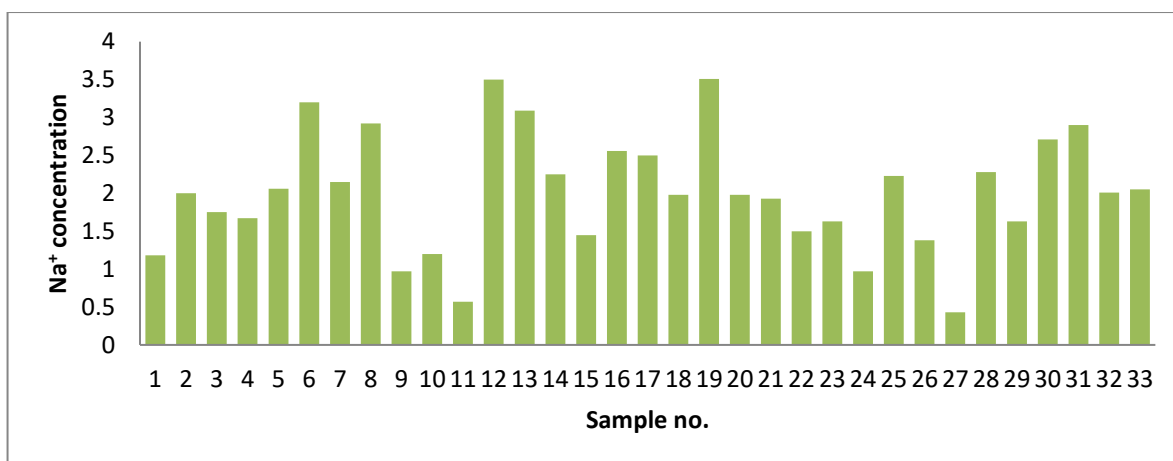
The sodium concentration varied from 0.43 to 3.51 meL<sup>-1</sup> with mean value of 2.00 me L<sup>-1</sup>. The maximum value of the sodium is found in the village Mansuriya and minimum value of sodium is found in village Bedakhal.

**Table 4.13: Distribution of ground water samples according to sodium concentration**

S. No.	Sodium (me L <sup>-1</sup> )	No. of Samples	% Samples
1.	0-5	33	100
2.	5-10	0	0
3.	10-15	0	0
4.	> 15	0	0
<b>Total</b>		33	

#### General statistics

<b>Range</b>	0.43 to 3.51 me L <sup>-1</sup>
<b>Mean</b>	2.0 meL <sup>-1</sup>
<b>SD</b>	0.76 %



**Fig. 4.6: Spatial distribution of Na<sup>+</sup> (meL<sup>-1</sup>) in the ground water samples of Satwas tehsil of Dewas district**

#### 4.8 Classes of chloride (Cl<sup>-</sup>) concentration

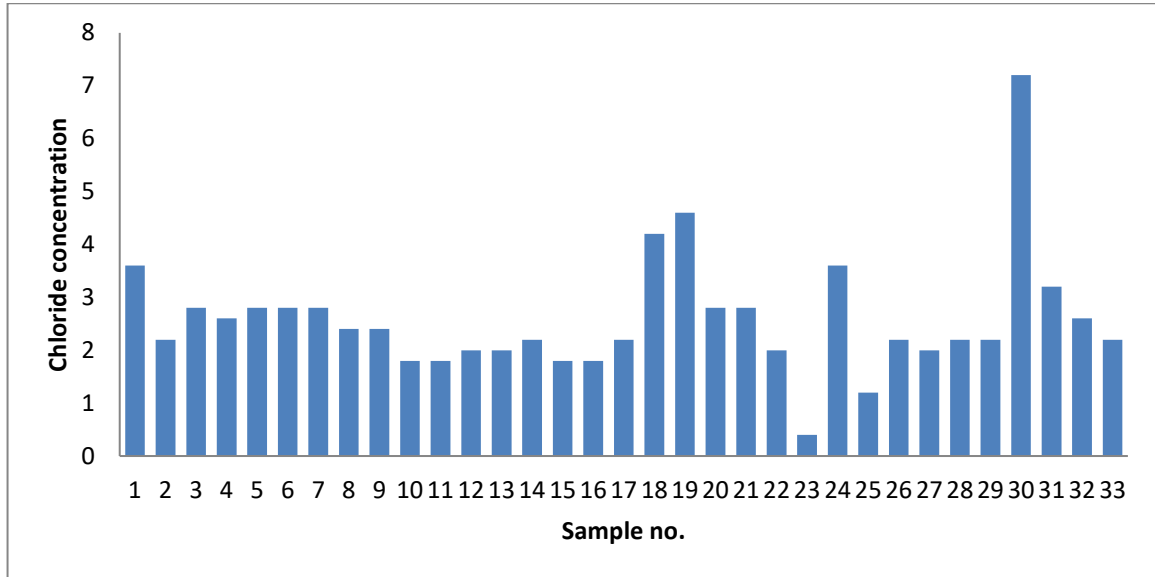
The data pertaining to Chloride (Cl<sup>-</sup>) concentration (me L<sup>-1</sup>) in ground water samples are presented in Table 4.5. The samples are classified in to four different classes (0-4, 4-8, 8-16, >16). It is quite clear from the table that 30 (90.9%) of water sample belongs to the chloride class 0-4 me L<sup>-1</sup>. Whereas 3 (9.1 %) water samples of the Satwas tehsil fall in the chloride (Cl<sup>-</sup>) class 4-8 me L<sup>-1</sup> (Table 4.14 & Fig. 4.7). In class 8-16 me L<sup>-1</sup> nothing water samples of Satwas tehsil belongs to it. Nothing of total water sample belongs to the chloride class >16 me L<sup>-1</sup>.

**Table 4.14: Distribution of ground water samples according to chloride concentration (meL<sup>-1</sup>)**

S. N.	Chloride (me L <sup>-1</sup> )	No. of Samples	% Samples
1.	0-4	33	90.9
2.	4-8	3	9.1
3.	8-16	00	00
4.	>16	00	00
Total		33	

### General statistics

<b>Range</b>	0.4 to 7.2 me L <sup>-1</sup>
<b>Mean</b>	2.58 me L <sup>-1</sup>
<b>SD</b>	1.13 %



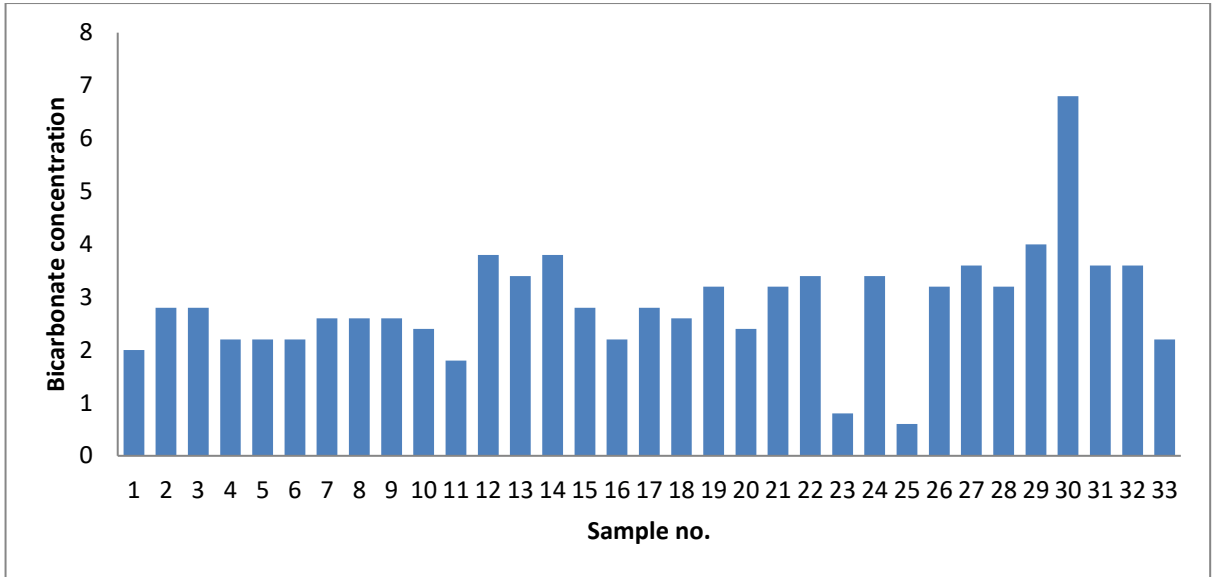
**Fig. 4.7: Spatial distribution of Cl<sup>-</sup> (meL<sup>-1</sup>) in the ground water samples of Satwas tehsil of Dewas district**

### 4.8 Bicarbonate (HCO<sub>3</sub><sup>-</sup>) concentration

The bicarbonate (HCO<sub>3</sub><sup>-</sup>) concentration (me L<sup>-1</sup>) in ground water samples range is 0.6- 6.8 me L<sup>-1</sup> and mean is 2.88 me L<sup>-1</sup>. Standard deviation is 1.03 %. (Table 4.6)

#### General statistics of HCO<sub>3</sub><sup>-</sup>

<b>Range</b>	0.6 to 6.8 me L <sup>-1</sup>
<b>Mean</b>	2.88 me L <sup>-1</sup>
<b>SD</b>	1.03 %



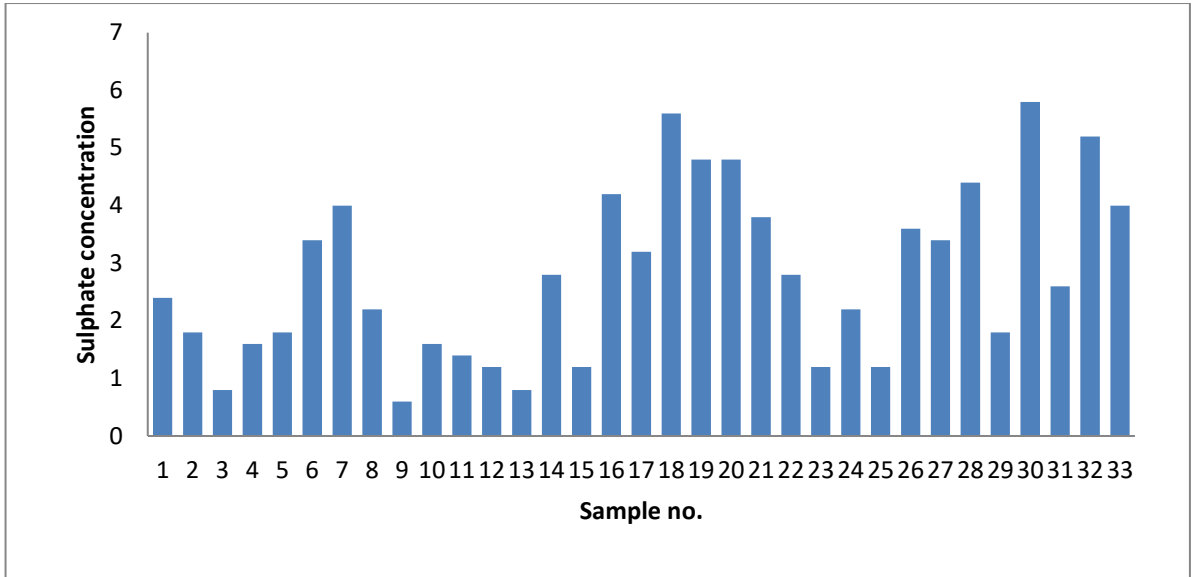
**Fig. 4.8: Spatial distribution of  $\text{HCO}_3^-$  ( $\text{meL}^{-1}$ ) in the ground water samples of Satwas tehsil of Dewas district**

#### **4.9 Sulphate ( $\text{SO}_4^{2-}$ ) concentration**

The sulphate ( $\text{SO}_4^{2-}$ ) concentration ( $\text{me L}^{-1}$ ) in ground water samples range is 0.4- 5.8  $\text{me L}^{-1}$  and mean is 4.02  $\text{me L}^{-1}$ . Standard deviation is 1.48 (Table 4.6)

#### **General statistics of $\text{SO}_4^{2-}$**

<b>Range</b>	0.4 to 5.8 $\text{me L}^{-1}$
<b>Mean</b>	4.02 $\text{me L}^{-1}$
<b>SD</b>	1.48 %



**Fig. 4.9: Distribution of SO<sub>4</sub><sup>2-</sup> (meL<sup>-1</sup>) in the ground water samples of Satwas tehsil of Dewas district**

#### **4.9 Correlation coefficient among different parameters of water quality**

The data pertaining to Correlation coefficient (r) among different parameters of ground water quality are given in the Table 4.15. Under different quality parameters of water the cation Ca<sup>2+</sup>, Mg<sup>2+</sup> shows positive and significant correlation with EC, HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup> and SO<sub>4</sub><sup>-</sup> content and negative correlation with pH. The Na<sup>+</sup> also shows positive & significant correlation with pH, EC Ca<sup>2+</sup>, Mg<sup>2+</sup>, HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup> and SO<sub>4</sub><sup>2-</sup> also. The K<sup>+</sup> also shows positive & significant correlation with Ca<sup>2+</sup>, Mg<sup>2+</sup>, EC, Cl<sup>-</sup> and SO<sub>4</sub><sup>-</sup> and negative correlation with pH. Chloride (Cl<sup>-</sup>) content of water shows positive Correlation with EC and HCO<sub>3</sub><sup>-</sup> whereas negative Correlation with pH. HCO<sub>3</sub><sup>-</sup>, shows positive and significant correlation with EC. SAR show positive & significant correlation with pH, Na<sup>+</sup> and K<sup>+</sup>, whereas, negative correlation with EC, Cl<sup>-</sup>, EC ,Ca<sup>2+</sup>, Mg<sup>2+</sup>, HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup> and SO<sub>4</sub><sup>2-</sup> also.

**Table 4.15: Correlation coefficient (r) among different parameters of water quality**

**Correlations among ground water parameters**

	pH	EC	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>	SAR
pH	1.000									
EC	-0.176	1.000								
HCO <sub>3</sub> <sup>-</sup>	-0.133	<b>0.758**</b>	1.000							
Cl <sup>-</sup>	-0.207	<b>0.861**</b>	<b>.651**</b>	1.000						
SO <sub>4</sub> <sup>2-</sup>	-0.104	<b>.771**</b>	<b>.381*</b>	<b>.562**</b>	1.000					
Ca <sup>2+</sup>	-0.221	<b>.902**</b>	<b>.730**</b>	<b>.825**</b>	<b>.794**</b>	1.000				
Mg <sup>2+</sup>	-0.280	<b>.875**</b>	<b>.737**</b>	<b>.816**</b>	<b>.791**</b>	<b>.916**</b>	1.000			
Na <sup>+</sup>	0.226	0.337	0.209	0.248	0.244	0.006	0.086	1.000		
K <sup>+</sup>	-0.149	0.200	-0.106	0.343	0.189	0.145	0.111	0.141	1.000	
SAR	0.133	<b>-.345*</b>	<b>-.346*</b>	-0.302	-0.281	<b>-.567**</b>	<b>-.488**</b>	<b>.629**</b>	0.108	1.000

\*\* Correlation is significant at the 0.01 level.

\* Correlation is significant at the 0.05 level.

## Results of soil samples of Satwas tehsil of Dewas district

### 4.2.1 SOIL REACTION

The pH of soils of Satwas tehsil ranged from 7.1 to 8.0 with a mean value of 7.56, standard deviation 0.25 % and coefficient of variation 3.30 % (Table 4.16). Out of 33 soil sample 51.5 % soil samples are neutral in pH and 48.5 % samples are slightly alkaline (Table 4.17).

**Table 4.16: pH of soil samples of Satwas tehsil**

S.No.	Name of village	pH
1.	Hardi	8.0
2.	Bekalya	7.9
3.	Gaja Khedi	7.8
4.	Jinwani	7.6
5.	Kanta Phod	7.7
6.	Salamatpura	7.5
7.	Badgaon	7.5
8.	Ektera	8.0
9.	Surmanya	7.3
10.	Pura	7.9
11.	Sindharni	7.6
12.	Balya	7.5
13.	Satwas	7.3
14.	Palasi	7.4
15.	Kothada	7.1
16.	Dagra Kheda	7.4
17.	Pagri	7.7
18.	Kher Kheda	7.7
19.	Mansuriya	7.3
20.	Khapras	7.3
21.	Narayan Pura	7.3
22.	Gola Gudan	7.3
23.	Gada Gaon	7.2
24.	Nimasa	7.2
25.	Panpat	7.4
26.	Bhat Vardi	7.5
27.	Beda Khal	7.7
28.	Bhamar	7.7
29.	Dhasaur	7.7
30.	Nimlay	7.5
31.	Banasa	8.0
32.	Kothda	8.0
33.	Borkhedi	7.7

The pH values varied from 7.10 to 8.0 with a mean of 7.56. The lowest pH in soil samples is recorded in villages Kothda (pH 7.10) at serial number 15, and highest value of pH is observed in village Hardi (pH 8.00) at sample number 01 (Table 4.16).

