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Appraisal of Soil Physical Properties and Preparation of Soil Variability Maps of Agricultural Research Station, Ummedganj-Kota

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aim: The soils of various fields of Agricultural Research Station, Ummedganj-Kota were collected and analyzed for the physical properties *viz.* soil colour, texture, bulk density, particle density, porosity and water holding capacity. The soil maps were prepared with the help of GIS software using geo-statistical analysis

Study Design: Soil sampling, soil analysis and soil mapping.

Place and Duration of Study: Agricultural Research Station, Ummedganj-Kota in 2019 and 2020

Methodology: Total 300 Geo-referenced surface (0-15 cm) soil samples collected. The bulk density of the soils ranged from 1.25 to 1.57 Mg m^{-3} (mean value 1.43 Mg m^{-3}), particle density ranged from 2.57 to 2.71 Mg m^{-3} (mean value 2.68 Mg m^{-3}) and the porosity of the soils ranged from 41.42 to 51.92% (mean value of 46.42%). Water holding capacity of the soils ranged from 35.11-52.46% (mean value of 44.31%). Soil colour of the different field soils were brown, dark brown, dark gray, very dark gray, and black.

Results: According to soil analysis data and soil variability maps field no. 14 was best in physical properties like bulk density (1.37 Mg m^{-3}), particle density (2.62Mg m^{-3}) and water holding capacity (49.02%) as compared to other fields of ARS, Ummedganj, Kota.

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Conclusion: Field no. 14 was best in physical properties like BD, PD, Porosity and WHC as compared to other fields because organic farming practices leads to increase soil organic matter which have positive relation with physical property of the soil.

Keywords: Physical properties; soil colour; texture; bulk density; particle density; porosity and water holding capacity.

1. INTRODUCTION

Soil is a component of the *lithosphere* and *biosphere* system, which is the source of infinite life, precious natural resource and non-renewable in short span of time. Soil is a three dimensional body with length, breadth and depth below the land surface [1]. Soils are considered as the integral part of the landscape and their characteristics are largely governed by the landforms in which they are developed [2]. It is the most important basic natural resource that determines the ultimate sustainability of any agricultural system. The soils of Rajasthan belong to five soil orders viz. Aridisol, Entisol, Alfisol, Inceptisol and Vertisol. According to soil survey manual, soil survey describes the characteristics of the soils in a given area, classifies the soils according to a standard system of classification, plots the boundaries of the soils on a map, and makes predictions about the behaviour of soils [3]. The different uses of the soils and how the response of management affects them are considered. The information collected in a soil survey helps in the improvement of land-use plans, evaluating and predicting the effects of land use on the environment.

Kota district comes under Agro Climatic Zone V, i.e. 'Humid South Eastern Plain'. Total area of the zone is 2.70 million hectares in south-eastern part of the Rajasthan, covers Sawai Madhopur, Karauli, Jhalawar, Baran, Kota and Bundi districts. The zone receives around 700 to 1000 mm rainfall per year which is the highest among all agro climatic zones of the state. The landscape is characterized by hills pediments and vast alluvial plain formed by the rivers Chambal, Parbati, Parwan, Kalisindh and their tributaries. Earlier no systematic study on the soil physical properties of ARS Kota was carried out. Therefore, the present research work was initiated to assess the soil physical properties of Agricultural Research Station Ummedganj, Kota. Geographic information system (GIS) is a powerful tool which helps to integrate many types of spatial information such as agro-climatic zone, land use, soil management, etc. to derive useful information [4].

2. MATERIAL AND METHODS

Agricultural Research Station, Ummedganj, Kota is situated in Agro-climatic zone V "Humid South Eastern Plain" which is situated in south eastern part of Rajasthan. According to Agro-ecological region map brought out by National Bureau of Soil Survey and Land Use Planning (NBSS & LUP, Nagpur), Kota falls in Agro-ecological region No 06. ARS, Ummedganj, Kota is located at the $75^{0}25'$ N latitude $25^{0}13'$ E longitude and an altitude of 258 m above mean sea level. Research farm have covers 107 ha, out of which 98 ha is under cultivation. The rest of the land is under roads, irrigation channels, bunds, buildings, tube wells and uncultivated waste. Major soils of the ARS farm were black cotton which comes in Vertisols soil order with clay loam texture having adequate drainage facility. Total 300 Geo-referenced surface (0-15 cm) soil samples, representing the different fields were collected following zigzag manner from 18 fields plus one waterlogged area. The latitude and longitude of sampling sites were recorded with the help of Global Positioning System (GPS). Soil variability maps for various soil properties were produced using the latitude and longitude,

