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Assessment of Soil Fertility Status under the Barren Land Soil of the Central Plain Zone of Uttar Pradesh, India

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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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ABSTRACT

Soil fertility evaluation of barren land is the most basic decision-making tool for an effective sustainable plan for a particular area. Thus, the present study was carried out to evaluate the soil fertility status in session variation of the two blocks of Kanpur Dehat (Akabrpur and Maitha). The

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soil samples were randomly collected based on the variability of land at a depth of 0-15 cm, 15-30 cm, and 30-60 cm in 5-5 sites in the both blocks. A GPS device was used to identify the location of the soil sampling points. Soil samples were analyzed for texture, pH, OC, EC, N, P, K, S, Fe, Zn, Cu, Mn, and exchangeable cations status following standard analytic methods in the laboratory of Soil Science and Agricultural Chemistry, C.S.A. University of Agriculture and Technology, Kanpur, UP. The soil organic carbon ranged from 0.18 to 0.34% of both blocks. Available nitrogen ranged from 102.78 to 138.39 kg ha^{-1}, available phosphorous ranged from 9.89 to 16.47 kg ha^{-1} and available potassium ranged from 230.65 to 276.38 kg ha-1 in the surface soil of Maitha, all of which showed a decrease in value with increase in depth. Exchangeable calcium ranged from 4.58 to 6.34 (cmol (p+) kg^{-1}), exchangeable magnesium ranged from 2.20 to 4.40 (cmol (p+) kg^{-1}), and the pH of the soil in both blocks was highly alkaline in nature, all of which varied significantly with site and depth. The results indicated that soils are not good for the cultivation of various crops. Farmers are required to maintain Soil Health Card which helps them to adopt suitable management practices and provide proper nutrition to soil.

Keywords: Barren land; macronutrients; micronutrients; GPS; organic carbon; suitability.

1. INTRODUCTION

The barren land of the central plain in Uttar Pradesh, India, presents a significant challenge to Agricultural productivity and land restoration efforts [1]. These barren lands are characterized by depleted organic carbon content and poor soil aggregate stability, which severely limit the establishment of vegetation and the overall health of the ecosystem [2]. Understanding the relationship between organic carbon and soil aggregate stability is crucial for devising effective strategies to restore and improve the fertility of these lands [3]. Organic carbon plays a fundamental role in soil health and functioning. It is a vital component of soil organic matter, which influences numerous physical, chemical, and biological properties of the soil [4]. Organic carbon content directly affects soil fertility, nutrient availability, water-holding capacity, and microbial activity, all of which are critical for plant growth and ecosystem sustainability [5]. Moreover, organic carbon is intimately linked to soil aggregate stability, a key indicator of soil structure and resistance to erosion [6].

"Soil testing is often used to determine the available nutrient status and nutrient-supplying power of soil which helps in developing cost-effective nutrient management practices that serve as a basis for amendments and sound fertilizer recommendations, which in turn leads to sustainable long-term agriculture production by way of adoption of good agronomic management practices by farmers in the study area (Subbaiah, *et al.,* 2022). Macronutrients (N, P, K, S) and micronutrients (Zn, Fe, Cu, Mn, and B) are very important soil elements that determine crop yields in general and physicochemical properties like pH, EC, Organic Carbon in particular under normal environmental conditions" [7]. "Soil fertility is one of the important factors controlling crop yields and soil characterization about to with concerning the evaluation of soil fertility of an area or a region is an important aspect in the text of sustainable production" [8]. "In the present context, maintaining soil fertility is a key problem in Indian agriculture, especially under the country's rapidly growing population in recent decades. Erratic rainfall, minimal recycling of farm residues including livestock waste, no adoption of soil and water conservation measures, continuous cultivation of exhaustive crops, and imbalanced fertilizer application are some of the major causes of soil degradation in India".