**Table 4.17: Categories of soil pH of Satwas tehsil**

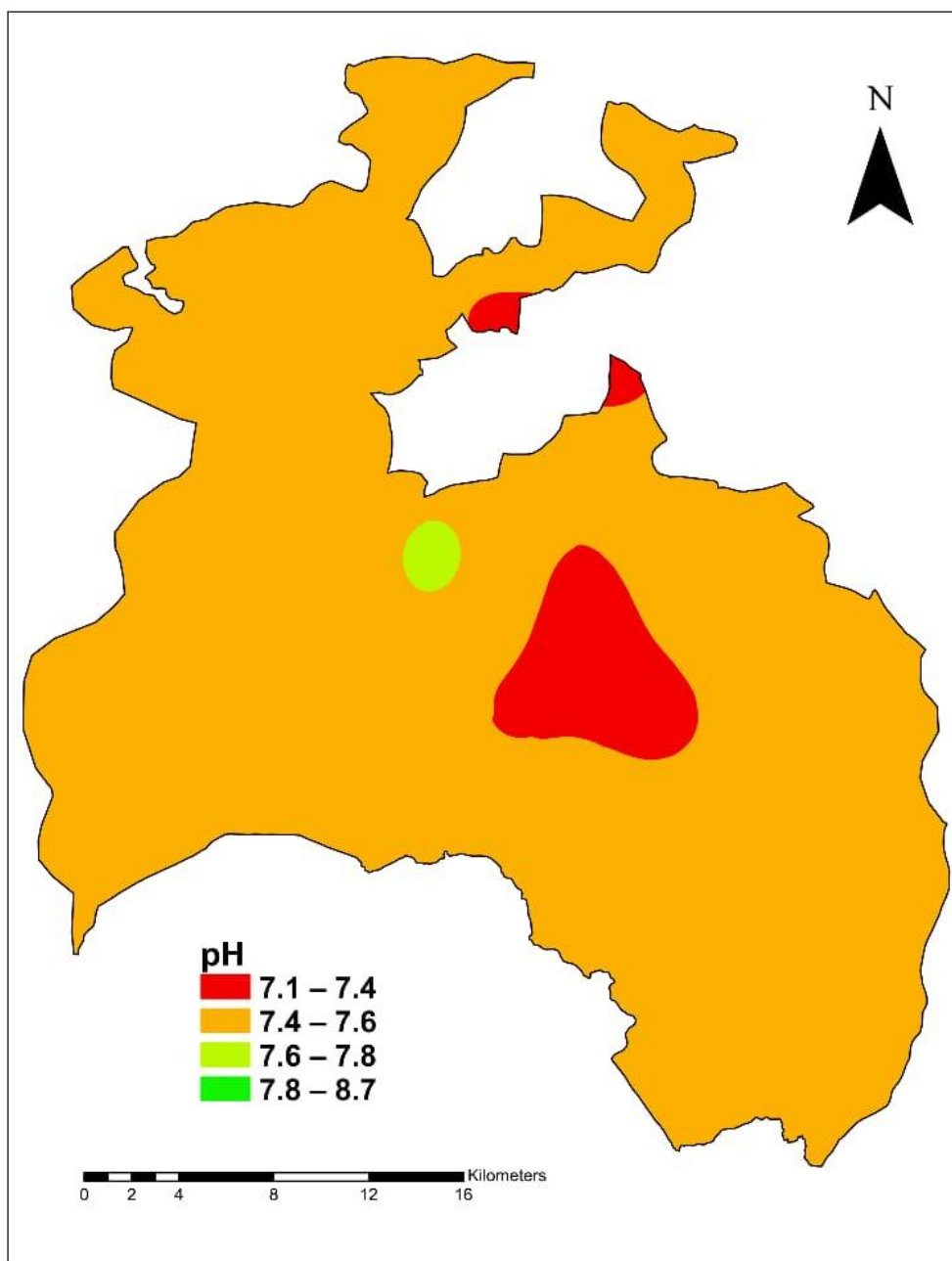
Soil pH class	No of samples	% Samples
Strongly acid (<5.0)	-	-
Moderately acid (5-6.0)	-	-
Slightly acid (6.0-6.5)	-	-
Neutral (6.5-7.5)	17	51.5 %
Slightly alkaline (7.5-8.5)	16	48.5 %

#### 4.1. Distribution of pH in the Satwas tehsil soils

Spatial variability map of pH of the soils of Satwas tehsil is presented in Fig. 4.10 to prepare the pH variability map. Soils are divided into four categories as depicted in Table 4.17. It is evident from the table & map (Table 4.18 and Fig. 4.10) that the maximum area falls under the category Class II (7.4 to 7.6) followed by category I (7.1 to 7.4) and minimum area under category III (7.6 to 7.8).

**Table 4.18: Extent of area under different pH classes of the soils of Satwas tehsil**

pH-availability Class	pH-availability range	Ranking of the class on the basis of area.
I.	7.1- 7.4	II
II.	7.4 - 7.6	I
III.	7.6- 7.8	III
IV.	7.8- 8.7	-



**Fig. 4.10: Distribution of pH in the soils of Satwas tehsil**

## 4.2. Electrical conductivity (EC)

Electrical conductivity of soil ranges from 0.70 to 3.60 dS m<sup>-1</sup> with a mean value of 1.66 dS m<sup>-1</sup>, standard deviation 0.87 and CV % 53.04 (Table 4.19). Most of the soil samples are normal for total soluble salt concentration. The extent of spatial distribution of soil electrical conductivity is shown in Fig. 4.11.

**Table 4.19: Electrical conductivity (EC) of soils of Satwas tehsil**

S.No.	Name of village	EC ( dS m <sup>-1</sup> )
1.	Hardi	1.2
2.	Bekalya	1.1
3.	Gaja Khedi	1.4
4.	Jinwani	0.7
5.	Kanta Phod	2
6.	Salamatpura	2.5
7.	Badgaon	3.2
8.	Ektera	0.7
9.	Surmanya	0.7
10.	Pura	1.2
11.	Sindharni	1.2
12.	Balya	2.4
13.	Satwas	0.9
14.	Palasi	0.9
15.	Kothada	0.9
16.	Dagra Kheda	3.3
17.	Pagri	1.5
18.	Kher Kheda	1.3
19.	Mansuriya	1.2
20.	Khapras	1.8
21.	Narayan Pura	1.8
22.	Gola Gudan	3.6
23.	Gada Gaon	3.6
24.	Nimasa	2.5
25.	Panpat	1.1
26.	Bhat Vardi	1.6
27.	Beda Khal	1.3
28.	Bhamar	0.8
29.	Dhasaur	0.8
30.	Nimlay	0.8
31.	Banasa	2.1
32.	Kothda	2.8
33.	Borkhedi	2.2

**Table 4.20: Categories of soil electrical Conductivity (EC) of soils of Satwas tehsil**

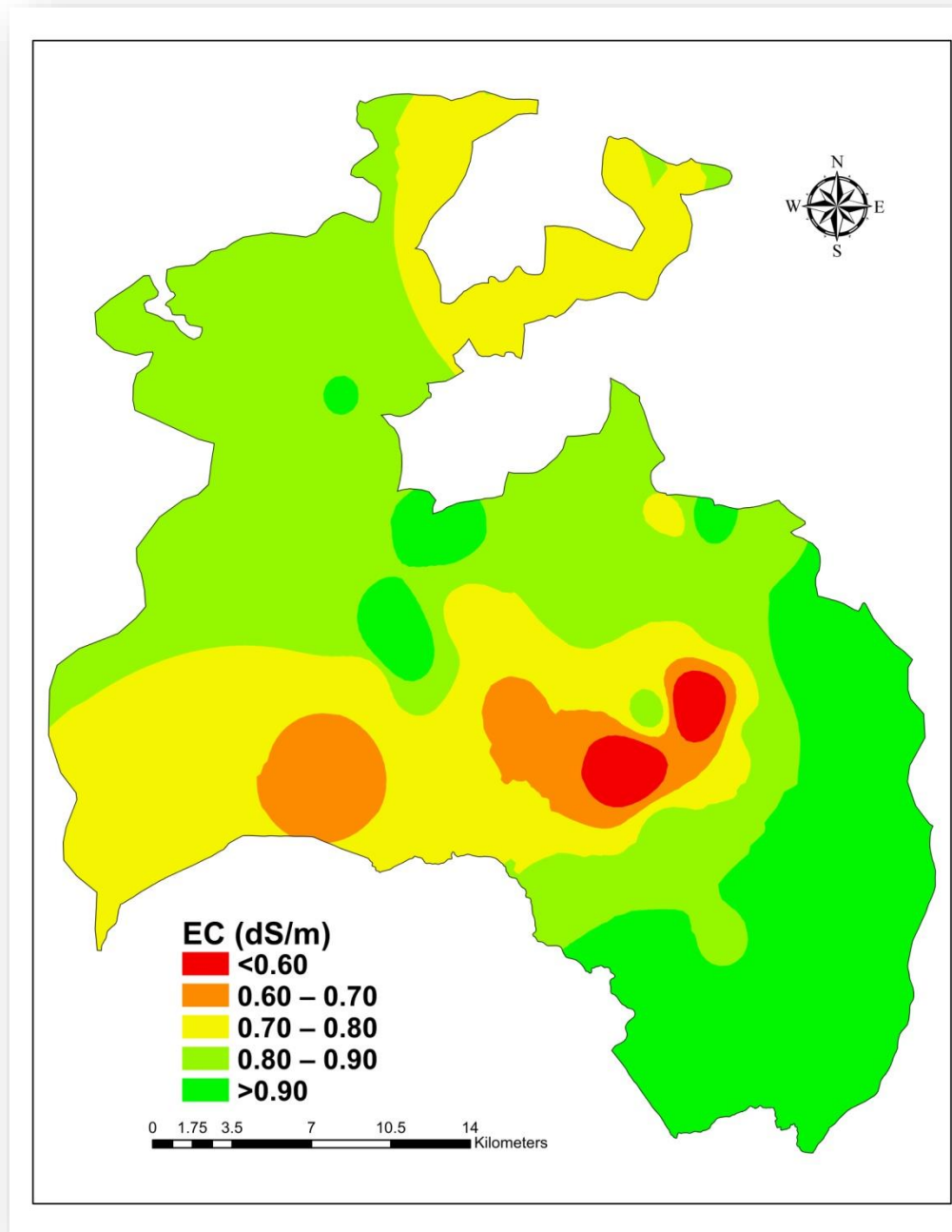
<b>EC (dS m<sup>-1</sup> )</b>	<b>No. of samples</b>	<b>% samples</b>
<b>&lt;0.8</b>	<b>03</b>	<b>9.1</b>
<b>0.8- 1.6</b>	<b>17</b>	<b>51.5</b>
<b>1.6- 2.5</b>	<b>08</b>	<b>24.2</b>
<b>&gt;2.5</b>	<b>05</b>	<b>15.2</b>

#### **4.2.1 Spatial distribution of EC in the Satwas tehsil soils**

Spatial variability map of EC of the soils of Satwas tehsil is presented in fig 4.11. To prepare the EC variability map the soils are divided in to five categories as depicted in Table 4.19. It is evident from the map (fig 4.11) that the maximum area falls under the category I (0.8 - 0.9) followed by category II. (0.7 – 0.8); Category V. (>0.9) and minimum area under category I (<0.6).

**Table 4.21: Extent of area under different EC classes of the soils of Satwas tehsil**

<b>EC- availability Class</b>	<b>EC-availability range ( dS m<sup>-1</sup> )</b>	<b>Ranking of the class on the basis of area.</b>
<b>I.</b>	<b>&lt;0.6</b>	<b>V</b>
<b>II.</b>	<b>0.6- 0.7</b>	<b>IV</b>
<b>III.</b>	<b>0.7 - 0.8</b>	<b>II</b>
<b>IV.</b>	<b>0.8 - 0.9</b>	<b>I</b>
<b>V.</b>	<b>&gt;0.9</b>	<b>III.</b>



**Fig: 4.11 Distribution of EC in the soils of Satwas tehsil**

**Table 4.22: Water soluble cations (me L<sup>-1</sup>) of surface soil samples collected from different villages of Satwas tehsil of Dewas district of M.P.**

S.No.	Name of village	Water soluble cations ( me L <sup>-1</sup> )			
		Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>
1.	Hardi	4.2	3	1.7	0.2
2.	Bekalya	7.2	2.4	1.4	00
3.	Gaja Khedi	6.2	2.2	2	0.1
4.	Jinwani	0.4	0.2	1.4	0.1
5.	Kanta Phod	4.8	1.2	1.3	0.1
6.	Salamatpura	13.2	4.6	1.3	0.2
7.	Badgaon	14.2	8.0	1.3	0.1
8.	Ektera	20.2	8.4	0.6	0.2
9.	Surmanya	4.8	1.6	0.7	0.1
10.	Pura	7.6	2.8	1.0	0.3
11.	Sindharni	5.8	4.2	1.1	0.6
12.	Balya	18.2	7.2	1.1	0.4
13.	Satwas	6.6	1.2	0.8	0.2
14.	Palasi	4.2	3.8	0.8	0.1
15.	Kothada	4.8	2.4	1.0	0.1
16.	Dagra Kheda	16	12	3.0	0.8
17.	Pagri	10.8	2.0	1.6	0.2
18.	Kher Kheda	8.2	4.0	1.1	0.8
19.	Mansuriya	1.2	0.8	2.8	2.1
20.	Khapras	12.2	3.4	0.6	0.9
21.	Narayan Pura	10.6	6.0	1.4	0.2
22.	Gola Gudan	23.8	9.2	2.5	1.0
23.	Gada Gaon	23.8	10	1.6	0.2
24.	Nimasa	17.8	5.2	1.8	0.5
25.	Panpat	7.2	1.8	1.9	0.5
26.	Bhat Vardi	10.8	2.8	1.6	0.1
27.	Beda Khal	7.2	4.4	0.6	0.3
28.	Bhamar	5.0	1.2	1.6	0.1
29.	Dhasaur	4.2	2.8	0.8	0.1
30.	Nimlay	2.8	2.0	2.6	0.6
31.	Banasa	14.2	6.4	1.1	0.1
32.	Kothda	8.8	5.8	1.1	1.7
33.	Borkhedi	12.2	6.4	2.2	0.1

Water soluble cation concentration in ground water samples of Satwas tehsil is presented in Table 4.22. The calcium concentration in the samples had a wide range (0.40 to 23.8 me L<sup>-1</sup>) followed by Mg<sup>2+</sup> (0.20 to 12.0 me L<sup>-1</sup>), Na<sup>+</sup>

(0.60 to 3.00 meL<sup>-1</sup>) and K<sup>+</sup> (00 to 2.10 me L<sup>-1</sup>). Mean value of, Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup> are, 9.67, 4.22, 1.43 and 0.39 respectively.

**Table 4.23: Water soluble anions (me L<sup>-1</sup>) of surface soil samples collected from different village of Satwas tehsil of Dewas district of M.P.**

S.No.	Name of village	Water soluble anions (me L <sup>-1</sup> )			
		CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>
1.	Hardi	0	1.6	4.4	3.2
2.	Bekalya	0	3.2	4.2	4.0
3.	Gaja Khedi	0	1.2	3.6	5.2
4.	Jinwani	0	1.4	6.6	3.2
5.	Kanta Phod	0	1.2	4.0	2.0
6.	Salamatpura	0	4.2	5.8	8.8
7.	Badgaon	0	6.2	7.8	10
8.	Ektera	0	12	8.8	9.8
9.	Surmanya	0	2.6	2.4	2.2
10.	Pura	0	4.0	4.2	3.8
11.	Sindharni	0	3.8	4.4	3.6
12.	Balya	0	6.4	7.8	9.8
13.	Satwas	0	1.8	4.2	3.2
14.	Palasi	0	2.2	4.2	2.6
15.	Kothada	0	2.4	2.2	3.8
16.	Dagra Kheda	0	9.8	10	11.8
17.	Pagri	0	4.8	5.2	4.8
18.	Kher Kheda	0	5.4	3.8	3.8
19.	Mansuriya	0	4.2	3.8	4.0
20.	Khapras	0	6.2	5.8	5.2
21.	Narayan Pura	0	5.6	6.4	5.6
22.	Gola Gudan	0	11.8	10.2	11.8
23.	Gada Gaon	0	11.6	11.4	12.4
24.	Nimasa	0	8.0	7.8	8.6
25.	Panpat	0	3.2	4.0	4.2
26.	Bhat Vardi	0	4.8	5.2	5.4
27.	Beda Khal	0	3.8	4.0	4.6
28.	Bhamar	0	2.6	3.2	1.8
29.	Dhasau	0	3.2	2.4	2.0
30.	Nimlay	0	2.8	3.2	1.8
31.	Banasa	0	8.2	7.2	6.0
32.	Kothda	0	9.6	8.8	8.8
33.	Borkhedi	0	6.8	6.6	7.8

The highest value of  $\text{HCO}_3^-$  ( $12.0 \text{ me L}^{-1}$ ) content in soil observed in Ektara village at sample number 08, while the minimum ( $1.20 \text{ me L}^{-1}$ ) recorded in village at kataphod sample number 05. Minimum value of  $\text{SO}_4^{2-}$  ( $1.80 \text{ me L}^{-1}$ ) are recorded in Surmavya village at sample no. 09 and maximum value of  $\text{SO}_4^{2-}$  ( $12.40 \text{ me L}^{-1}$ ) are observed in Gadgaon at sample no 23. Mean value of  $\text{SO}_4^{2-}$  are found to be  $5.62 \text{ me L}^{-1}$  (Table 4.23).