Table 1. Methods for analysis of soil physical properties

S. No.	Soil Parameter	Method	Reference
1.	Soil Colour	Munsell soil colour chart	Munsell [5]
2.	Texture	Hydrometer method	Bouyoucos [6]
3.	Bulk density (Mg m^{-3})	Core sampler method	Richards [7]
4.	Particle density (Mg $m^{-3)}$	Pycnometer / RD Bottle method	Richards [7]
5.	Water Holding capacity (%)	Keen Box Method	Keen and Reczkowaski [8]

the point shape files showing the location of the observation were generated by using Arc GIS 10.5. The other parameters like range, mean, standard deviation and coefficient of variation were calculated by classical statistical approaches. The soils of different fields were processed and analyzed for different physical properties as described in Table 1.

3. RESULTS AND DISCUSSION

Total 300 soil samples were analyzed for the physical properties like soil colour, texture, bulk density, particle density, porosity and water holding capacity of the ARS fields, Kota. The analytical results and their discussion are presented as under.

3.1 Soil Texture (Mechanical Analysis)

The composition of soil separates governs the physical characteristics of the soils. Mechanical analysis provides the percentage of sand, silt and clay fraction in soil and classify their textural class. The data revealed that the sand content in soils ranged from 20.30-27.30%, with mean value of 23.46% having standard deviation 2.13 and CV 9.03%. The silt particles ranged from 32.60-38.20% with a mean value 35.96% having standard deviation 1.61 and CV 4.47% whereas; clay particles ranged from 35.91-45.88% with a mean value 40.57% having standard deviation 2.79 and CV 6.89% (Table 2). Among these three soil particles clay and sand content showed highest variability and minimum in case of silt. On the basis of soil texture analysis, it found that most of the soils of ARS, Ummedganj farm were clay loam to clayey in taxture.

It is evident from the spatial distribution Map 1, that in case of sand content, the highest area falls under the category I (20.30-21.71%), followed by category III (23.11-24.50%), category IV (24.51-25.90 %), category V (25.91-27.30%) and lowest area falls under the category II (21.71-23.10%). For silt content, the spatial distribution Map 2 showed that, the highest area falls under the category V (37.09-38.20%), followed by category IV (35.97-37.08%), category III (34.85-35.96%), category II (33.73-34.84%) and lowest area falls under the category IV (32.60-33.72%). In case of clay content, the spatial distribution Map 3 showed that, the highest area falls under the category II (37.91-39.90%), followed by category IV (41.90-43.89%), category V (43.90-45.88%), category I (35.91-37.90%) and lowest area falls under the category III (39.91-41.89%). Overall clay content was maximum in amount among three soil separates, which was a basic feature of black cotton soils. Generally sand content was low compared to silt and clay in all the sites. These soils were known to produce high clay content due to basaltic parent materials. The variation in soil texture might be due to the variation in topographic position, nature of parent material, in situ weathering of clay and age of the soils [9]. Similar finding for soil textural class were also observed MP by Rajendiran et al., [10] in soils of Alirajpur and Barik et al., [11] in the soils of Puri district, Odisha. According to the USDA textural triangle the soils of the study areas were clay loam to clayey in texture. Similar particle size distribution and textural classes were reported by Anitha et al., [12] in black soils of Gurjala mandal of Guntur district, Andhra Pradesh.