The central plain of Uttar Pradesh, known for its fertile soils and agricultural productivity in some areas, also harbors extensive stretches of barren land. These areas often suffer from a combination of factors, including overgrazing, deforestation, unsustainable land management practices, and improper irrigation, leading to severe land degradation [9]. Restoring these barren lands requires a comprehensive understanding of the role of organic carbon in soil aggregate stability and the underlying processes involved [10]. This study aims to investigate the relationship between organic carbon and soil aggregate stability in the barren land of the central plain of Uttar Pradesh. By examining the spatial distribution of organic carbon content and soil aggregate stability, we can identify the area most susceptible to degradation and prioritize restoration efforts. Additionally, we will explore the factors influencing organic carbon accumulation and its impact on soil aggregate stability, such as land use history, soil management practices, and vegetation cover [11]. The findings from this study will contribute to the development of targeted and sustainable strategies for rehabilitating the barren lands of the central plain of Uttar Pradesh. By enhancing organic carbon content and improving soil aggregate stability, we can promote the establishment of vegetation, increase agricultural productivity, and mitigate the environmental challenges associated with land degradation [12]. Ultimately, this research aims to support the sustainable development and resilience of the region's agricultural systems and ecosystems.

2. MATERIALS AND METHODS

2.1 Study Sites

The Kanpur Dehat district lies in the center of Uttar Pradesh. It lies between 26° 31’ to 350 75.94’ N latitude and 790 49’ to 840 46.9’’ E longitude with a total geographical area of 3021 sq. km having an elevation of about 126 m above the mean sea level. The entire study area was carried out in 10 villages namely Rura, Muridpur, Mandauli, Gutaiya, Barra, Kashipur, Tikari, Shobhan, Rampur Shiwali, and Hathika, falling under two blocks namely Akbarpur and Maitha with five –five different sites taken from villages. The selection of the village was based on its Barren land soil type with the help of GPS, there was no found the vegetation, farming situation, and crops grown. The climate in Kanpur is warm and temperate. When compared with winter, the summers have much more rainfall. The climate is classified as Cwa according to Köppen and Geiger [13]. The average annual temperature is 25.3 °C in Kanpur. The annual rainfall is 939 mm/37.0 inches. The given location is in the northern hemisphere. The particular spot is situated in the upper half of the planet. Summer starts here at the end of June and ends in September. There are the months of summer: June, July, August, and September.

2.2 Sample Collection and Laboratory Analysis

The soil samples were collected at different depths of 0- 15 cm, 15-30 cm, and 30-45 cm respectively at the site. The collected soil samples were air-dried, ground with a wooden pestle and mortar, and sieved through a 2-mm sieve (0.2 mm sieve for organic carbon), labelled, and stored at the Soil Laboratory of the Department of Soil Science and Agriculture Chemistry, C.S. Azad University of Agriculture and Technology, Kanpur-208002, UP, India following standard laboratory procedures.

The soil samples were analyzed for soil pH and electrical conductivity (EC) was recorded in 1:2.5 soil to water suspension (Jackson, 1973), the organic carbon (OC) determined by Walkley and Black 1934 method, Exchangeable bases were collected using neutral normal ammonium acetate and the exchanged ion measured following the procedure outlined in Hesse (1970). The Ca^{++} and Mg^{++} were determined by complex metric titration, involving ethylene diamine tetra acetic acid (EDTA) and Na^{+} was determined. The macronutrients like available nitrogen and phosphorus were by alkaline potassium permanganate method (Subbiah and Asija, 1956; Sharawat and Burford, 1982) and Spectrophotometer fallow by the method (Olsen, *et al.,* 1954), respectively. Available potassium was determined by a flame photometer with neutral normal ammonium acetate as an extractant (Hanway and Heidel, 1952). The available Sulphur content of the soil samples was determined by the turbidimetric method (Black, 1965). Micronutrients viz., available zinc (DTPA extractable) was determined by using Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978).

2.3 Data Analysis

Data were subjected to descriptive statistics such as minimum, maximum, mean, and standard deviation using the SPSS, Ver. 2023.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Properties of Soil in Akbarpur and Maitha Block

Table 1 provides the physicochemical properties of soil (from 0 to 60 cm) in the barren land of Akbarpur and Maitha block. The measurements are categorized into different depth ranges (0-15 cm, 15-30 cm, and 30-60 cm). The properties measured include pH, electrical conductivity (EC), organic carbon (OC), calcium (Ca), magnesium (Mg), and sodium (Na) content. The table also includes statistics such as the minimum, maximum, mean, standard deviation (SD), and coefficient of variation (CV) for each property and depth range.