**Table 4.24: Exchangeable cations present in soil samples of Satwas tehsil of Dewas district**

S.No.	Name of village	Exchangeable cations ( $\text{c mol (p}^+) \text{ kg}^{-1}$ )			
		$\text{Ca}^{2+}$	$\text{Mg}^{2+}$	$\text{Na}^+$	$\text{K}^+$
1.	Hardi	26.6	14.3	2.9	0.6
2.	Bekalya	24.0	12.9	3.6	0.6
3.	Gaja Khedi	23.6	12.7	5.1	0.5
4.	Jinwani	23.7	12.8	3.7	0.5
5.	Kanta Phod	22.8	12.3	4.1	0.6
6.	Salamatpura	21.9	11.8	4.5	0.5
7.	Badgaon	22.5	12.1	4.7	0.5
8.	Ektera	24.0	12.9	4.6	0.6
9.	Surmanya	22.9	12.3	3.8	0.2
10.	Pura	23.0	12.4	6.1	0.6
11.	Sindharni	22.0	11.9	6.9	0.4
12.	Balya	24.6	13.2	4.1	0.5
13.	Satwas	26.1	14.1	4.3	0.4
14.	Palasi	25.0	13.5	4.1	0.5
15.	Kothada	22.1	11.9	5.4	0.5
16.	Dagra Kheda	22.6	12.2	4.4	0.6
17.	Pagri	23.0	12.4	4.2	0.7
18.	Kher Kheda	24.3	13.1	3.1	0.8
19.	Mansuriya	24.0	12.9	3.4	0.7
20.	Khapras	23.5	12.7	5.2	0.8
21.	Narayan Pura	24.5	13.2	2.9	0.4
22.	Gola Gudan	26.4	14.2	3.6	0.6
23.	Gada Gaon	25.9	13.9	4.1	0.5
24.	Nimasa	26.6	14.3	3.2	0.4

S.No.	Name of village	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>
25.	Panpat	26.7	14.4	3.1	0.5
26.	Bhat Vardi	23.6	12.7	6.1	0.4
27.	Beda Khal	24.1	13.0	2.8	0.6
28.	Bhamar	28.5	15.4	2.3	0.8
29.	Dhasaur	26.0	14.0	3.6	0.7
30.	Nimlay	24.5	13.2	3.4	0.6
31.	Banasa	23.8	12.8	6.4	0.7
32.	Kothda	23.7	12.8	4.2	0.5
33.	Borkhedi	23.8	12.8	3.2	0.8

Exchangeable cation concentration in soil samples of Satwas tehsil is presented in Table 4.24. The exchangeable calcium concentration in the soil samples had a wide range (21.9 to 28.5 me L<sup>-1</sup>) followed by Mg<sup>2+</sup> (11.8 to 15.4 me L<sup>-1</sup>), Na<sup>+</sup> (2.30 to 6.90 meL<sup>-1</sup>) and K<sup>+</sup> (0.20 to 2.80 me L<sup>-1</sup>). Mean value of exchangeable Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup> are, 24.25, 13.06, 4.15 and 0.56 respectively.

**Table 4.25: SAR, CEC and ESP of Soil samples of Satwas tehsil of Dewas district**

S.No.	Name of village	SAR	CEC	ESP
1.	Hardi	0.3	45.3	6.4
2.	Bekalya	0.2	42.0	8.6
3.	Gaja Khedi	0.4	43.1	11.8
4.	Jinwani	0.9	41.6	8.9
5.	Kanta Phod	0.3	41.7	9.8
6.	Salamatpura	0.2	40.1	11.2
7.	Badgaon	0.1	40.9	11.5
8.	Ektera	0.1	42.7	10.8
9.	Surmanya	0.1	40.2	9.5
10.	Pura	0.2	42.1	14.5
11.	Sindharni	0.2	41.2	14.7
12.	Balya	0.1	43.2	9.5
13.	Satwas	0.1	45.3	9.5
14.	Palasi	0.1	43.6	9.4
15.	Kothada	0.2	39.9	13.5
16.	Dagra Kheda	0.3	41.5	10.6
17.	Pagri	0.2	41.1	10.2
18.	Kher Kheda	0.2	42.2	7.3

S.No.	Name of village	SAR	CEC	ESP
19.	Mansuriya	1.0	41.6	8.2
20.	Khapras	0.1	42.7	12.2
21.	Narayan Pura	0.2	41.5	7.0
22.	Gola Gudan	0.2	46.3	7.8
23.	Gada Gaon	0.1	45.5	9.0
24.	Nimasa	0.2	45.6	7.0
25.	Panpat	0.3	45.8	6.8
26.	Bhat Vardi	0.2	42.8	14.3
27.	Beda Khal	0.1	41.1	6.8
28.	Bhamar	0.3	47.0	4.9
29.	Dhasau	0.1	44.3	8.1
30.	Nimlay	0.6	41.7	8.2
31.	Banasa	0.1	43.7	14.6
32.	Kothda	0.1	42.3	9.9
33.	Borkhedi	0.2	40.6	7.9

**Table 4.26: Maximum, minimum, mean and SD value of water soluble cations and anions in soils of Satwas tehsil of Dewas district**

S.No.	pH	EC dSm <sup>-1</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>	SAR (mmolL <sup>-1</sup> ) <sup>1/2</sup>
			me L <sup>-1</sup> (water soluble cations and anions)							
<b>Maximum</b>	7.10	3.60	12.0	11.4	12.4	23.8	12.0	3.00	2.10	1.00
<b>Minimum</b>	8.00	0.70	1.20	2.20	1.80	0.40	0.20	0.60	0.00	0.10
<b>Mean</b>	7.56	1.66	5.04	5.56	5.62	9.67	4.22	1.43	0.39	0.24

The SAR confined from 0.10 to 1.00 with a mean value of 0.24 (Table 4.25). The lowest SAR value of 0.10 is recorded in village Gadgaon and Dhasu at sample number 23 and 29 and highest value of SAR 1.00 in village Mansuriya at sample number 19 (Table 4.25 & 4.26). The ESP confined from 4.90 to 14.70 with a mean value of 9.66. The lowest ESP value of 4.9 is recorded in village Bhamar at sample number 28 and highest value of ESP 14.7 in village Sindharni at sample number 11 (Table 4.25). The CEC ranged from 39.9 to 47.0 with a mean value of 42.70. The lowest CEC value of 39.90

is recorded in village Kothda at sample number 15, and highest value of ESP 47.0 in village Bhamar at sample number 28 (Table 4.25).

#### 4.3. Organic carbon (OC)

The organic carbon content of the soils of Satwas Tehsil ranged from 0.25 to 0.79 % with an average value of 0.46 % with standard deviation 0.14% and coefficient of variation (CV) 30.4 % (Table 4.27).

**Table 4.27: Organic carbon (%) content of soils of Satwas tehsil**

S.No.	Name of village	OC (%)
1.	Hardi	0.34
2.	Bekalya	0.40
3.	Gaja Khedi	0.79
4.	Jinwani	0.44
5.	Kanta Phod	0.34
6.	Salamatpura	0.38
7.	Badgaon	0.43
8.	Ektera	0.32
9.	Surmanya	0.29
10.	Pura	0.42
11.	Sindharni	0.50
12.	Balya	0.51
13.	Satwas	0.60
14.	Palasi	0.47
15.	Kothada	0.38
16.	Dagra Kheda	0.61
17.	Pagri	0.28
18.	Kher Kheda	0.25
19.	Mansuriya	0.27
20.	Khapras	0.36
21.	Narayan Pura	0.34
22.	Gola Gudan	0.52
23.	Gada Gaon	0.47
24.	Nimasa	0.55
25.	Panpat	0.64
26.	Bhat Vardi	0.62
27.	Beda Khal	0.58
28.	Bhamar	0.37
29.	Dhasaur	0.32
30.	Nimlay	0.69
31.	Banasa	0.67
32.	Kothda	0.56
33.	Borkhedi	0.69

**Table 4.28: Distribution of organic carbon status in the soils of Satwas tehsil**

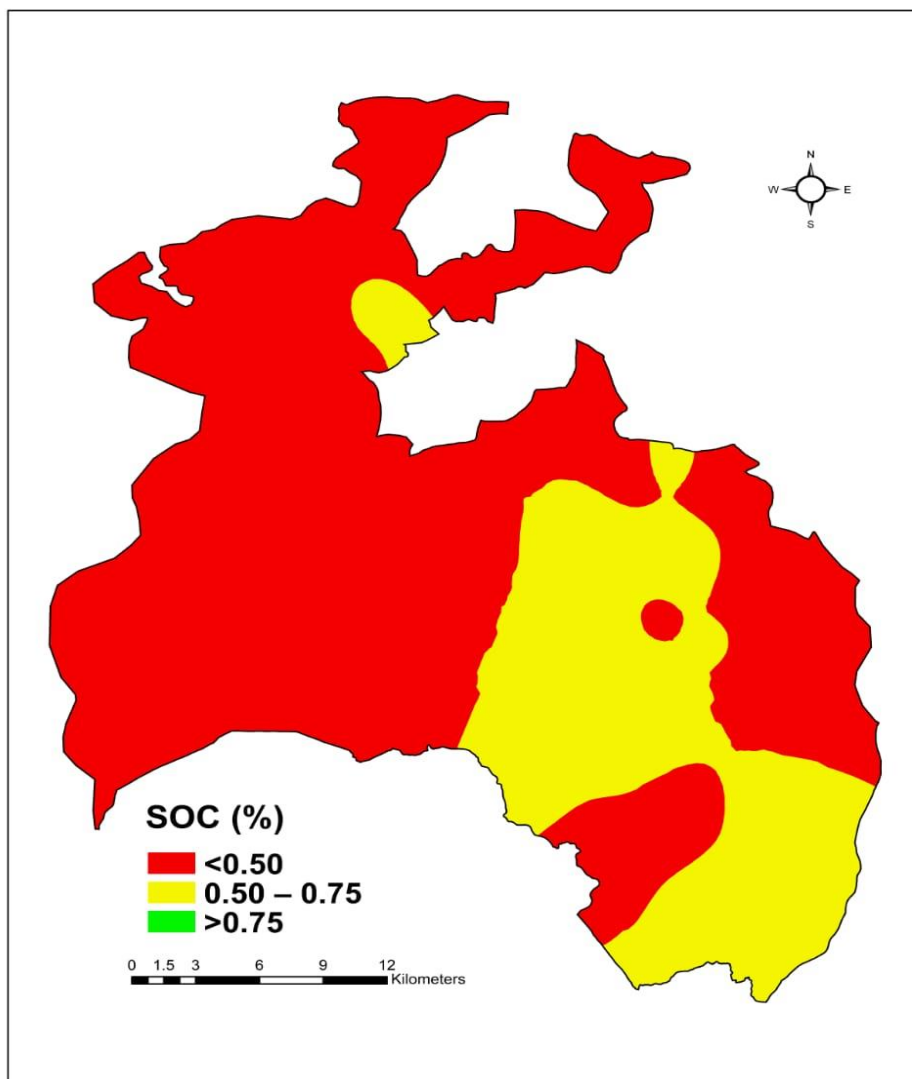
<b>Organic carbon %</b>	<b>No of samples</b>	<b>% Samples</b>
<b>Very Low (&lt;0.25)</b>	<b>00</b>	<b>-</b>
<b>Low (0.25-0.50)</b>	<b>22</b>	<b>66.7</b>
<b>Medium (0.50-0.75)</b>	<b>11</b>	<b>33.3</b>
<b>High(&gt;0.75)</b>	<b>-</b>	<b>-</b>

**Table 4.29: Extent of area under different organic carbon availability classes of the soils of Satwas tehsil**

<b>OC- availability Class</b>	<b>Available-OC, (%)</b>	<b>Ranking of the class on the basis of area.</b>
<b>Low</b>	<b>&lt;0.5</b>	<b>I</b>
<b>Medium</b>	<b>0.5– 0.75</b>	<b>II</b>
<b>High</b>	<b>0.75</b>	<b>III</b>

#### **4.3.1: Distribution of Organic carbon in the Satwas tehsil soils:**

Spatial variability map of organic carbon of the soils of Satwas Tehsil depicted in fig 4.12. To prepare the organic carbon variability map soils are divided in to three categories (Table 4.29). It is evident from the map that the maximum area falls under the category I (<0.50) followed by category II. (0.50-0.75) and minimum area under category III. (>0.75), area falls under low to Medium status of organic carbon which requires immediate attention to sustain the soil health of Satwas tehsil.



**Fig. 4.12: Spatial distribution of OC in the soils of Satwas tehsil**

#### **4.4. Available N status of the soils of Satwas tehsil**

The available N content of the soils of Satwas tehsil ranged from 119 to 278 kg ha<sup>-1</sup> with an average value of 191.2 kg ha<sup>-1</sup> with standard deviation 40.75 % and coefficient of variation (CV%) 21.30 % (Table 4.30). Considering the soil test rating for available N (400 kg ha<sup>-1</sup> as high in the status of N) most of the soils (87.9%) of Satwas tehsil fall under status (low <250 kg ha<sup>-1</sup>) (Table 4.31).

**Table 4.30: Nitrogen (kg ha<sup>-1</sup>) content of soils of Satwas tehsil**

<b>S.No.</b>	<b>Name of village</b>	<b>N (kg ha<sup>-1</sup>)</b>
1.	Hardi	158
2.	Bekalya	180
3.	Gaja Khedi	278
4.	Jinwani	189
5.	Kanta Phod	158
6.	Salamatpura	172
7.	Badgaon	187
8.	Ektera	150
9.	Surmanya	135
10.	Pura	184
11.	Sindharni	200
12.	Balya	202
13.	Satwas	225
14.	Palasi	195
15.	Kothada	172
16.	Dagra Kheda	228
17.	Pagri	125
18.	Kher Kheda	119
19.	Mansuriya	125
20.	Khapras	165
21.	Narayan Pura	158
22.	Gola Gudan	205
23.	Gada Gaon	195
24.	Nimasa	213
25.	Panpat	240
26.	Bhat Vardi	232
27.	Beda Khal	220
28.	Bhamar	169
29.	Dhasaur	150
30.	Nimlay	258
31.	Banasa	251
32.	Kothda	215
33.	Borkhedi	258

**Table 4.31: Distribution of available nitrogen status in the soils of Satwas tehsil**

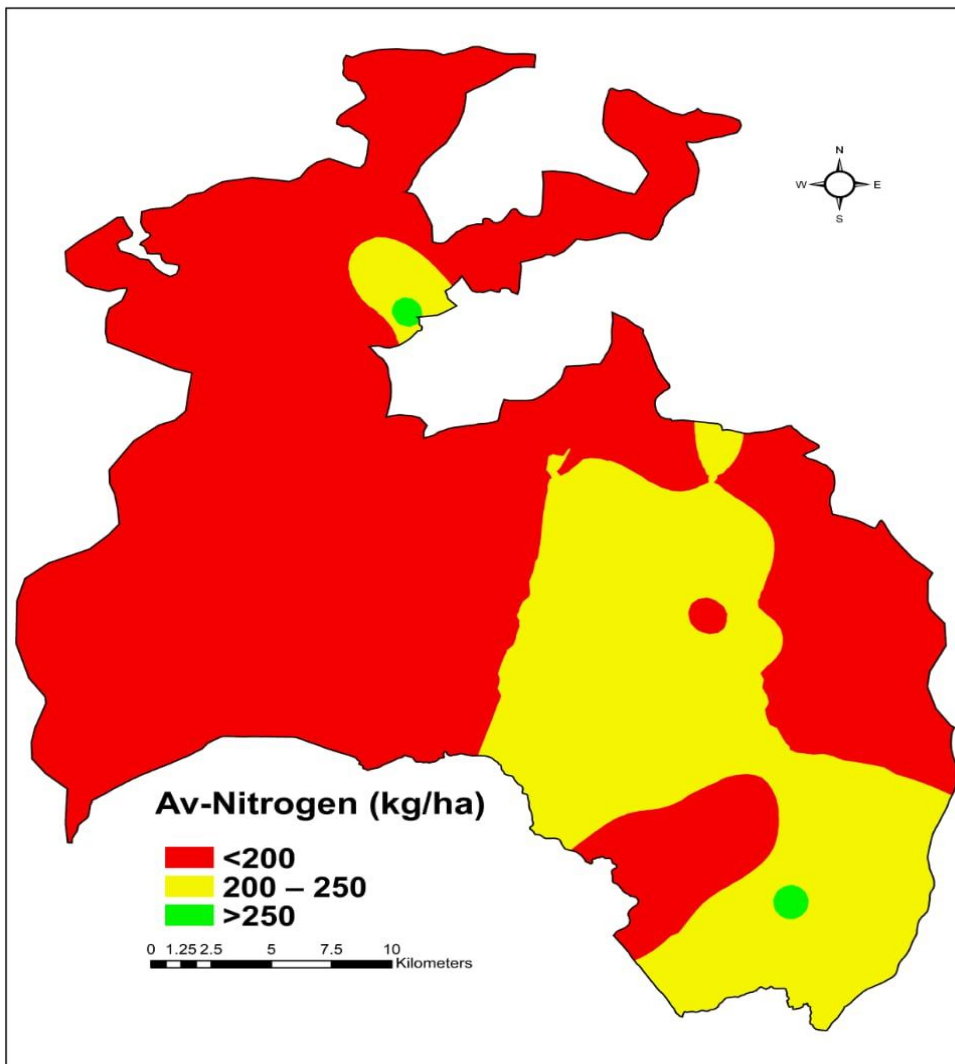
Available- N (kg ha <sup>-1</sup> )	No of samples	% Samples
Low (<250)	29	87.9
Medium (250-400)	04	12.1
High (>400)	-	-

#### 4.4.1: Spatial distribution of available N

N in the Satwas tehsil soils variability map of available N of the soils of Satwas Tehsil is presented in fig 4.13. To prepare the N variability map, the soils are divided in to three categories as depicted 4.32). It is evident from the map that the maximum area falls under the category I. (<200 kg ha<sup>-1</sup>) followed by category II. (200- 250 kg ha<sup>-1</sup>) and minimum area falls under the category III. (>250 kg ha<sup>-1</sup>).