3.2 Water Holding Capacity

Water holding capacity (WHC) is the ability of certain soils to physically hold water against the force of gravity. This is happens when soil particles holding water molecules strongly by the force of cohesion. WHC of the soils at Agricultural Research Station, Ummedganj, Kota ranges from 35.11-52.46% with a mean value of 44.31%. It is evident from the spatial distribution Map 4, that maximum area falls under the category III (42.06-45.52%) followed by category IV (45.53-48.99%), category II (38.59-42.05%), category V (49.00-52.46%) and minimum area under category I (35.11-38.58%). Soil texture plays an important role and directly influenced the WHC of the soil. As the proportion of clay increases in the soil, the WHC increases due to clay can bind or hold the water molecules more effectively. Certain types of soil organic matter can hold up 20 times their weight in water [13]. On the basis of investigation, the field number 14 have highest WHC (49.02%) compared to other fields because organic farming practices applied in Field number 14 from some years through addition of organic matter increases the number of micropores and macropores in the soil by gluing soil particles together. The results are in close agreement with the findings of Nath [14] in the soil of Sivasagar, Assam and Ravikumar and Somashekar [15] in the soils of Varahi River basin in the Udupi district of Western Karnataka.

3.3 Bulk Density

Knowledge of soil bulk density (BD) is essential for better understanding the physical behaviour of soil and their management.

Table 2. Particle size distribution and WHC in soils of ARS, Ummedganj Kota

Soil Separate	Sand (%)	Silt (%)	Clay (%)	WHC (%)
Range	20.30-27.30	32.60-38.20	35.91-45.88	35.11-52.46
Mean	23.46	35.96	40.57	44.31
S.D.	2.13	1.61	2.79	3.04
CV %	9.03	4.47	6.89	6.85

Bulk density is defined as the mass of solids per unit volume of the soil [16]. High BD indicates compactness of the soil means higher the BD the compaction will be more in soil. The BD of the soils of Agricultural Research Station Ummedganj, Kota ranged from 1.25 to 1.57 Mg m^{-3} with a mean value of 1.43 Mg m^{-3}, standard deviation 0.04 and coefficient of variation 3.00% (Table 3). It is evident from the spatial distribution Map 5, that maximum area for bulk density falls under the category III (1.379-1.442 Mg m^{-3}) followed by category IV (1.443-1.506 Mg m^{-3}); category V (1.507-1.570 Mg m^{-3}) category I (1.250-1.314 Mg m^{-3}) and minimum area under category II (1.315-1.378 Mg m^{-3}). BD influenced by the amount of organic matter, texture, mineral matter, depth and porosity of the soil. The soils have high BD when dry and low values when in a swollen stage due to moisture variations [17]. On the basis of present investigation field number 14 showed lowest BD values (mean value 1.37 M gm^{-1}) compared to other fields and the possible explanation of this, because of organic farming practices performed in field number 14 from the year 2016. BD varies inversely with respect to soil organic matter content i.e., higher the organic matter content lower will be the bulk density [18]. It is denote that soils have more organic matter become more friable, porous and chemically active if rich in organic matter which tend to make soil lower in bulk density. Similar findings recorded by, Chaudhari et al. [19] in the soils of Coimbatore, Ahad et al. [20] in the soil of Kupwara, Kashmir and Singh et al. [21] in the soils of Chambal Regions of Madhya Pradesh.

3.4 Particle Density

The particle density is the true density of soil and it depends upon the accumulative densities of the individual inorganic (mineral matter) and organic constituents of the soil. Particle density is higher if large amounts of heavy minerals present in the soil. The presence of organic matter lowers the particle density. The particle density of the soils of Agricultural Research Station Ummedganj, Kota ranged from 2.57 to 2.71 Mg m^{-3} with a mean value of 2.68 Mg m^{-3} (Table 3). It is evident from the spatial distribution Map 6, that maximum area falls under the category IV (2.655-2.682 Mg m^{-3}) followed by category V (2.683-2.710 Mg m^{-3}); category III (2.627-2.654 Mg m^{-3}) category II (2.599-2.626 Mg m^{-3}) and minimum area under category I (2.570-2.598 Mg m^{-3}). It is depending on the accumulative densities of the individual inorganic and organic constituents of the soil. The variation in composition of soil solids, such as an increase or decrease in soil mineral or organic matter significantly changed the PD of the soils. The results are in close agreement with the findings of Chaudhari et al. [19] in the soils of Coimbatore and Gupta et al. [22] in the soil of Sivaliks. On the basis of soil analysis data, the field number 14 have lowest particle density values (2.62 Mg m^{-3}) compared to other fields because of organic farming practices performed in field number 14 from the year 2016.