Table 1. Phyisico-chemical properties of soil (from 0 to 60 cm) in barren land of Akbarpur and Maitha Block

	Akbarpur							Maitha					
	Depth	**pH**	**EC (dS/m)**	**OC%**	**Cation (c mol (p+) kg^{-1})**			**pH**	**EC(dS/m)**	**OC%**	**Cation (c mol (p+) kg^{-1})**		
					Ca	**Mg**	**Na**				**Ca**	**Mg**	**Na**
Min.	0-15	8.52	2.54	0.18	4.58	2.20	8.66	8.74	2.54	0.25	3.86	3.68	7.88
	15-30	8.99	2.44	0.16	5.33	2.05	9.14	9.44	2.44	0.22	5.12	4.56	8.33
	30-60	10.25	3.45	0.10	5.48	1.80	10.24	9.42	3.45	0.19	4.88	5.78	9.12
Max.	0-15	8.90	4.48	0.26	6.34	4.40	10.24	9.62	4.48	0.34	5.64	6.12	11.21
	15-30	9.42	4.56	0.25	6.90	4.21	10.86	10.12	4.56	0.32	6.45	6.42	11.56
	30-60	10.45	4.68	0.21	7.55	3.55	12.68	10.24	4.68	0.31	7.46	7.35	11.24
Mean	0-15	8.67	3.65	0.23	5.36	3.06	9.67	9.16	3.65	0.29	4.90	4.99	9.88
	15-30	9.22	3.71	0.21	6.00	2.90	10.26	9.78	3.71	0.26	5.77	5.40	10.33
	30-60	10.34	4.36	0.16	6.63	2.48	11.09	9.81	4.36	0.24	6.41	6.47	10.31
SD	0-15	0.16	0.75	0.03	0.76	0.91	0.64	0.38	0.75	0.04	0.68	0.88	1.23
	15-30	0.17	0.82	0.03	0.66	0.91	0.67	0.25	0.82	0.04	0.56	0.71	1.28
	30-60	0.09	0.52	0.05	0.82	0.79	1.02	0.34	0.52	0.04	1.20	0.66	0.76
CV (%)	0-15	0.02	0.20	0.13	0.14	0.30	0.07	0.04	0.20	0.13	0.14	0.18	0.12
	15-30	0.02	0.22	0.16	0.11	0.31	0.07	0.03	0.22	0.15	0.10	0.13	0.12
	30-60	0.01	0.12	0.29	0.12	0.32	0.09	0.04	0.12	0.18	0.19	0.10	0.07

3.1.1 Akbarpur block

Soil pH is a measure of the acidity or alkalinity of the soil. It plays an important role in the availability of nutrients essential for plant growth. The pH value of the barren land is highly alkaline of Akbarpur block. The values of pH ranged from 8.52 to 8.90 with a mean value of 8.67 with an SD value of 0.16 and a CV value of 0.02 % at the surface of the soil and all sites of soil sample decreasing to increasing level surface to the subsurface of sites. Soil electrical conductivity is a measure of the salinity of the soil. It could be an indicator of nutrient availability in the soil (Sahu *et al.,* 2016). The low status of EC may be due to the leaching of salts to lower horizons as suggested by Singh and Mishra (2012). The sample had very low soil organic carbon content on both blocks of sites. The values were 0.18 to 0.26 % in the surface soils and decreased to 0 .10 to 0.21% at 30-60 cm depth. The low OC content of these soils may be attributed to the occasional addition of organic materials, lack of natural vegetation, poor decomposition due to low rainfall, oxidation due to high summer temperature, and wind erosion. A similar result was also reported by Prasad, et al., [14]. Exchangeable calcium and magnesium were extracted using neutral normal ammonium acetate and measured by EDTA titration. The exchangeable Ca content in the Akbarpur block varied between 4.58 to 6.34 Cmol (P^+) kg^{-1}, whereas, the Mg content varied between 2.20 to 4.40 C mol (P^+) kg^{-1} on the surface of soil (0-15 cm). There was enough calcium and magnesium content in the soil to support plant growth. But Exchangeable sodium was a high quantity so harmful to plant growth.