**Table 4.32: Extent of area under different N availability classes of the soils of Satwas tehsil**

N- availability Class	Available-N , kg ha <sup>-1</sup>	Ranking of the class on the basis of area.
Low	<200	I
Medium	250-250	II
High	>250	III



**Fig. 4.13: Spatial distribution of N in the soils of Satwas tehsil**

#### **4.5. Available P status of the soils of Satwas tehsil**

The available P content of the soils of Satwas tehsil ranged from 8.00 to 32 kg ha<sup>-1</sup> with an average value of 15.35 kg ha<sup>-1</sup> with standard deviation 6.58 % and coefficient of variation (CV %) 42.86 (Table 4.33) Considering the soil test rating for available P (<10.0 kg ha<sup>-1</sup> as low, 10.0 – 20.0 kg ha<sup>-1</sup> as medium and >20.0 kg ha<sup>-1</sup> as high in the status of P) the soils of Satwas tehsil fall under low to medium in available P content. 33.4%

samples are low P status, 48.5 % samples under medium P status and 18.1 % samples are high in P status (Table 4.34)

**Table 4.33: Available P (kg ha<sup>-1</sup>) content of soils of Satwas tehsil**

S.No.	Name of village	P (kg ha <sup>-1</sup> )
1.	Hardi	27.2
2.	Bekalya	23.2
3.	Gaja Khedi	19.2
4.	Jinwani	27.2
5.	Kanta Phod	23.2
6.	Salamatpura	19.2
7.	Badgaon	11.2
8.	Ektera	16.0
9.	Surmanya	27.2
10.	Pura	32.0
11.	Sindharni	19.2
12.	Balya	8.00
13.	Satwas	16.0
14.	Palasi	19.2
15.	Kothada	9.60
16.	Dagra Kheda	11.2
17.	Pagri	9.60
18.	Kher Kheda	8.00
19.	Mansuriya	15.6
20.	Khapras	16.0
21.	Narayan Pura	19.2
22.	Gola Gudan	9.60
23.	Gada Gaon	16.0
24.	Nimasa	11.2
25.	Panpat	16.0
26.	Bhat Vardi	9.60
27.	Beda Khal	11.2
28.	Bhamar	8.00
29.	Dhasaur	9.60
30.	Nimlay	8.00
31.	Banasa	11.2
32.	Kothda	9.60
33.	Borkhedi	9.60

**Table 4.34: Distribution of available phosphorus status in the soils of Satwas tehsil**

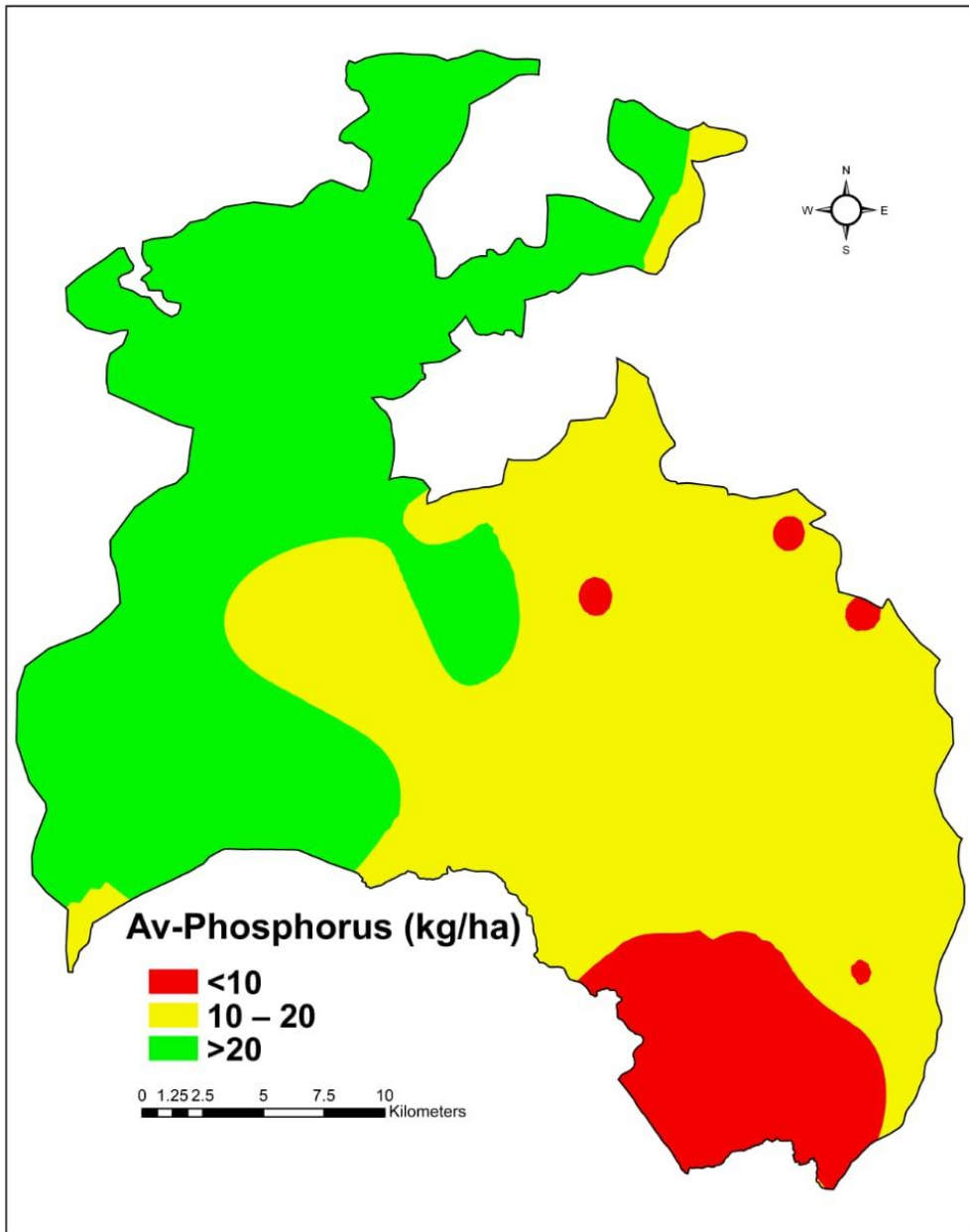
Available-P (kg ha <sup>-1</sup> )	No. of Samples	% samples
Low < 10	11	33.4
Medium (10 - 20)	16	48.5
High (>20)	06	18.1

#### **4.5.1: Spatial distribution of available P**

.To prepare the P variability map soils are divided in to three categories (Table 4.35).The spatial variability map of available-P of Satwas tehsil fig. 4.14. It is observed that the maximum area falls under the category II. (10- 20 kg ha<sup>-1</sup>) followed by category I. (<10 kg ha<sup>-1</sup>); minimum area under the category III. (> 20 kg ha<sup>-1</sup>) P in the Satwas tehsil soils (Table 4.35).

**Table 4.35: Extent of area under different P availability classes of the soils of Satwas tehsil**

P-availability Class	Available-P, kg ha <sup>-1</sup>	Ranking of the class on the basis of area.
I.	<10	II.
II.	10-20	I.
III.	> 20	III.



**Fig. 4.14: Spatial distribution of P in the soils of Satwas tehsil**

#### **4.6 Available K status of the soils of Satwas tehsil**

The data indicated that available K content of the soils of Satwas Tehsil ranged from 189 kg ha<sup>-1</sup> to 435 kg ha<sup>-1</sup> with an average value of 356.4 kg ha<sup>-1</sup> with, standard deviation 60.60 % and coefficient of variation (CV) 16.90 % (Table 4.36). Considering the soil test rating for available K (< 250 kg ha<sup>-1</sup> as low, 250 – 400 kg ha<sup>-1</sup> as medium and >400 kg ha<sup>-1</sup> as high in the status of K).The soils of Satwas tehsil fall under medium to high status in available K content. In general out of 33 samples, 60.6% (20) samples fall

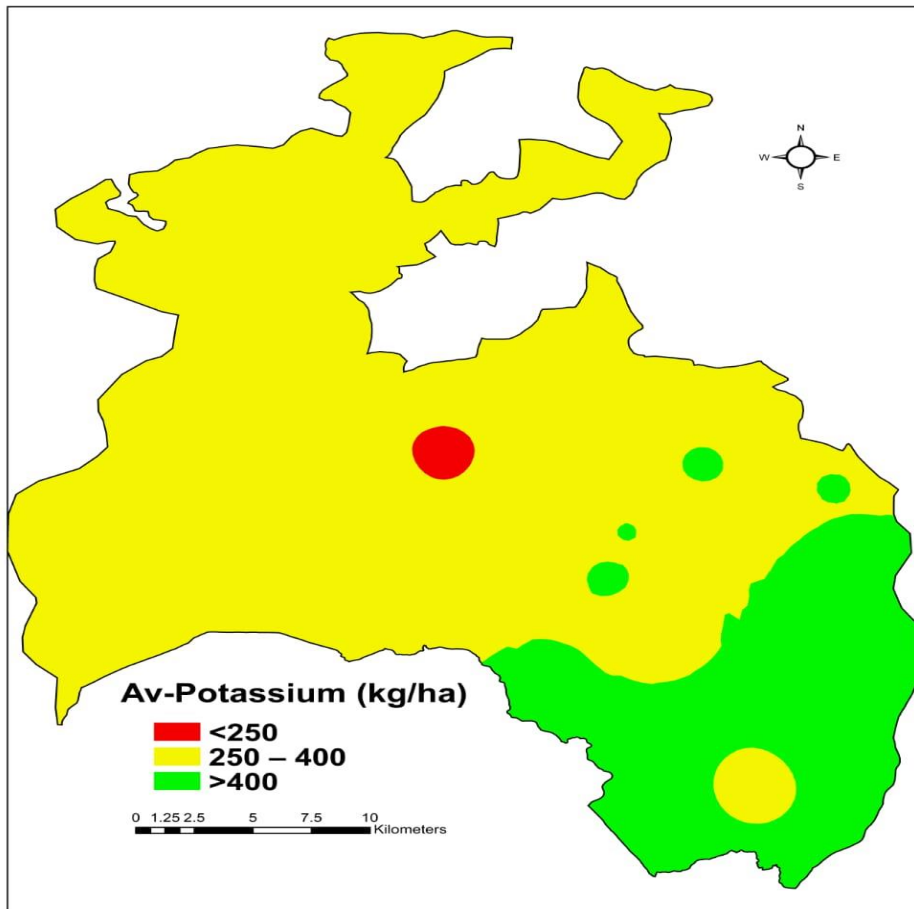
under medium status and 33.4 % (11) samples are high in K status.(table 4.37)

**Table 4.36: Available K (Kg ha<sup>-1</sup>) content of soils of Satwas tehsil**

S.No.	Name of village	K (kg ha <sup>-1</sup> )
1.	Hardi	250
2.	Bekalya	295
3.	Gaja Khedi	350
4.	Jinwani	325
5.	Kanta Phod	350
6.	Salamatpura	315
7.	Badgaon	375
8.	Ektera	350
9.	Surmanya	365
10.	Pura	189
11.	Sindharni	295
12.	Balya	315
13.	Satwas	325
14.	Palasi	355
15.	Kothada	345
16.	Dagra Kheda	310
17.	Pagri	240
18.	Kher Kheda	315
19.	Mansuriya	425
20.	Khapras	415
21.	Narayan Pura	435
22.	Gola Gudan	400
23.	Gada Gaon	355
24.	Nimasa	405
25.	Panpat	410
26.	Bhat Vardi	365
27.	Beda Khal	425
28.	Bhamar	435
29.	Dhasaur	405
30.	Nimlay	385
31.	Banasa	410
32.	Kothda	435
33.	Borkhedi	425

**Table 4.37: Distribution of available potassium status in the soils of Satwas tehsil**

Available-K (kg ha <sup>-1</sup> )	No. of samples	% samples
Low (<250)	02	6.0
Medium (250-400)	20	60.6
High (>400)	11	33.4



**Fig.4.15: Distribution of K in the soils of Satwas tehsil**

**Table 4.38: Extent of area under different K availability classes of the soils of Satwas tehsil**

K-availability Class	Available-K , kg ha <sup>-1</sup>	Ranking of the class on the basis of area.
I.	<250	III.
II.	250-400	I.
III.	> 400	II.

#### **4.6.1: Spatial distribution of available K**

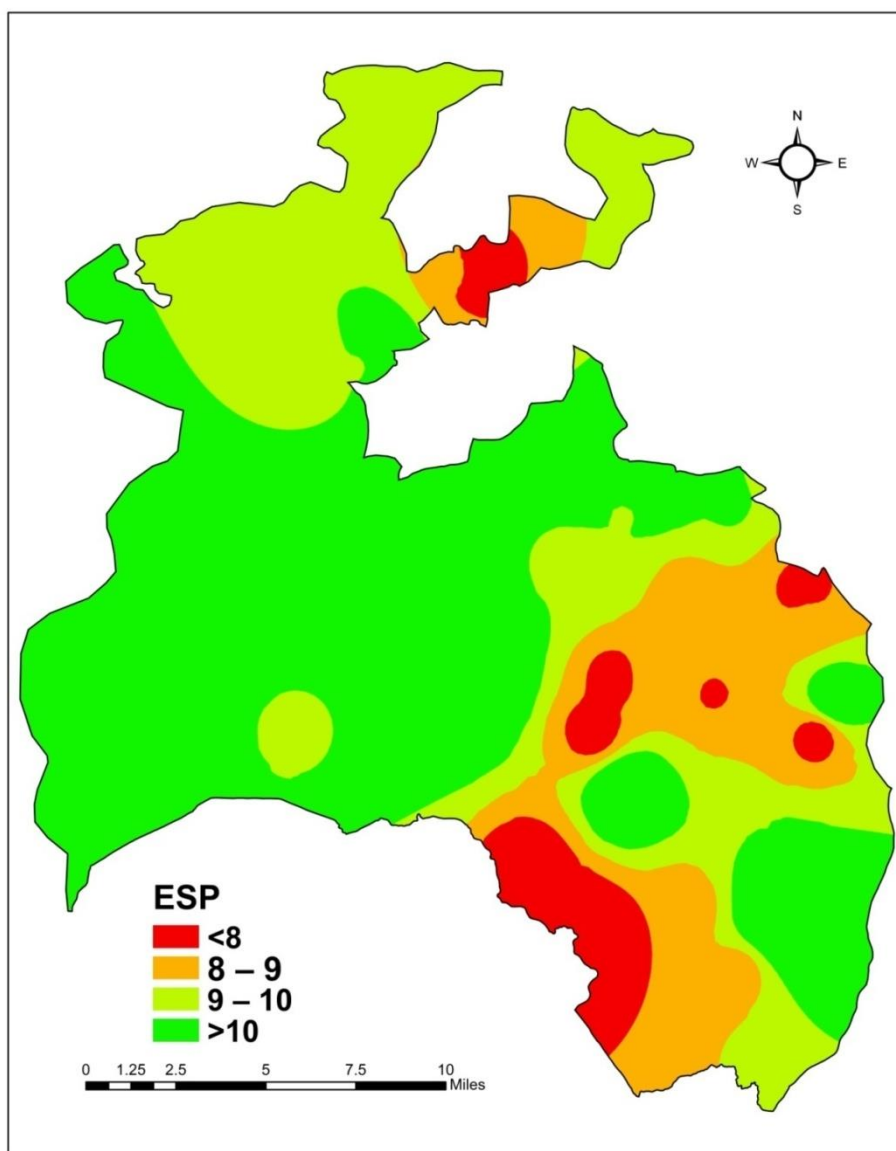
The spatial variability map of available-K of soils of Satwas tehsil (fig. 4.15) indicated that the maximum area falls under the category II (250-400 kg ha<sup>-1</sup>) followed by category III. (>400 kg ha<sup>-1</sup>) and minimum area under category I (<250 kg ha<sup>-1</sup>).

#### 4.7: Spatial distribution of ESP

The spatial variability map of soils of Satwas tehsil (Fig. 4.16) indicated that the maximum area falls under the category III (>10%) followed by category II (8-10%) and minimum area under category I (<8 %).

**Table 4.39: Extent of area under different ESP classes of the soils of Satwas tehsil**

ESP Class	ESP %	Ranking of the class on the basis of area.
I.	<8	III.
II.	8-10	II.
III.	>10	I.