3.5 Porosity

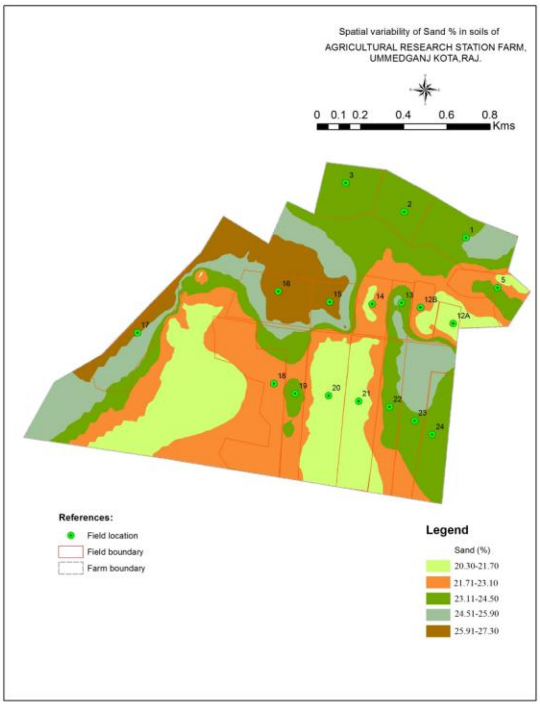
Total porosity can be calculated by using bulk density and particle density of soil [23]. It can be easily changed or modified with the tillage operations as well as addition of mineral or organic matter. The porosity in the soils of Agricultural Research Station Ummedganj, Kota ranged from 41.42 to 51.92% with a mean value of 46.52%. It is evident from the spatial distribution Map 7, that maximum area falls under the category III (45.63-47.72%) followed by category IV (47.73-49.82%), category II (43.53-45.62%), category I (41.42-43.52%) and minimum area under category V (49.83-51.92%). Porosity of the soil increases with increment in the percentage of organic matter content in the soils because of well aggregate formation. Porosity depends upon the texture, structure, compactness and organic matter content of the soil. The result is in close agreement with finding of Naresh et al., [24] in the sandy loam soils of subtropical climatic conditions of Western U.P. India and Ahad et al., [20] in the soil of Kupwara Kashmir.

Table 3. Status of bulk density, particle density and porosity in the soils of Agricultural Research Station, Ummedganj, Kota

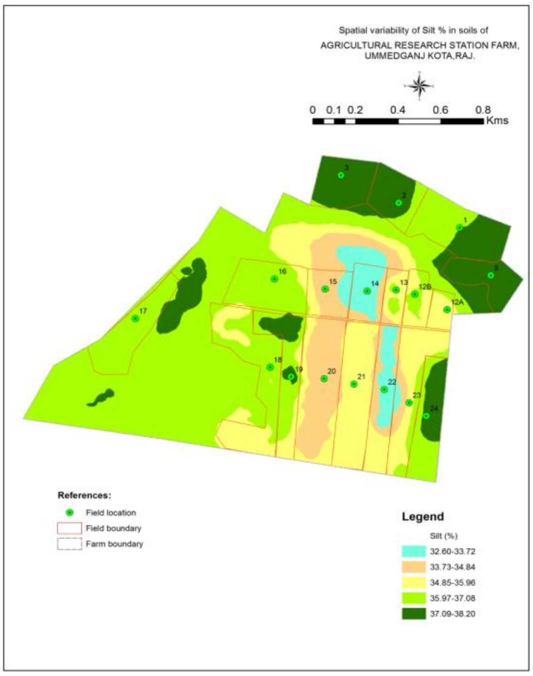
General statistics	BD (Mg m^{-3})	PD (Mg m^{-3})	Porosity (%)
Range	1.25-1.57	2.57-2.71	41.42-51.92
Mean	1.43	2.68	46.52
Standard deviation	0.04	0.02	1.52
CV%	3.00	0.67	3.27

Table 4.Soil colour of different fields at Agricultural Research Station Ummedganj, Kota