3.1.2 Maitha

Physio-chemical properties of soil are given the data in the Table 1. The pH value of the Maitha block is highly alkaline. The pH ranges between 8.74 to 9.62 and the mean value of pH is 9.46. The pH of 100 % soil samples was found more than 8.5 pH. The high degree of sodium saturation on hydrolysis gives OH^- ion and high carbonate and bicarbonate. Similar results were also reported by Singh et al. (2010). Whereas the EC value of the soils was in the neutral range i.e. 2.54 to 4.48 dS/m and the average value of EC was 3.65 dS/m and the CV value is 0.20%. The EC of 100% soil sample under the ratting of electrical conductivity. These values are fairly comparable to the result reported by Singh et al. (2010). The organic carbon content of the soils was very low due to a deficit of vegetation. It ranged between 0.25 to 0.34%. The average, SD and CV, value of OC was 0.29, 0.04 and 0.13% respectively. The OC of the 100 percent sample was found lower than 0.50% of OC. The low OC content of these soils may be attributed to the occasional addition of organic materials, lack of natural vegetation, poor decomposition due to low rainfall, oxidation due to high summer temperature, and wind erosion [15]. A similar result was also reported by Prasad [14]. "Available Ca (cmol(p^+) kg^{-1}) and Mg (cmol(p^+) kg^{-1}) were medium to high in all sites of different Barren land, ranging from 3.86 to 5.64 and 3.68 to 6.12 in surface soils and from 4.88 to 7.46 and 5.78 to 7.35 in subsurface soils(30-60 cm), respectively. The mean available Ca and Mg (cmol (p+) kg^{-1}) in surface soils were 4.90 and 4.99 in the barren land, 4.1 and 1.7, respectively. With depth, there was an increase in content under different sites of the Maitha block" [16].

3.2 Nutrient Status in the Soil of Akbarpur Blocks and Maitha Block

3.2.1 Akbarpur

"Akbarpur block of soil nutrient data shows Table 2. Nitrogen content in soil samples ranged from 105.25 to 140.86 kg ha^{-1} with a mean and CV value of 120.45 kg ha^{-1} and 0.12% recorded in the Akbarpur block. The lowest nitrogen content was observed in the subsurface (30-60 cm) of soil while the highest nitrogen content was in the surface of the soil but this nitrogen content compared to the soil fertility index was overall very less amount content. The nitrogen content of the study region is low probably due to the low organic carbon content present in the soil" [17]. "The available phosphorus content of the soil samples ranged from 12.36 to 18.94 kg ha^{-1} with an average, SD and CV value of 16.00 kg ha^{-1}, 2.45 and 0.15%, respectively. The lowest value of phosphorus content was observed in the subsurface soil, whereas the highest value was in the surface of soil. About 50% of phosphorus is found in organic form the decomposition of the organic matter produces humus which forms complexes with Al and Fe and protects the P fixation" [18]. "The available potassium content of the soil ranged from 233.12 to 278.85 kg ha^{-1} with a mean value of 256 kg ha^{-1} on the surface of the soil. In the study region potassium content is which high, may be due to elite, rich potassium minerals found in the soil" [16] The data on micronutrients were recorded in which the nutrient index value indicates the Zn, Mn, Cu, and B were deficient while the Fe content was sufficient. Overall, the Zn content of the studied block ranges from 0.44 to 0.68 mg kg^{-1} with mean value 0.57 mg kg^{-1} while the Mn ranges from 4.64 to 6.25 mg kg^{-1} with a mean value of 5.45 mg kg^{-1}. The Fe content ranges from 11.89 to 14.25 mg kg^{-1} with a mean value 13.03 mg kg^{-1}, and the Cu content of the soil samples on the whole ranges from 1.4 to 1.89 mg kg^{-1} with a mean value of 1.29 mg kg^{-1}. A similar work reported by Gautam et al. [19].

3.2.2 Maitha

The results of the soil nutrient status (Table 3) revealed that low to medium content of available N, P, and K were found in all sites, and it varied from 102.78 to 138.39, 9.89 to 16.47 kg ha^{-1}, and 230.65 to 276.65 kg ha^{-1} in surface soils; 22.89 to 31.20, 3.16 to 4.68 and 81.89 to 107.98 kg ha-1in subsurface soils under all sites of Maitha block. The content of available N, P, and K were higher in the surface horizons as compared to