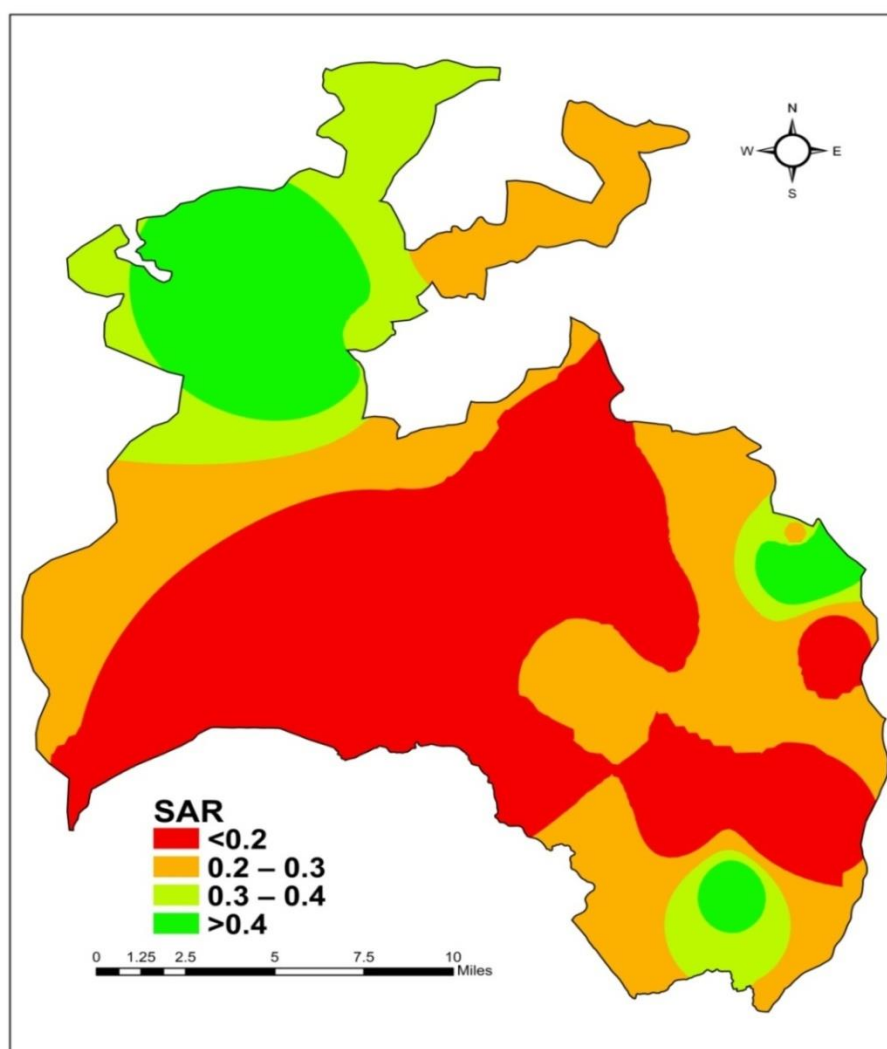
**Fig. 4.16: Spatial distribution of ESP in the soils of Satwas tehsil**

#### 4.8: Spatial distribution of SAR

The spatial variability map of SAR in soils of Satwas tehsil (Fig 4.17 & Table 4.40) indicated that the maximum area falls under the category I (<0.2) followed by category II (0.2-0.3) and minimum area under the category IV. >0.4.

**Table 4.40: Extent of area under different SAR classes of the soils of Satwas tehsil**

SAR Class	SAR	Ranking of the class on the basis of area.
I.	<0.2	I.
II.	0.2-0.3	II.
III.	0.3-0.4	III.
IV	>0.4	IV.



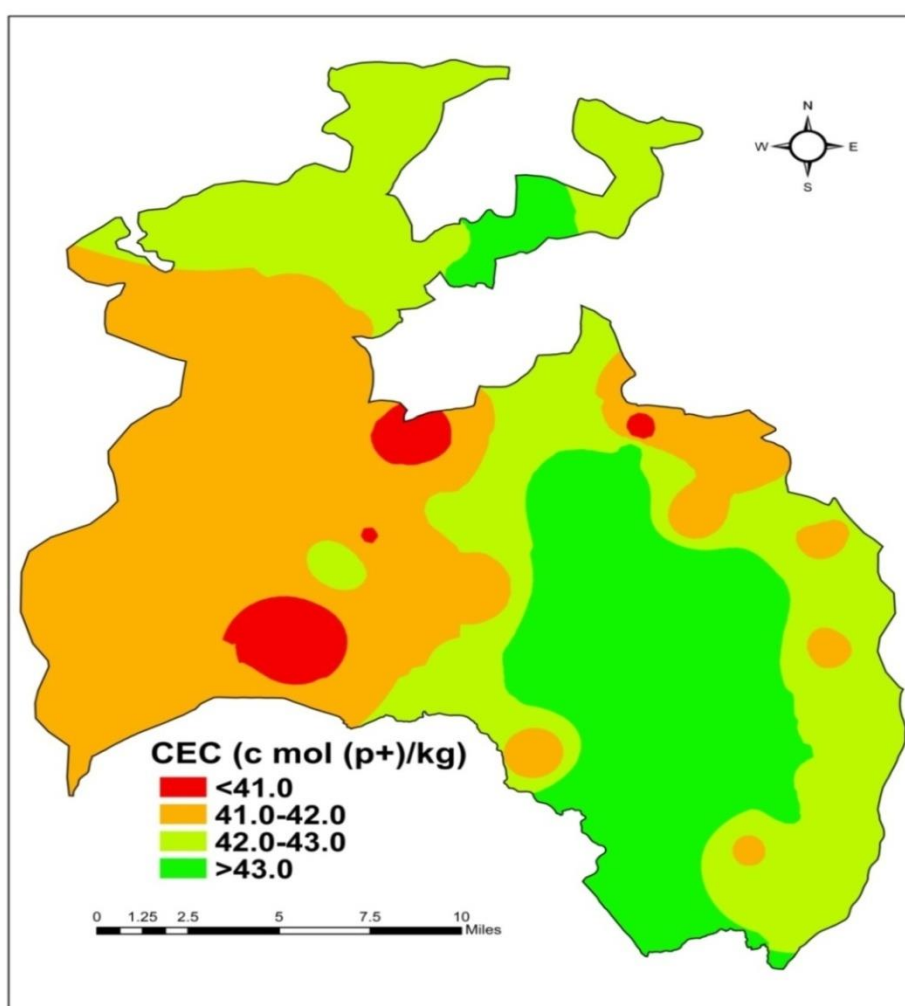
**Fig 4.17: Spatial distribution of SAR in the soils of Satwas tehsil**

#### 4.9: Spatial distribution of CEC

The spatial variability map of CEC in soils of Satwas Tehsil (Fig. 4.18 & Table 4.41) indicated that the maximum area falls under the category II (41-42) followed by category III. (42-43) and minimum area under category I (<41) (Table 4.41).

**Table 4.41: Extent of area under different CEC classes of the soils of Satwas tehsil**

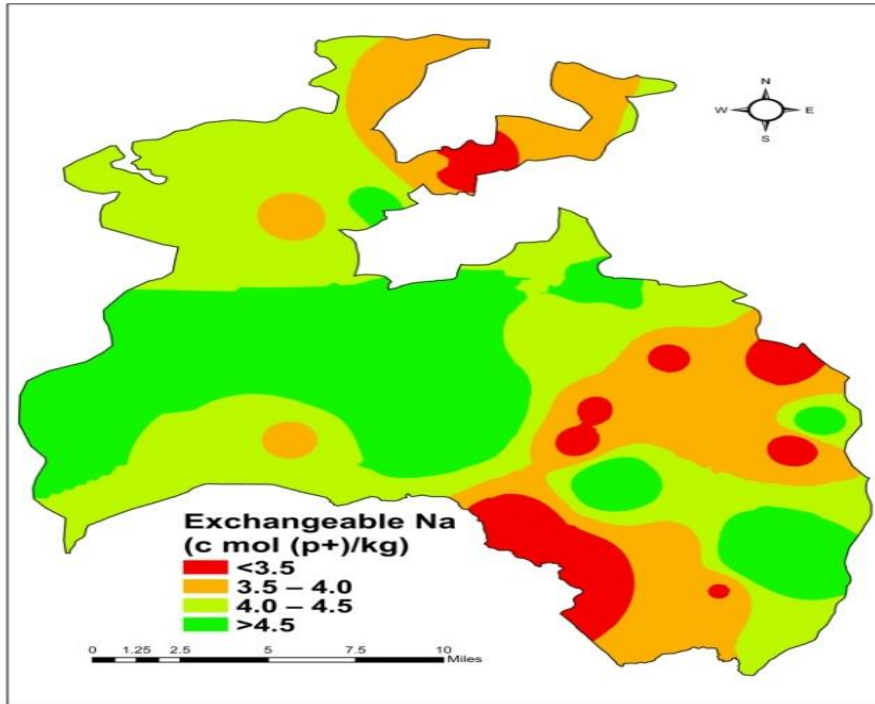
CEC Class	CEC	Ranking of the class on the basis of area.
I.	<41	IV
II.	41-42	I.
III.	42-43	II.
IV	>43	III.



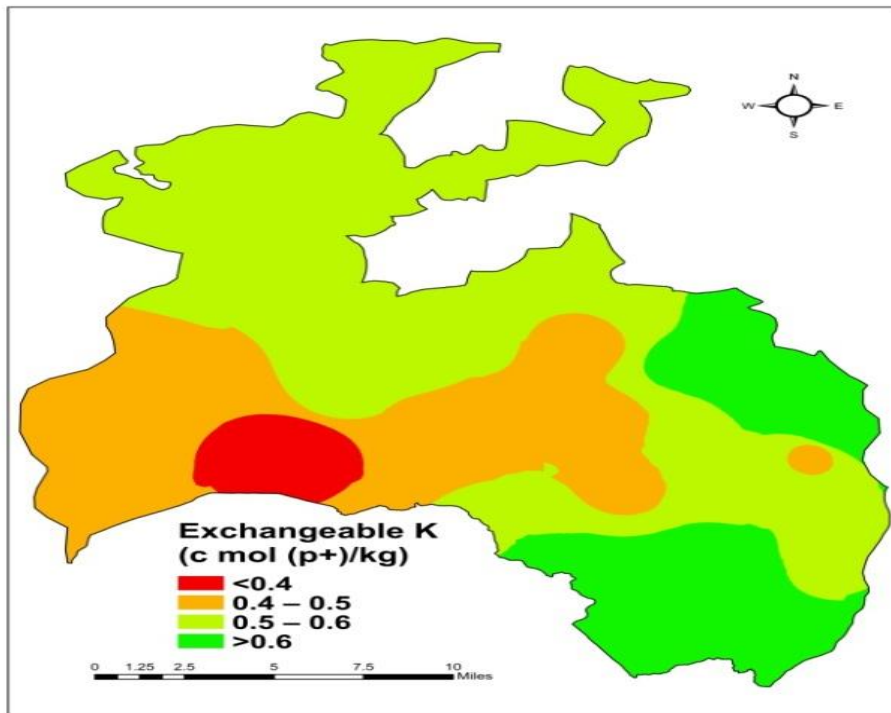
**Fig 4.18: Spatial distribution of CEC in the soils of Satwas tehsil**

**Table 4.42: Descriptive statistics soil properties**

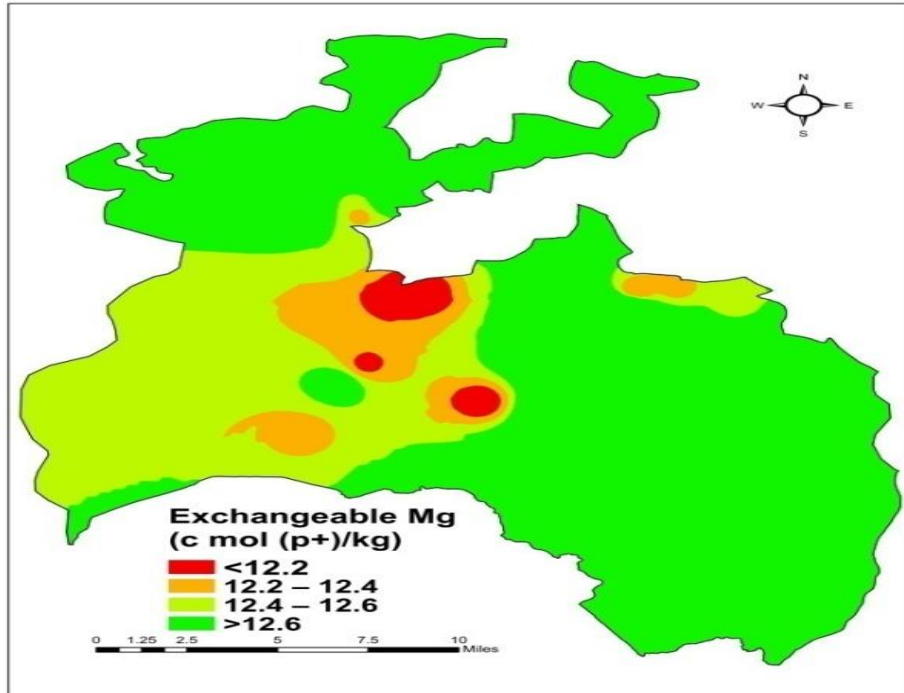
<b>Parameters</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Mean</b>	<b>Std. Deviation</b>
<b>pH</b>	7.10	8.00	7.57	0.26
<b>EC</b>	0.70	3.60	1.67	0.88
<b>Ca<sup>2+</sup> (me L<sup>-1</sup>)</b>	0.40	23.80	9.67	6.15
<b>Mg<sup>2+</sup> (me L<sup>-1</sup>)</b>	0.20	12.00	4.22	2.92
<b>Na<sup>+</sup> (me L<sup>-1</sup>)</b>	0.60	3.00	1.44	0.64
<b>K<sup>+</sup> (me L<sup>-1</sup>)</b>	0.00	2.10	0.40	0.47
<b>HCO<sup>3-</sup> (me L<sup>-1</sup>)</b>	1.20	12.00	5.05	3.16
<b>Cl<sup>-</sup> (me L<sup>-1</sup>)</b>	2.20	11.40	5.56	2.42
<b>SO<sub>4</sub><sup>2-</sup> (me L<sup>-1</sup>)</b>	1.80	12.40	5.62	3.20
<b>SAR</b>	0.10	1.00	0.24	0.21
<b>Ca<sup>2+</sup> (cmol (p<sup>+</sup>) kg<sup>-1</sup>)</b>	21.90	28.50	24.25	1.59
<b>Mg<sup>2+</sup>(cmol (p<sup>+</sup>) kg<sup>-1</sup>)</b>	11.80	15.40	13.06	0.85
<b>Na<sup>+</sup> (cmol (p<sup>+</sup>) kg<sup>-1</sup>)</b>	2.30	6.90	4.16	1.11
<b>K<sup>+</sup> (cmol (p<sup>+</sup>) kg<sup>-1</sup>)</b>	0.20	0.80	0.56	0.14
<b>CEC</b>	39.90	47.00	42.73	1.94
<b>ESP</b>	4.90	14.70	9.71	2.58
<b>N (kg ha<sup>-1</sup>)</b>	119.00	278.00	191.24	40.75
<b>OC (%)</b>	0.25	0.79	0.46	0.14
<b>P (kg ha<sup>-1</sup>)</b>	8.00	32.00	15.26	0.42
<b>K (kg ha<sup>-1</sup>)</b>	189	435	356.4	60.6



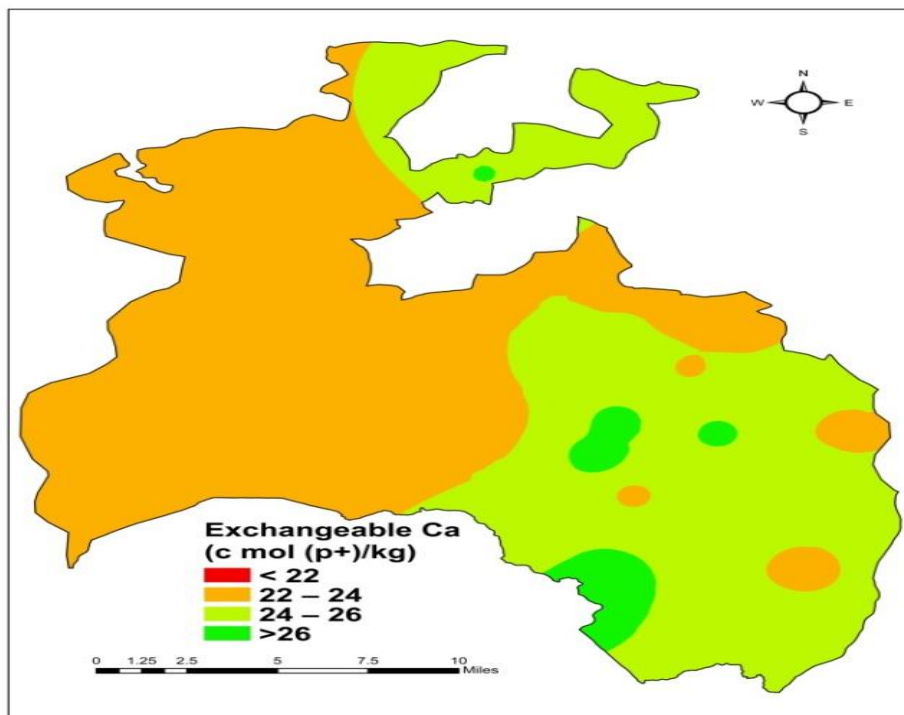
**Fig 4.19: Spatial distribution of exchangeable Na<sup>+</sup> in the soils of Satwas tehsil**