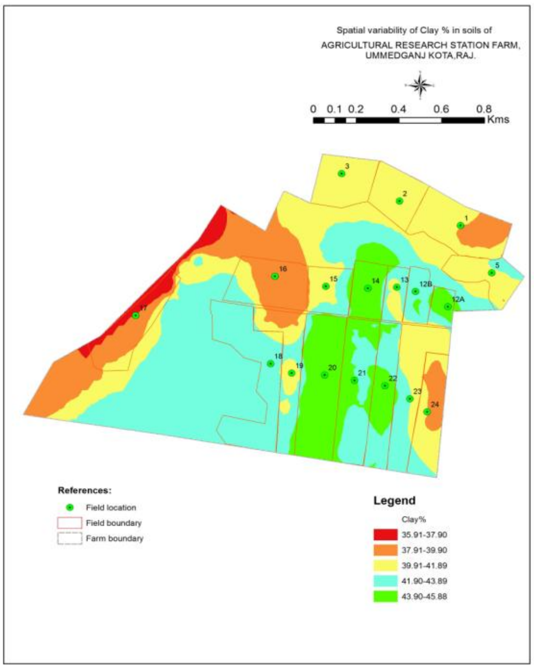
S. No.	Field No.	Colour notation	Colour
1	1	7.5YR 4/1	Dark gray
2	2	7.5YR 3/2	Dark Brown
3	3	7.5YR 4/2	Brown
4	5	7.5YR 4/3	Brown
5	12A	7.5YR 4/1	Dark gray
6	12B	7.5YR 3/1	Very dark gray
7	13	7.5YR 4/1	Dark gray
8	14	7.5YR 2.5/1	Black
9	15	7.5YR 3/1	Very dark gray
10	16	7.5YR 3/1	Very dark gray
11	17	7.5YR 4/1	Dark gray
12	18	7.5YR 4/1	Dark gray
13	19	7.5YR 2.5 / 1	Black
14	20	7.5YR 3/1	Very dark gray
15	21	7.5 YR 2.5/1	Black
16	22	7.5 YR 3/1	Very dark gray
17	23	7.5 YR 4/1	Dark gray
18	24	7.5 YR 3/1	Very dark gray
19	25	7.5 YR 3/1	Very dark gray



Map 1. Distribution of sand (%) in the soils of ARS Ummedganj, Kota



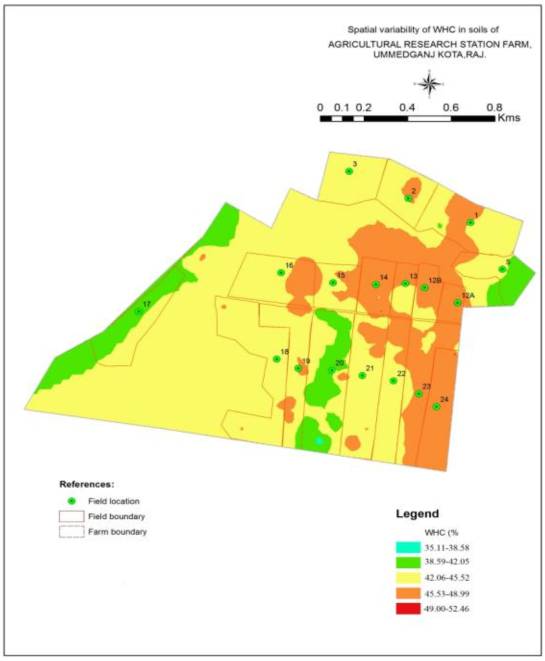
Map 2. Distribution of silt (%) in the soils of ARS Ummedganj, Kota



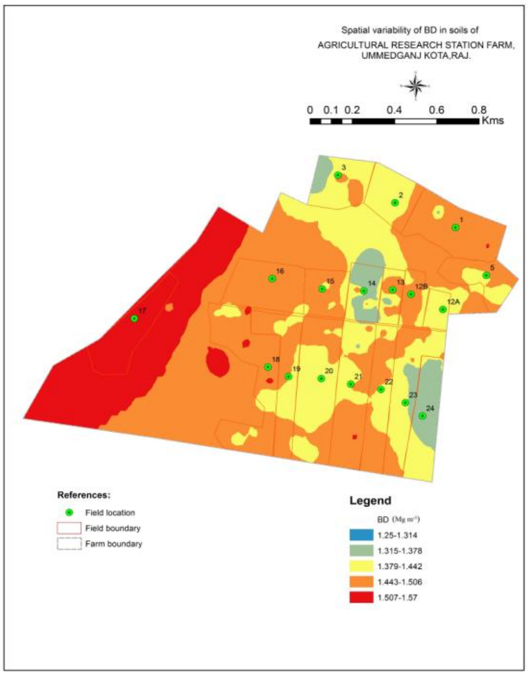
Map 3. Distribution of clay (%) in the soils of ARS Ummedganj, Kota

3.6 Soil Colour

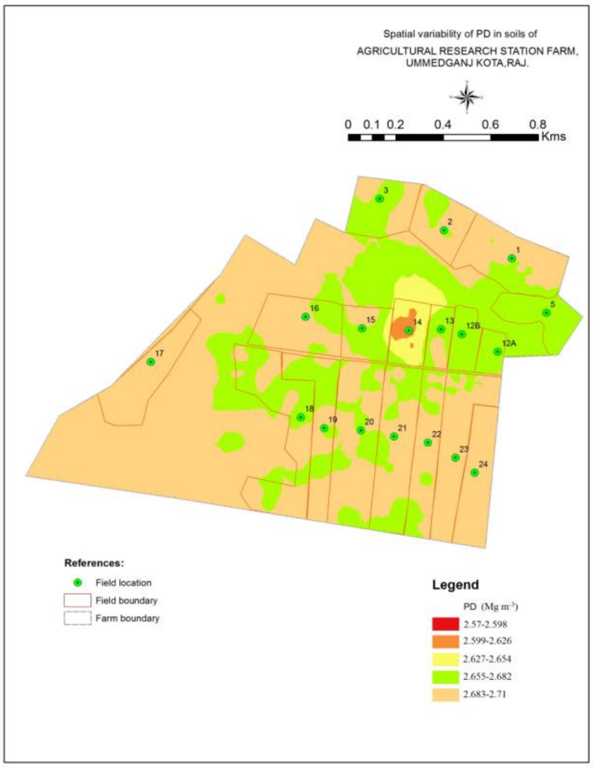
Soil colour provides important information regarding soil conditions and some another property of soils. For example, dark coloured soils absorb more solar radiation than the light coloured soils that causes dark soils warm up faster. On the basis of soil colour assessment, the soils of ARS, Ummedganj, Kota farm were brown, dark brown, dark gray, very dark gray and black in colour, among which highest area falls under very dark gray soil colour . The possible reason behind this may be due to presence of *titaniferus magnetite* ($Fe^{+2}(Fe^{+3}Ti)_2O_4$) mineral present in such type of Vertisols (Black cotton soil). The results are in conformity with the findings of Singh et al. [21] in the soils of Chambal region of Madhya Pradesh, Priyadarshini et al. [25] in soils of North-Eastern Coastal Plain Agroclimatic Zone of Odisha, and Barik et al. [11] in the soils of Puri district, Odisha.



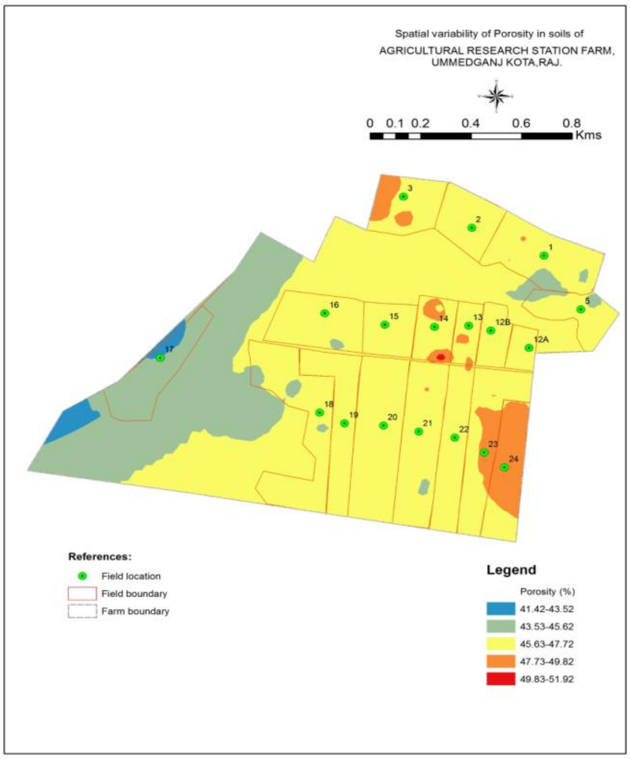
Map 4. Distribution of WHC (%) in the soils of ARS Ummedganj, Kota