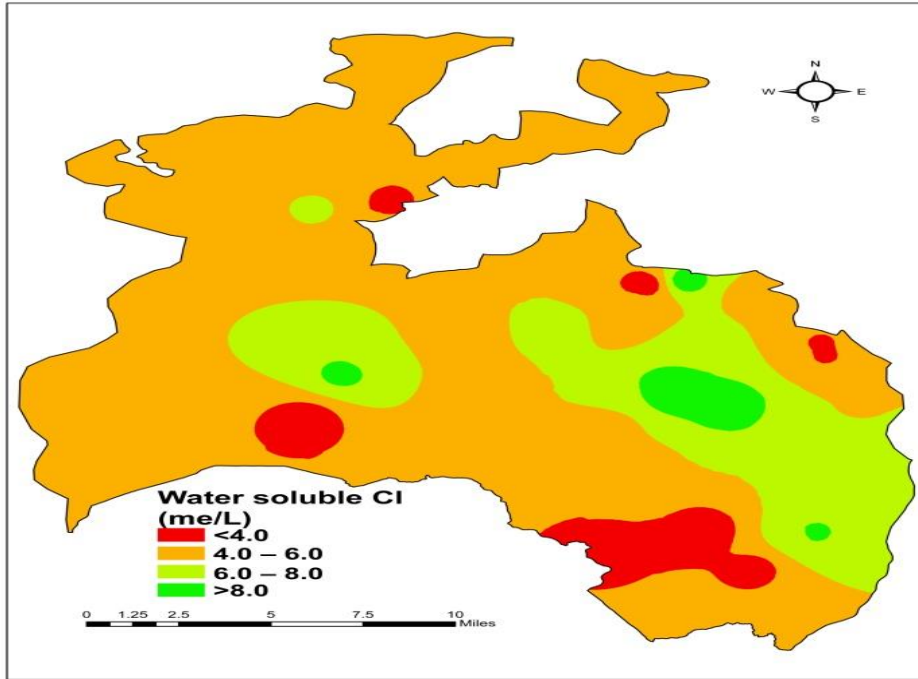
**Fig 4.20: Spatial distribution of exchangeable K<sup>+</sup> in the soils of Satwas tehsil**



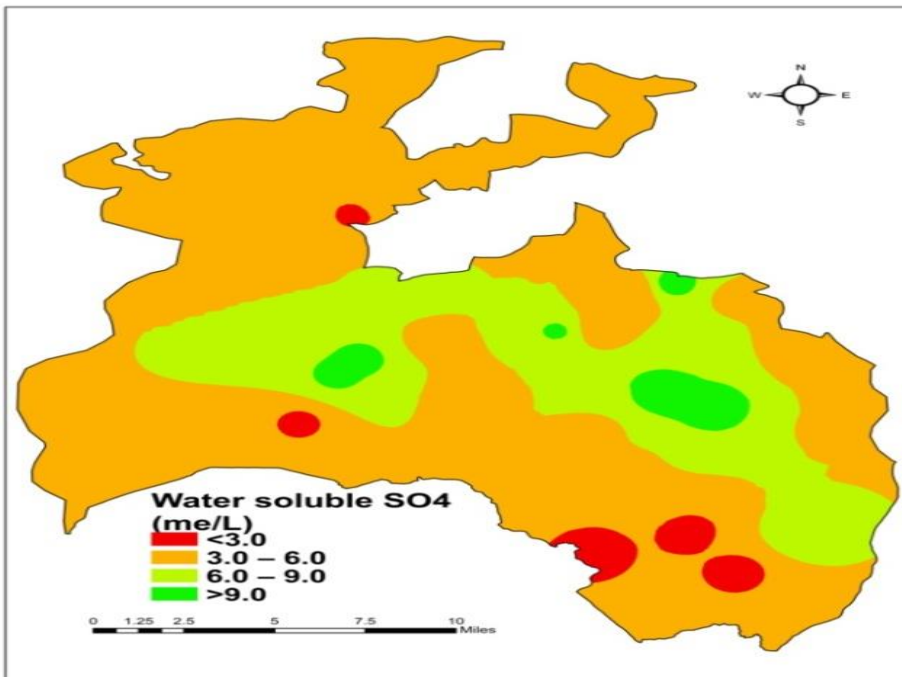
**Fig 4.21: Spatial distribution of exchangeable  $Mg^{2+}$  in the soils of Satwas tehsil**



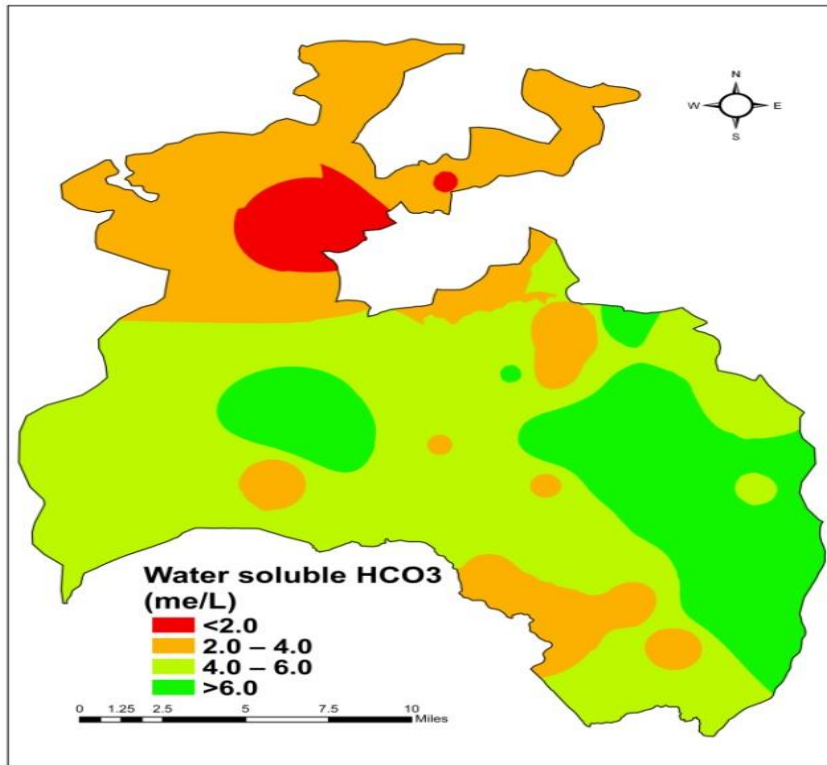
**Fig 4.22: Spatial distribution of exchangeable  $Ca^{2+}$  in the soils of Satwas tehsil**



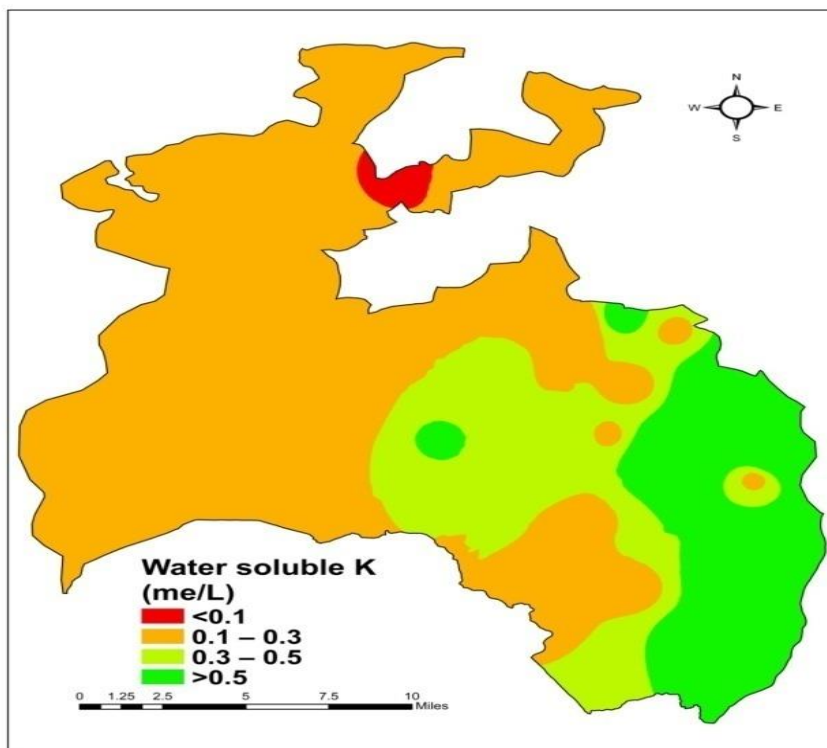
**Fig.4.23: Spatial distribution of Water soluble anion (chloride) in the soils of Satwas tehsil**



**Fig.4.24: Spatial distribution of Water soluble anion (sulphate) in the soils of Satwas tehsil**



**Fig 4.25: Spatial distribution of Water soluble anion (bicarbonate) in the soils of Satwas tehsil**



**Fig.4.26: Spatial distribution of water soluble cation (K<sup>+</sup>) in the soils of Satwas tehsil**

**Table 4.43: Correlations among soil parameters**

	pH	EC	Ca	Mg	Na	K	HCO <sub>3</sub>	Cl	SO <sub>4</sub>	SAR	Ca	Mg	Na	K	CEC	ESP	N kg ha <sup>-1</sup>	OC	Pkgha <sup>-1</sup>
pH	1.00																		
EC	-0.20	1.00																	
Ca	-0.15	<b>.758**</b>	1.00																
Mg	-0.07	<b>.776**</b>	<b>.845**</b>	1.00															
Na	-0.19	<b>.345*</b>	0.10	0.18	1.00														
K	-0.13	0.24	0.01	0.10	<b>.375*</b>	1.00													
HCO <sub>3</sub>	-0.03	<b>.698**</b>	<b>.875**</b>	<b>.862**</b>	0.16	0.33	1.00												
Cl	-0.06	<b>.813**</b>	<b>.844**</b>	<b>.850**</b>	0.24	0.20	<b>.876**</b>	1.00											
SO <sub>4</sub>	-0.14	<b>.854**</b>	<b>.899**</b>	<b>.893**</b>	0.26	0.20	<b>.863**</b>	<b>.916**</b>	1.00										
SAR	-0.08	-0.26	<b>-.481**</b>	<b>-.418*</b>	<b>.573**</b>	<b>.369*</b>	-0.32	-0.19	-0.28	1.00									
Ca	-0.07	-0.07	0.08	-0.05	0.14	-0.01	0.05	0.03	-0.07	-0.01	1.00								
Mg	-0.06	-0.08	0.07	-0.07	0.14	0.00	0.03	0.03	-0.08	-0.01	<b>.999**</b>	1.00							
Na	0.10	0.07	0.12	0.10	-0.25	-0.09	0.09	0.07	0.09	-0.22	<b>-.602**</b>	<b>-.600**</b>	1.00						
K	<b>.372*</b>	-0.01	-0.01	0.01	0.17	0.19	0.12	-0.03	-0.06	0.13	0.16	0.16	-0.20	1.00					
CEC	-0.03	0.09	0.25	0.06	0.12	0.00	0.17	0.19	0.08	-0.12	<b>.905**</b>	<b>.905**</b>	-0.27	0.10	1.00				
ESP	0.09	0.06	0.09	0.08	-0.26	-0.10	0.06	0.04	0.09	-0.19	<b>-.702**</b>	<b>-.701**</b>	<b>.984**</b>	-0.19	<b>-.401*</b>	1.00			
N kg ha <sup>-1</sup>	-0.03	-0.17	-0.02	-0.14	-0.04	-0.05	-0.10	-0.12	-0.02	0.12	-0.16	-0.16	-0.03	0.06	-0.14	0.01	1.00		
OC	-0.05	-0.17	-0.01	-0.15	-0.07	-0.05	-0.10	-0.12	-0.04	0.10	-0.13	-0.14	-0.01	0.02	-0.10	0.03	<b>.986**</b>	1.00	
Pkgha <sup>-1</sup>	0.15	-0.31	-0.34	-0.34	-0.22	-0.22	<b>-.405*</b>	-0.22	-0.32	0.19	-0.18	-0.18	0.12	<b>-.355*</b>	-0.13	0.13	0.14	0.13	1.00

\*\* Correlation is significant at the 0.01 level.

\* Correlation is significant at the 0.05 level.

#### 4.10 Correlations among soil parameters

The data pertaining to correlation coefficient (r) among different parameters of soil quality are given in the Table 4.43. Under different quality parameters of soil pH is positive and significantly correlated with EC,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$  and K. The  $\text{Na}^+$  also shows positive & significant correlation with EC,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$  and  $\text{SO}_4^-$  also and negative correlation with pH. The  $\text{K}^+$  also shows positive & significant correlation with pH, EC,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$  and negative correlation with  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ . Calcium ( $\text{Ca}^{2+}$ ) content of soil shows positive Correlation with EC and  $\text{HCO}_3^-$ ,  $\text{Na}^+$  and  $\text{Cl}^-$  whereas negative correlation with pH,  $\text{SO}_4^-$ , K. Mg shows positive and significant correlation with EC,  $\text{Ca}^{2+}$ ,  $\text{Na}^+$ ,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$  whereas negative correlation with pH, and  $\text{SO}_4^{2-}$ . SAR show positive & significant correlation with  $\text{Na}^+$  and  $\text{K}^+$ , whereas negative correlation with, pH, EC,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$  and  $\text{SO}_4^-$  also.

## CHAPTER- V

### DISCUSSION

An investigation entitled “**Assessment of soil properties and ground water quality in Satwas tehsil of Dewas district, Madhya Pradesh**” is carried out during the year 2019-20. The data regarding the chemical parameters obtained from the results are discussed in this chapter with suitable diagram, reference and scientific reasoning.

#### **5.1 Ground water samples and its quality parameters**

The present study on ground water is carried out in Satwas tehsil of Madhya Pradesh and 33 ground water samples from different wells/tube wells are collected during the year 2019-20.

Ground water samples had been categorized according to depth of source into three classes; (Table 4.1). About 36.3 % samples are found in < 50 m depth and 48.5 % samples found between 50-300 m depth and 15.2 % samples are found in > 300 m depth.

##### **5.1.1 pH values of irrigation water**

pH is an important parameter to determine the quality of the ground water and it is used to assess the acidity or basicity of the ground water. The pH values of the ground water collected from the different location of the Satwas tehsil are neutral to alkaline. It ranged from 7.12 to 8.70 with the mean value of 7.50 (Table 4.9). It is evident from the data of ground water samples of various locations which contained the higher amount of chloride and SAR recorded the higher pH. Correlation coefficient data between these parameters viz. SAR confirmed these findings. Divekar *et al.* (2005) also observed that the higher concentration of bicarbonate in water samples responsible for the development of alkalinity and thereby the higher pH values. This is because of the fact, that the pH of water samples reflects the dissolved  $\text{CO}_3^{2-}$  that originate either from the dissolution of atmospheric  $\text{CO}_2$  or from the weathering of carbonaceous rocks. The pH of good water category (A) shows the lower pH as compared to other category of water. The application of water

(B category) in soil may create salinity problem in soil after continuous use in the long run. Raghav *et al.* (2005) also observed the use of poor quality water and its adverse effects on soil physical properties in arid and semi arid regions of the country.

### **5.1.2 Electrical conductivity (EC) of ground water**

The total concentration of soluble salts expressed as electrical conductivity in ground water of Satwas tehsil varied from 0.24 to 1.98 dSm<sup>-1</sup> (Table 4.10). The classes as per USDA classification (Richards,1954) & based on electrical conductivity (Salinity hazards) are classified as low (0-0.25 dS m<sup>-1</sup>), medium (0.25-0.75 dS m<sup>-1</sup>), high (0.75-2.25 dS m<sup>-1</sup>) and very high (>2.25 dS m<sup>-1</sup>) and SAR values Sodium hazards as low (<10), Medium (10-18), high (18-26) and very high (>26). As per the classification given by Richards (1954), (76%) samples belonged to class of medium to high conductivity (Table 4.6). Only 11 (5.5%) samples had EC more than 2.25 dS m<sup>-1</sup> of very high conductivity class. The higher electrical conductivity (EC) in ground water samples is also observed by Bathusha and Saseetharan (2007) in Coimbatore city and Shahid *et al.* (2008) Julana block of Jind district of Haryana. Continuous application of higher electrical conductivity water may create soil salinity and deteriorate physical properties of soil.

It is concluded from the results that most of the water samples show medium to high EC. This is mainly due to the presence of neutral salts of chloride and sulphate in ground water samples. Electrical conductivity is found to be positively correlated with Cl<sup>-</sup> (r=0.86\*\*), Ca<sup>2+</sup> (r=0.90\*\*), Mg<sup>2+</sup> (r=0.87\*\*) and HCO<sub>3</sub><sup>-</sup> (r=0.75\*\*) and SO<sub>4</sub><sup>2-</sup> (r=0.77\*\*) (Table 4.15). The study conducted by Dubey *et al.* (1988) also observed that irrigation water containing Cl<sup>-</sup> and SO<sub>4</sub><sup>2-</sup> helped in exchangeable calcium build up in soil and counteracted the deleterious effect of high SAR of irrigation water.

### **5.1.3 Residual sodium carbonate (RSC)**

The soluble bicarbonates in ground water samples of Satwas tehsil varied from 0.6 to 6.8 me L<sup>-1</sup> (Table 4.12) and there are no soluble carbonates found in the water samples of the Satwas tehsil. The concentration of

bicarbonate anion is important because they affect the precipitation of calcium and thereby result in excessive sodium saturated in soil. The carbonate and bicarbonate concentrations are very useful to judge the temporary hardness and alkalinity. There is no RSC values found in ground water samples of Satwas tehsil. Apraj *et al.* (2017) also found low RSC in groundwater in areas of Palghar tehsil of Coastal Konkan with the mean value of  $0.74 \text{ me L}^{-1}$ . The continuous and indiscriminate use of higher RSC ( $>1.25 \text{ me L}^{-1}$ ) underground water may be expected to build excessive sodium in soil solution and exchange complex and clog the soil pores which leads to drainage problem.

#### **5.1.4 Sodium Adsorption Ratio (SAR)**

The Sodium adsorption ratio (SAR) of ground water samples are in the range of 0.07 to 1.44 ( $\text{mmol L}^{-1}$ )<sup>1/2</sup> with mean value 0.46 % and standard deviation 0.26% (Table 4.11). Sodium hazard is defined separately because of its specific detrimental effect on soil physical properties. The sodium hazard is typically expressed as sodium adsorption ratio (SAR) in ( $\text{mmol L}^{-1}$ )<sup>1/2</sup>. This index quantifies the proportion of sodium ( $\text{Na}^+$ ) to calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ) in a sample. Calcium flocculates, while sodium disperses (pushes apart) soil particles. This dispersed soil readily forms crust and creates water infiltration and permeability problems. Singh *et al.* (2014) also found mean SAR values of irrigation water below 10 ( $\text{mmol L}^{-1}$ )<sup>1/2</sup>.