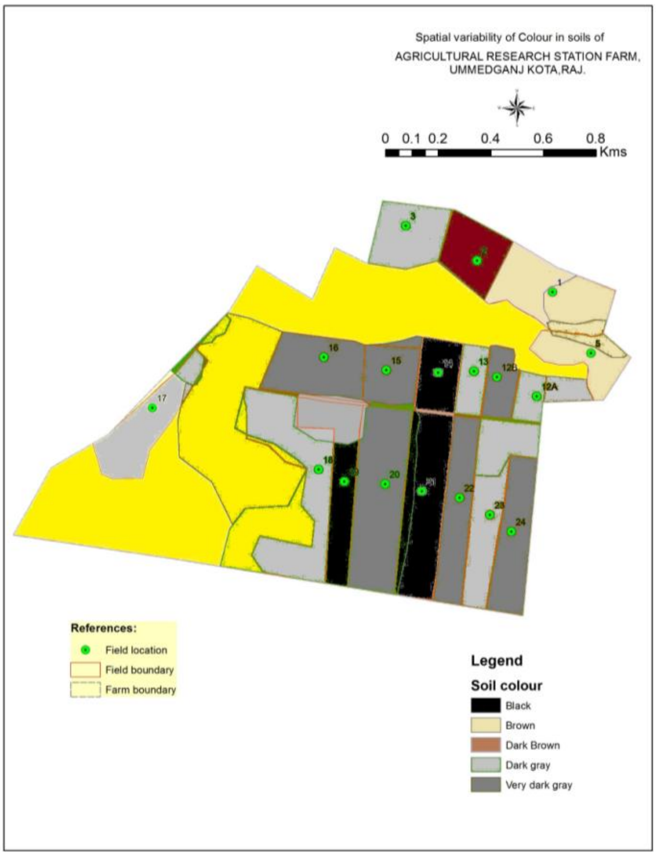
Map 5. Distribution of BD ($Mg\ m^{-3}$) in the soils of ARS Ummedganj, Kota



Map 6. Distribution of PD (Mg m^{-3}) in the soils of ARS Ummedganj, Kota



Map 7. Distribution of Porosity (%) in the soils of ARS Ummedganj, Kota



Map 8. Distribution of colour in the soils of ARS Ummedganj, Kota

4. CONCLUSION

It can be concluded from the above results that the soils of Agricultural Research Station, Ummedganj-Kota were characterized as clay loam to clayey in texture. The bulk density ranged from 1.25 to 1.57 Mg m^{-3} with a mean value of 1.43 Mg m^{-3}, particle density of the soils ranged from 2.57 to 2.71 Mg m^{-3} with mean value of 2.68 Mg m^{-3} and the porosity of the soils ranged from 41.42 to 51.92% with mean value of 46.42%. Water holding capacity of the soils ranged from 35.11-52.46% with mean value of 44.31% and soil colour varied from brown, dark brown, dark gray, very dark gray and black. According to soil analysis data and soil variability maps field no. 14 was best in physical properties like BD, PD (1.37 and 2.62Mg m^{-3}) and WHC (49.02%) as compare to other fields of ARS, Ummedganj, Kota. Organic matter increases with batter physical property of the soil. Clay content and organic matter increases with increases water holding capacity, porosity and decrease BD, PD of the soil. For environment balance,sustainable productivity and soil health we need to focuses on organic farming.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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