The SAR of ground water is significantly correlated with pH ( $r=0.133^{**}$ ),  $\text{Na}^+$  ( $r=0.629$ ) and K ( $r=0.108^{**}$ ) of water. It is concluded from the results that the total ions concentration in the collected ground water samples is low and within the safe limits. All samples of the Satwas tehsil had SAR values  $< 10$  (Table 4.7).

#### **5.1.5 Use of different qualities water in agriculture**

Most of the ground water of Satwas tehsil (91%), which belongs to 'A' category (Minhas *et al.*, 1998) known as good quality water can be used safely for all the crops including wheat and leguminous crops as well as vegetables.

### **5.1.6 Frequency distribution of ground water (Minhas *et al.*, 1998)**

The ground water samples from many water resources are collected from Satwas tehsil for determining water quality. The analysis is performed according to the standard methods of assessing ground water quality (Richards, 1954). The ground water samples are classified into different categories as referred by Minhas *et al.* (1998). On the basis of EC, SAR and RSC values, the collected water samples are categorized as good quality (A), marginally saline (B1), saline (B2), high SAR saline (B3), marginally alkali (C1), alkali (C2) and very high alkali (C3) Table 4.7. Out of 33 ground water samples, 100% samples came under category – A. Bangar *et al.* (2008) also observed that the out of 712 ground water samples, 80% samples indicated good water quality, whereas 14% are found saline (marginally saline -9%, saline-4% & high SAR saline-1%) and 6% as alkali (marginally alkali-5% and alkali-1% categories) in Ujjain district of Madhya Pradesh.

### **5.2 Soil samples and its quality parameters**

In the present study, soil samples are studied in Satwas tehsil of district Dewas. These soil samples are analyzed to characterize the soils of study area in terms of physico-chemical properties. Based on these characters, the soils are classified for different fertility classes. The soil variability Maps are also prepared for various chemical properties using GIS (Arc GIS software). The results obtained in the present study are discussed below:

#### **5.2 Chemical properties**

##### **5.2.1 Soil reaction (pH) of soil sample**

The pH is an important properties of soil, it processes and speciation of chemical element in soil. The pH of soils of Satwas tehsil ranged from 7.1 to 8.0 with a mean value of 7.56, standard deviation 0.25 and coefficient of variation 3.3 %.( Table 4.16). Out of 33 soil samples 51.5 % soil samples are neutral in pH and 48.5 % samples are slightly alkaline (Table 4.17).

The variability map (Fig. 4.10) of soil pH shown that the maximum area falls under the category Class IV (6.5 to 7.5) followed by category III (7.5 to 8.5) and minimum area under category I ( 6.0 to 6.5) neutral to slightly alkaline reaction might be due to the parent material which is basic in nature with high

or moderately high content of calcium and magnesium in a form that is readily released with weathering (Dudal, 1965). Similar observations are made by Singh *et al.* (2009) in soils of district Gajipur, Uttar Pradesh. Higher pH values are also recorded by Balpande *et al.* (1996) in degraded Vertisols in Purna Valley.

### **5.2.2 Electrical conductivity**

The electrical conductivity of soils under study ranged between 0.70 to 3.6 dSm<sup>-1</sup> at 25°C with mean value of 1.66 dS m<sup>-1</sup>, (Table 4.19) it showed a considerable variation with type of topography of soils. It reveals It is evident from the fig.4.11 that the maximum area falls under the category I (0.8 - 0.9 dSm<sup>-1</sup>) followed by category II (0.7– 0.8 dSm<sup>-1</sup>); Category V. (>0.9 dSm<sup>-1</sup>) and minimum area under category I (<0.6) dSm<sup>-1</sup> at 25°C. .The EC is existed as normal in Satwas tehsil < 1 dSm<sup>-1</sup> at 25°C. Singh (2012) Dilliwar *et al.* (2014) and Singh *et al.* (2014) also reported similar results.

### **5.2.3 Water soluble cations**

The water soluble cation concentration in ground water samples of Satwas tehsil is presented in Table 4.22. The calcium concentration in the samples had a wide range (0.40 to 23.8 me L<sup>-1</sup>) followed by Mg<sup>2+</sup> (0.20 to 12.0 me L<sup>-1</sup>), Na<sup>+</sup> (0.60 to 3.00 meL<sup>-1</sup>) and K<sup>+</sup> (0.00 to 2.10 me L<sup>-1</sup>). Mean value of, Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup> are, 9.67, 4.22, 1.43 and 0.39 respectively.

### **5.2.4 Water soluble anions**

The water soluble anion concentration in ground water samples of Satwas tehsil is presented in Table 4.23. The chloride concentration (Cl<sup>-1</sup>) is the dominant ion with maximum value (11.4 me L<sup>-1</sup>) observed in village Gadgaon at serial number 23 (Table 4.23). The highest value of HCO<sub>3</sub><sup>-</sup> (12.0 me L<sup>-1</sup>) observed in Ektara village at sample number 08, while the minimum (1.20 me L<sup>-1</sup>) recorded in village at kataphod sample number 05. Minimum value of SO<sub>4</sub><sup>2-</sup> (1.80 me L<sup>-1</sup>) are recorded in Surmavya village at serial no. 09 and maximum value of SO<sub>4</sub><sup>2-</sup> (12.40 me L<sup>-1</sup>) are observed in Gadgaon at serial no 23. Mean value of SO<sub>4</sub><sup>2-</sup> are found to be 5.62 me L<sup>-1</sup> (Table 4.23)

### **5.2.5 Exchangeable cations**

The exchangeable calcium concentration in the soil samples had a wide range (21.9 to 28.5 me L<sup>-1</sup>) followed by Mg<sup>2+</sup> (11.8 to 15.4 me L<sup>-1</sup>), Na<sup>+</sup> (02.30 to 6.90 me L<sup>-1</sup>) and K<sup>+</sup> (0.20 to 2.80 me L<sup>-1</sup>). Mean value of exchangeable Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup> are, 24.25, 13.06, 4.15 and 0.56 me L<sup>-1</sup> respectively (Table 4.24).

### **5.2.6 Exchangeable sodium percentage and Sodium absorption ratio**

The ESP of soils under study indicated a wide variation ranging 4.9 to 14.7%, with mean value of 9.71 % and standard deviation 2.58 % (Table 4.25). The SAR confined from 0.10 to 1.00 with a mean value of 0.24. (Table 4.25 and table 4.26).

### **5.2.7 Cation exchange capacity**

The cation exchange capacity (CEC) exhibited a range between 39.9 to 47.0 cmol (p+) kg<sup>-1</sup> (Table 4.25) with mean value of 42.7 cmol (p+) kg<sup>-1</sup> and standard deviation 1.94, as a consequence of variation in their clay fraction. Among the exchangeable cations, Ca<sup>++</sup> dominates the exchange complex though Na<sup>+</sup> also possess comparable value with Ca<sup>++</sup> which followed by Mg<sup>+</sup>.

### **5.2.8 Fertility status**

The data related to the fertility status of Satwas tehsil are presented in Appendix. The available nitrogen content varied between 119 and 278 kg ha<sup>-1</sup>, available phosphorus ranged from 8.0 to 32 kg ha<sup>-1</sup>, available potassium ranged from 189 kg ha<sup>-1</sup> to 435 kg ha<sup>-1</sup> (Table 4.42). Rajeshwar (2009) and Sharma *et al.* (2008) observed similar trend of nutrient status in the study area soils.

### **5.2.9 Organic Carbon**

The organic carbon content under present investigation ranged from 0.25 % to 0.79 %, with mean value of 0.46 %. The standard deviation 0.14 % and coefficient of variation (CV) is 30.40 % (Table 4.27). Organic carbon decreased with the depth and is always less than one per cent due to its rapid

decomposition and mineralization under prevailing condition of high temperature and low rainfall (Miller and Donahue, 1983). Spatial variability Map of organic carbon of the soils of Satwas tehsil depicted in fig. 4.12. To prepare the organic carbon variability map soils are divided in to three categories (Table 4.29). It is evident from the Map that the maximum area falls under the category I (<0.50) followed by category II. (0.50-0.75); and minimum area under category IV (>0.75), area falls under low to Medium status of organic carbon which requires immediate attention to sustain the soil health of Satwas tehsil .

#### **5.2.10 Available N**

The available N content (Table 4.30) of the soils of Satwas Tehsil ranged from 119 to 278 kg ha<sup>-1</sup> with an average value of 191.2 kg ha<sup>-1</sup>. with standard deviation 40.75 % and coefficient of variation (CV%) 21.30 %(Table 4.30). Considering the soil test rating for available N (400 as high in the status of N) most of the soils (75.75%) of Satwas tehsil fall under status (low <250). To prepare the N variability map, the soils are divided in to three categories as depicted in (table 4.32). It is evident from the map that the Maximum area falls under the category III. (<200 kg ha<sup>-1</sup>) followed by category II. (200-250 kg ha<sup>-1</sup>) and category III. (>250 kg ha<sup>-1</sup>).

#### **5.2.11 Available P**

The available P content (Table 4.33) of the soils of Satwas tehsil ranged from 8.00 to 32 kg ha<sup>-1</sup> with an average value of 15.35 kg ha<sup>-1</sup> with standard deviation 6.58 kg ha<sup>-1</sup> and Coefficient of Variation (CV%) 42.86 %. Considering the soil test rating for available p (< 10.0 kg ha<sup>-1</sup> as low, 10.0 – 20.0 kg ha<sup>-1</sup> as medium and >20.0 kg ha<sup>-1</sup> as high in the status of P) the soils of Satwas tehsil fall under low to medium in available P content. 33.4% samples are low P status, 48.5 % samples under medium P status and 18.1 % samples are high in P status (Table 4.34). The spatial variability map of available- P of Satwas Tehsil (fig 4.14). It is observed that the maximum area falls under the category II (10-20 kg ha<sup>-1</sup>) followed by category I. (<10kg ha<sup>-1</sup>), minimum area under the category III. (>20 kg ha<sup>-1</sup>) P in the Satwas tehsil soils.

### 5.2.12 Available K

The data indicated that available K content of the soils of Satwas tehsil ranged from 189 kg ha<sup>-1</sup> to 435 kg ha<sup>-1</sup> with an average value of 356 kg ha<sup>-1</sup> with, standard deviation 60.60 % and coefficient of variation (CV) 17.00 % (Table 4.36). Considering the soil test rating for available K (< 250 kg ha<sup>-1</sup> as low, 250 - 400 kg ha<sup>-1</sup> as medium and >400 kg ha<sup>-1</sup> as high in the status of K). The soils of Satwas tehsil fall under low to medium status in available K content. In general out of 33 samples, 60.6 % samples fall under medium status and 33.4 % samples are high in K status (Table 4.37). Similar results are observed by Verma *et al.* (2005) in soils of Sardulgarh, Bhikhi and Budhlada block sand, Nirawar *et al.* (2009) in soils of Ahemedpur Tehsil of Latur District and Sharma *et al.* (2017) in soils of Jhabua district. Kaolinite type of clay mineralogy are the causes for medium and low rating. Adequate (medium or 65 high) available K in these soils may be attributed to the prevalence of potassium-rich minerals like Illite and Feldspars (Sharma *et al.*, 2008).

## **CHAPTER – VI**

### **SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK**

Soil is a reservoir of nutrients and plays a pivotal role in supporting the growth of crops and other vegetation maintaining the earth's environment clean. Ground Water is most important in shaping the land and regulating the climate. Water is one of the most important and abundant compounds of the ecosystem. All living organisms on the earth need water for their survival and growth. With this objective in view, a study entitled “**Assessment of soil properties and ground water quality in Satwas tehsil of Dewas district, Madhya Pradesh**” is conducted during 2019-20 in the Department of Soil Science, College of Agriculture, Indore (M.P.). Satwas tehsil is one of the important tehsil located in the Dewas district of Madhya Pradesh state (India). It is located at latitude of 22° 53' 50" N and longitude of 76° 69' 15" E. In this view around 33 ground water samples and 33 soil samples are collected from the every village of tehsil. These water samples are analysed in the laboratory of Salt Affected Soils Project, College of Agriculture, Indore for different quality parameters such as pH, EC, total cations ( $\text{Ca}^{2+}$  ,  $\text{Mg}^{2+}$  ,  $\text{Na}^{+}$  ,  $\text{K}^{+}$ ) and total anions ( $\text{HCO}_3^{2-}$  ,  $\text{HCO}_3^{-}$  ,  $\text{Cl}^{-}$  ,  $\text{SO}_4^{2-}$ ). The values of SAR and RSC are also worked out by the formula given by the Richards,(1954).

#### **6.1 The salient findings of the experiment are summarized below:**

##### **6.1.1 Study of ground water:**

❖ The ground water samples collected from different sources from Satwas tehsil for assessment of their chemical parameters. The analyses are performed according to the standard methods for ground water samples (Richards, 1954).The ground water samples are classified into different categories as referred by Minhas *et al.* (1998). On the basis of EC, SAR and RSC values, the collected water samples are categorized as good quality (A), marginally saline (B1), saline (B2), high SAR saline (B3), marginally alkali

(C1), alkali (C2) and very high alkali (C3). Out of 33 ground water samples, 100% samples came under category A.

❖ In Satwas tehsil, the pH of 33 ground water samples are neutral to slightly alkaline in nature (7.12 to 8.0) with the mean value of 7.50 and standard deviation of ground water samples is 0.30. Out of 33 ground water samples 60.6 % samples are found in pH range 6.6 to 7.5, whereas 36.4% ground water samples had pH 7.5 to 8.5 and remaining 3.1% ground water samples are >8.5 pH.

❖ In Satwas tehsil the EC of 33 ground water samples in the range 0.24 to 1.98 dS m<sup>-1</sup> and the average value of 0.88 dS m<sup>-1</sup> and standard deviation 0.28. As per the classification given by Richards (1954), 75.8% samples belonged to class of medium conductivity 0.25 to 0.75 dS m<sup>-1</sup> whereas 15.1 % samples belonged to low conductivity <0.25 dS m<sup>-1</sup> and only 9.1 % samples had EC 0.75 to 2.25 dS m<sup>-1</sup> of high conductivity class.

❖ The values of SAR varied from 0.07 to 1.44 with the mean value of 0.46 (mmol L<sup>-1</sup>)<sup>1/2</sup>. Whereas RSC are totally absent in ground water samples of Satwas tehsil.

❖ Among the different cations calcium are dominant varied from 0.4 to 10.8 me L<sup>-1</sup> and the average value of 4.02 me L<sup>-1</sup> followed by magnesium varied from 0.2 to 6.4 meL<sup>-1</sup> and the average value of 2.20 me L<sup>-1</sup> ,whereas sodium and potassium 0.43 to 3.51 me L<sup>-1</sup>, 0 to 0.55 meL<sup>-1</sup> respectively. Mean value of sodium and potassium 2.00 and 0.06 me L<sup>-1</sup> respectively in different wells / tubewells of Satwas tehsil.

❖ In different wells / tube wells among the different anions bicarbonate is dominant followed by sulphate and chloride. HCO<sub>3</sub><sup>-</sup> varied from 0.6 to 6.8 meL<sup>-1</sup> and the mean value of 2.87 me L<sup>-1</sup> and SO<sub>4</sub><sup>2-</sup> varied from 0.6 to 5.8 me L<sup>-1</sup> and mean value of 2.79 meL<sup>-1</sup> and Cl<sup>-</sup>, varied from 0.40 to 7.2 me L<sup>-1</sup> and the average value of 2.58 me L<sup>-1</sup>.

❖ Under different quality factors of water, HCO<sub>3</sub><sup>-</sup> content of water show positive and significant Correlation with EC whereas negative correlation with pH.

❖ Under different quality parameters of water, calcium (Ca<sup>2+</sup>) content of water show positive and significant Correlation with EC, HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup> whereas negative correlation with pH.

### 6.1.2 Chemical properties of soil:

- ❖ The pH of soils of Satwas tehsil ranged from 7.1 to 8.0 with a mean value of 7.56, standard deviation 0.25 and coefficient of variation 3.3 %. The electrical conductivity of soils under study ranged between 0.7 to 3.6 dS m<sup>-1</sup> at 25°C with mean value of 1.66 dS m<sup>-1</sup>.
- ❖ Status of available N, P, K, in soils the poor and low status of available nitrogen is observed in the soil samples of Satwas tehsil. The available P content is medium and available K is also observed medium to high in soils of Satwas tehsil.
- ❖ The cation exchange capacity (CEC) exhibited a range between 39.9 to 47.0 cmol (p+) kg<sup>-1</sup> with mean value of 42.7 cmol (p+) kg<sup>-1</sup> and standard deviation 1.94 %.
- ❖ The ESP of soils under study indicated a wide variation ranging 4.9 to 14.7%, with mean value of 9.71 % and standard deviation 2.58 %. These soils of Satwas tehsil are in satisfactory range.
- ❖ The exchangeable calcium concentration in the soil samples had a wide range (21.9 to 28.5 me L<sup>-1</sup>) followed by Mg<sup>2+</sup> (11.8 to 15.4 me L<sup>-1</sup>), Na<sup>+</sup> (02.30 to 6.90 me L<sup>-1</sup>) and K<sup>+</sup> (0.20 to 2.80 me L<sup>-1</sup>). Mean value of exchangeable Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup> are, 24.25, 13.06, 4.15 and 0.56 respectively.
- ❖ The SAR confined from 0.10 to 1.00 with a mean value of 0.24. The lowest SAR value of 0.10 is recorded in village Gadgaon and Dhasu at sample number 23 and 29 and highest value of SAR 1.00 in village Mansuriya at sample number 19.
- ❖ Water soluble calcium concentration in the samples had a wide range (0.40 to 23.8 me L<sup>-1</sup>) followed by Mg<sup>2+</sup> (0.20 to 12.0 me L<sup>-1</sup>), Na<sup>+</sup> (0.60 to 3.00 meL<sup>-1</sup>) and K<sup>+</sup> (00 to 2.10 me L<sup>-1</sup>). Mean value of, Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup> are, 9.67, 4.22, 1.43 and 0.39 respectively.
- ❖ In case of anion, Cl<sup>-1</sup> is the dominant ion with maximum value (11.4 me L<sup>-1</sup>) observed in village Gadgaon at serial number 23.

## 6.2 Conclusion:

- ❖ It can be concluded from the research that the soils of Satwas tehsil of Dewas district, Madhya Pradesh are characterized under neutral to slightly alkaline in soil reaction (pH) and EC in most of the soil samples are normal for total soluble salt concentration, All samples are within the permissible limit. Among the exchangeable cations calcium ( $\text{Ca}^{2+}$ ) is dominant in soil samples. Among the different water soluble cations calcium ( $\text{Ca}^{2+}$ ) is dominant and among the different water soluble anions chloride ( $\text{Cl}^-$ ) is dominant in soil samples of Satwas tehsil of Dewas district. Organic carbon content are low to medium rating, available N content are also low to medium fertility status and medium in available P status and high in available K status and Hence, the soils require attention regarding nutrient management practices and regular monitoring of soil health for better crop production, in future.
- ❖ Total 33 ground water samples are studied and concluded that the ground water samples are neutral to slightly alkaline in nature which is acceptable pH range for irrigation suitability. Electrical conductivity is in medium class (76% samples). Among the different cations calcium is dominant and among the different anions bicarbonate is dominant in ground water samples of Satwas tehsil.

### 6.3 Suggestion for future work:

1. Continuous monitoring of ground water quality season wise in areas of poor quality water will be helpful to take immediate steps in minimizing further deterioration of the quality of soils.
2. Effect of poor quality water should be monitored in soil at different length of time. This will be helpful in formulating proper management practices in the affected areas.
3. The study should be conducted in district as a whole for getting valuable information for planers.
4. Detail soil study should be done for assessing soil salinity / alkalinity with the use of poor quality water.

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## APPENDICE

### ❖ Chemical concentration of ground water of Satwas tehsil of Dewas district

S.No.	Name of village	pH	EC (dSm <sup>-1</sup> )	Soluble Cations ( me L <sup>-1</sup> )			
				Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>
1.	Hardi	7.1	0.74	4.6	2.4	1.18	0.12
2.	Bekalya	7.2	0.71	3.2	1.6	2	0.02
3.	Gaja Khedi	7.5	0.8	3.2	1.2	1.75	0.29
4.	Jinwani	7.5	0.92	3.6	1.2	1.67	0.01
5.	Kanta Phod	7.4	0.82	2.8	2	2.06	0.02
6.	Salamatpura	7.6	0.98	3.4	1.8	3.2	0.06
7.	Badgaon	7.7	1.13	4.6	2.4	2.15	0.05
8.	Ektera	8.7	0.7	3.2	1.2	2.92	0.06
9.	Surmanya	8	0.59	2.8	1.4	0.97	0.03
10.	Pura	7.6	0.73	2.8	1.4	1.2	0.03
11.	Sindharni	7.2	0.65	3.2	1.2	0.57	0.03
12.	Balya	7.1	0.9	2.2	1.2	3.5	0.06
13.	Satwas	7.7	0.81	2	1.2	3.09	0.05
14.	Palasi	7.4	0.92	4.4	2.2	2.25	0.05
15.	Kothada	7.7	0.69	2.4	2	1.45	0.02
16.	Dagra Kheda	7.9	0.98	4.2	1.4	2.56	0.01
17.	Pagri	7.8	0.81	3.8	1.8	2.5	0.01
18.	Kher Kheda	7.3	1.29	6.6	3.6	1.98	0.55
19.	Mansuriya	7.4	1.27	5.4	3.6	3.51	0.24
20.	Khapras	7.3	1.04	5.2	3.4	1.98	0.02
21.	Narayan Pura	7.7	0.98	5.6	2.2	1.93	0.01
22.	Gola Gudan	7.5	0.82	4.2	2.4	1.5	0.01
23.	Gada Gaon	7.3	0.24	0.6	0.2	1.63	0.01
24.	Nimasa	7.2	0.91	5.4	2.8	0.97	0.03
25.	Pan Pat	7.4	0.31	0.4	0.2	2.23	0.17
26.	Bhat Vardi	7.4	0.9	4.4	3.2	1.38	0.01
27.	Beda Khal	7.3	0.89	5.8	2.8	0.43	0.01
28.	Bhamar	7.6	0.98	4.8	2.8	2.28	0.02
29.	Dhasaur	7.5	0.8	4	2.4	1.63	0.01
30.	Nimlay	7.2	1.98	10.8	6.4	2.71	0.05
31.	Banasa	7.6	0.93	3.6	2.8	2.9	0.01
32.	Kothda	7.3	1.14	6	3.6	2.01	0
33.	Borkhedi	7.7	0.84	3.6	2.8	2.05	0.01

S.No.	Name of village	Anions (me L <sup>-1</sup> )			
		CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>
1.	Hardi	0	2.0	3.6	2.4
2.	Bekalya	0	2.8	2.2	1.8
3.	Gaja Khedi	0	2.8	2.8	0.8
4.	Jinwani	0	2.2	2.6	1.6
5.	Kanta Phod	0	2.2	2.8	1.8
6.	Salamatpura	0	2.2	2.8	3.4
7.	Badgaon	0	2.6	2.8	4.0
8.	Ektera	0	2.6	2.4	2.2
9.	Surmanya	0	2.6	2.4	0.6
10.	Pura	0	2.4	1.8	1.6
11.	Sindharni	0	1.8	1.8	1.4
12.	Balya	0	3.8	2.0	1.2
13.	Satwas	0	3.4	2.0	0.8
14.	Palasi	0	3.8	2.2	2.8
15.	Kothada	0	2.8	1.8	1.2
16.	Dagra Kheda	0	2.2	1.8	4.2
17.	Pagri	0	2.8	2.2	3.2
18.	Kher Kheda	0	2.6	4.2	5.6
19.	Mansuriya	0	3.2	4.6	4.8
20.	Khapras	0	2.4	2.8	4.8
21.	Narayan Pura	0	3.2	2.8	3.8
22.	Gola Gudan	0	3.4	2.0	2.8
23.	Gada Gaon	0	0.8	0.4	1.2
24.	Nimasa	0	3.4	3.6	2.2
25.	Panpat	0	0.6	1.2	1.2
26.	Bhat Vardi	0	3.2	2.2	3.6
27.	Beda Khal	0	3.6	2.0	3.4
28.	Bhamar	0	3.2	2.2	4.4
29.	Dhasau	0	4.0	2.2	1.8
30.	Nimlay	0	6.8	7.2	5.8
31.	Banasa	0	3.6	3.2	2.6
32.	Kothda	0	3.6	2.6	5.2
33.	Borkhedi	0	2.2	2.2	4

❖ **Chemical concentration of soil saturation extract**

S. No.	Name of Village	Location	pHs	ECe dSm <sup>-1</sup>	Water soluble								SAR	Exchangeable				CEC	ESP
					Ca	Mg	Na	K	CO <sub>3</sub>	HCO <sub>3</sub>	Cl	SO <sub>4</sub>		Ca	Mg	Na	K		
					meL <sup>-1</sup>									c mol (p <sup>+</sup> ) kg <sup>-1</sup>					
<b>SATWAS</b>																			
1.	Hardi	22° 38' 09.8"N & 76° 49' 13.2"E	8.0	1.2	4.2	3	1.7	0.2	0	1.6	4.4	3.2	0.3	26.6	14.3	2.9	0.6	45.3	6.4
2.	Bekalya	22° 36' 20.9"N & 76° 35' 44.8"E	7.9	1.1	7.2	2.4	1.4	0	0	3.2	4.2	4	0.2	24.0	12.9	3.6	0.6	42	8.6
3.	Gaja Khedi	22° 35' 39.7"N & 76° 33' 46.4"E	7.8	1.4	6.2	2.2	2	0.1	0	1.2	3.6	5.2	0.4	23.6	12.7	5.1	0.5	43.1	11.8
4.	Jinwani	22° 35' 16.9"N & 76° 32' 04.5"E	7.6	0.7	0.4	0.2	1.4	0.1	0	1.4	6.6	3.2	0.9	23.7	12.8	3.7	0.5	41.6	8.9
5.	Kanta Phod	22° 34' 49.9"N & 76° 33' 13.9"E	7.7	2	4.8	1.2	1.3	0.1	0	1.2	4	2	0.3	22.8	12.3	4.1	0.6	41.7	9.8
6.	Salamatpura	22° 33' 37.8"N & 76° 34' 18.7"E	7.5	2.5	13.2	4.6	1.3	0.2	0	4.2	5.8	8.8	0.2	21.9	11.8	4.5	0.5	40.1	11.2
7.	Badgaon	22° 32' 16.5"N & 76° 34' 46.3"E	7.5	3.2	14.2	8	1.3	0.1	0	6.2	7.8	10	0.1	22.5	12.1	4.7	0.5	40.9	11.5
8.	Ektera	22° 30' 50.7"N & 76° 34' 41.3"E	8	0.7	20.2	8.4	0.6	0.2	0	12	8.8	9.8	0.1	24.0	12.9	4.6	0.6	42.7	10.8
9.	Surmanya	22° 26' 36.5"N & 76° 32' 02.5"E	7.3	0.7	4.8	1.6	0.7	0.1	0	2.6	2.4	2.2	0.1	22.9	12.3	3.8	0.2	40.2	9.5
10.	Pura	22° 30' 07.3"N & 76° 35' 22.7"E	7.9	1.2	7.6	2.8	1	0.3	0	4	4.2	3.8	0.2	23.0	12.4	6.1	0.6	42.1	14.5
11.	Sindharni	22° 27' 53.7"N & 76° 36' 33.1"E	7.6	1.2	5.8	4.2	1.1	0.6	0	3.8	4.4	3.6	0.2	22.0	11.9	6.9	0.4	41.2	14.7
12.	Balya	22° 30' 33.0"N & 76° 38' 32.6"E	7.5	2.4	18.2	7.2	1.1	0.4	0	6.4	7.8	9.8	0.1	24.6	13.2	4.1	0.5	43.2	9.5
13.	Satwas	22° 31' 39.7"N & 76° 40' 15.3"E	7.3	0.9	6.6	1.2	0.8	0.2	0	1.8	4.2	3.2	0.1	26.1	14.1	4.3	0.4	45.3	9.5
14.	Palasi	22° 34' 17.6"N & 76° 37' 37.7"E	7.4	0.9	4.2	3.8	0.8	0.1	0	2.2	4.2	2.6	0.1	25.0	13.5	4.1	0.5	43.6	9.4
15.	Kothada	22° 36' 57.6"N & 76° 42' 12.4"E	7.1	0.9	4.8	2.4	1	0.1	0	2.4	2.2	3.8	0.2	22.1	11.9	5.4	0.5	39.9	13.5
16.	Dagra Kheda	22° 37' 57.3"N & 76° 40' 53.9"E	7.4	3.3	16	12	3	0.8	0	9.8	10	11.8	0.3	22.6	12.2	4.4	0.6	41.5	10.6
17.	Pagri	22° 32' 03.3"N & 76° 43' 02.4"E	7.7	1.5	10.8	2	1.6	0.2	0	4.8	5.2	4.8	0.2	23.0	12.4	4.2	0.7	41.1	10.2
18.	Kher Kheda	22° 30' 56.1"N & 76° 46' 09.1"E	7.7	1.3	8.2	4	1.1	0.8	0	5.4	3.8	3.8	0.2	24.3	13.1	3.1	0.8	42.2	7.3
19.	Mansuriya	22° 29' 34.3"N & 76° 46' 06.4"E	7.3	1.2	1.2	0.8	2.8	2.1	0	4.2	3.8	4	1	24.0	12.9	3.4	0.7	41.6	8.2
20.	Khapras	22° 27' 30.2"N & 76° 45' 54.9"E	7.3	1.8	12.2	3.4	0.6	0.9	0	6.2	5.8	5.2	0.1	23.5	12.7	5.2	0.8	42.7	12.2
21.	Narayan Pura	22° 26' 35.5"N & 76° 45' 27.2"E	7.3	1.8	10.6	6	1.4	0.2	0	5.6	6.4	5.6	0.2	24.5	13.2	2.9	0.4	41.5	7.0
22.	Gola Gudan	22° 27' 33.1"N & 76° 42' 44.2"E	7.3	3.6	23.8	9.2	2.5	1	0	11.8	10.2	11.8	0.2	26.4	14.2	3.6	0.6	46.3	7.8
23.	Gada Gaon	22° 28' 08.7"N & 76° 41' 17.3"E	7.2	3.6	23.8	10	1.6	0.2	0	11.6	11.4	12.4	0.1	25.9	13.9	4.1	0.5	45.5	9.0
24.	Nimasa	22° 27' 56.2"N & 76° 40' 05.8"E	7.2	2.5	17.8	5.2	1.8	0.5	0	8	7.8	8.6	0.2	26.6	14.3	3.2	0.4	45.6	7.0
25.	Pan Pat	22° 26' 32.9"N & 76° 39' 38.5"E	7.4	1.1	7.2	1.8	1.9	0.5	0	3.2	4	4.2	0.3	26.7	14.4	3.1	0.5	45.8	6.8
26.	Bhat Vardi	22° 25' 04.3"N & 76° 40' 35.8"E	7.5	1.6	10.8	2.8	1.6	0.1	0	4.8	5.2	5.4	0.2	23.6	12.7	6.1	0.4	42.8	14.3
27.	Beda Khal	22° 23' 18.5"N & 76° 38' 08.9"E	7.7	1.3	7.2	4.4	0.6	0.3	0	3.8	4	4.6	0.1	24.1	13.0	2.8	0.6	41.1	6.8
28.	Bhamar	22° 21' 34.5"N & 76° 39' 37.4"E	7.7	0.8	5	1.2	1.6	0.1	0	2.6	3.2	1.8	0.3	28.5	15.4	2.3	0.8	47	4.9
29.	Dhasau	22° 22' 24.0"N & 76° 42' 15.6"E	7.7	0.8	4.2	2.8	0.8	0.1	0	3.2	2.4	2	0.1	26.0	14.0	3.6	0.7	44.3	8.1
30.	Nimlay	22° 20' 49.9"N & 76° 43' 36.3"E	7.5	0.8	2.8	2	2.6	0.6	0	2.8	3.2	1.8	0.6	24.5	13.2	3.4	0.6	41.7	8.2

S. No.	Name of Village	Location	pHs	ECe	Water soluble								SAR	Exchangeable				CEC	ESP
					Ca	Mg	Na	K	CO <sub>3</sub>	HCO <sub>3</sub>	Cl	SO <sub>4</sub>		Ca	Mg	Na	K		
					dSm <sup>-1</sup> meL <sup>-1</sup>									c mol (p <sup>+</sup> ) kg <sup>-1</sup>					
31.	Banasa	22° 22' 13.7"N & 76° 44' 39.1"E	8	2.1	14.2	6.4	1.1	0.1	0	8.2	7.2	6	0.1	23.8	12.8	6.4	0.7	43.7	14.6
32.	Kothda	22° 22' 19.0"N & 76° 44' 58.5"E	8	2.8	8.8	5.8	1.1	1.7	0	9.6	8.8	8.8	0.1	23.7	12.8	4.2	0.5	42.3	9.9
33.	Borkhedi	22° 30' 01.1"N & 76° 41' 53.0"E	7.7	2.2	12.2	6.4	2.2	0.1	0	6.8	6.6	7.8	0.2	23.8	12.8	3.2	0.8	40.6	7.9

## VITA

*The author of this manuscript, Miss. Pooja Rathore D/o Shri Rakesh Rathore was born on 15<sup>th</sup>, November 1995 at Hosangabad District of Madhya Pradesh. I passed High School Examination from Board of Secondary Education Madhya Pradesh with first Division (77.33% marks) in 2011 from Tagore Public Higher Secondary School Seoni malwa District Hosangabad and passed Higher Secondary School Examination from Tagore Public Higher Secondary School Seoni malwa District Hosangabad with First Division (72.6 marks).I successfully passed B.Sc. (Agriculture) in the year 2018 from College of Agriculture Indore, RVSKVV Gwalior, Madhya Pradesh with First Division 7.67 OGPA on 10.00 point scale. For the further study, I got admission in the College of Agriculture, Indore, for Master Degree in Soil Science & Agricultural Chemistry. I successfully completed the entire course requirement for the degree with First Division and securing an approximate 7.03 OGPA on 10.00 point scale. For the partial fulfilment of Master's Degree, I was assigned a research problem entitled "**Assessment of Soil Properties and Ground Water Quality in Satwas Tehsil of Dewas District, Madhya Pradesh**" which is being submitted in the form of thesis.*

**(Pooja Rathore)**