Table 2. Nutrient content of soil (from 0 to 60 cm) in barren land of Akbarpur

	Depth	Macro nutrients ($kgha^{-1}$)				Micro nutrients ($Mgha^{-1}$)			
		N	P	K	S	Cu	Fe	Mn	Zn
Min.	0-15	105.25	12.36	233.12	13.25	1.04	11.89	4.64	0.44
	15-30	45.86	10.25	210.45	12.77	1.02	9.19	5.63	0.23
	30-60	25.36	5.63	84.36	10.12	0.36	4.56	2.44	0.13
Max.	0-15	140.86	18.94	278.85	16.54	1.89	14.25	6.25	0.68
	15-30	67.15	13.45	288.45	15.60	2.11	11.80	6.63	0.46
	30-60	33.67	7.15	110.45	11.78	0.65	6.14	4.25	0.24
Mean	0-15	120.45	16.00	259.86	14.80	1.29	13.03	5.45	0.57
	15-30	58.57	11.26	239.38	14.32	1.45	10.44	5.89	0.34
	30-60	30.44	6.35	94.18	10.95	0.50	5.54	3.40	0.20
SD	0-15	13.88	2.45	17.67	1.26	0.35	0.88	0.75	0.09
	15-30	8.17	1.34	29.16	1.15	0.41	1.01	0.43	0.09
	30-60	3.76	0.76	10.44	0.73	0.13	0.62	0.66	0.04
CV (%)	0-15	0.12	0.15	0.07	0.09	0.27	0.07	0.14	0.16
	15-30	0.14	0.12	0.12	0.08	0.28	0.10	0.07	0.26
	30-60	0.12	0.12	0.11	0.07	0.26	0.11	0.19	0.21

Table 3. Nutrient content of soil (from 0 to 60 cm) in barren land of Maitha block

	Depth	Macro Nutrients (kgha-1)				Micro Nutrients (Mgha-1)			
		N	P	K	S	Cu	Fe	Mn	Zn
Min.	0-15	102.78	9.89	230.65	10.78	1.00	9.42	6.08	0.40
	15-30	43.39	7.78	207.98	10.30	0.98	6.72	7.07	0.19
	30-60	22.89	3.16	81.89	7.65	0.32	2.09	3.88	0.09
Max.	0-15	138.39	16.47	276.38	14.07	1.85	11.78	7.69	0.64
	15-30	64.68	10.98	285.98	13.13	2.07	9.33	8.07	0.42
	30-60	31.20	4.68	107.98	9.31	0.61	3.67	5.69	0.20
Mean	0-15	117.98	13.53	257.39	12.33	1.25	10.56	6.89	0.53
	15-30	56.10	8.79	236.91	11.85	1.41	7.97	7.33	0.30
	30-60	27.97	3.88	91.71	8.48	0.46	3.07	4.84	0.16
SD	0-15	13.88	2.45	17.67	1.26	0.35	0.88	0.75	0.09
	15-30	8.17	1.34	29.16	1.15	0.41	1.01	0.43	0.09
	30-60	3.76	0.76	10.44	0.73	0.13	0.62	0.66	0.04
CV (%)	0-15	0.12	0.18	0.07	0.10	0.28	0.08	0.11	0.18
	15-30	0.15	0.15	0.12	0.10	0.29	0.13	0.06	0.30
	30-60	0.13	0.20	0.11	0.09	0.28	0.20	0.14	0.26

subsurface horizons. A regular decreasing pattern of available N, P, and K was observed with depth. The highest amount of available N in the surface horizon may be attributed to the high amount of carbon. The lower P in sub-surface horizons as compared to surface horizon was due to the fixation of released P by clay minerals, oxides of iron, and aluminum. Available S (kg ha^{-1}) content was also low to medium in most soils of different sites of barren land and varied from 10.78 to 14.07 kg ha^{-1} in surface soils and from 7.56 to 9.31 kg ha-1 in subsurface soils, respectively. The mean available S (kg ha^{-1}) in surface soils was 12.33 in all sites of the Maitha block. However, the highest available S was observed in the surface horizons and decreased with depth. The DTPA-Cu, Fe, and Zn were higher in surface horizon than sub-surface under all sites of barren land and it ranged from 1.00 to 1.85, 9.42 to 11.78, and 0.40 to 0.64 (mg kg^{-1}) in surface soils, from 0.32 to 0.61, 2.09 to 3.67 and 0.09 to 0.20 (mg kg^{-1}) in subsurface soils, respectively. The mean available Cu, Fe, and Zn (mg kg^{-1}) in surface soils were 1.25, 10.56, and 0.0.53, respectively in all sites of barren land. The DTPA- Mn varied from 6.08 to 7.69 with a mean value was 6.89 (mg kg-1) in surface soils; from 3.88 to 5.69 with mean and SD values were 4.84 (mg kg^{-1}) and 0.75 in subsurface soils, respectively under all sites. Irrespective of sample sites, the Mn showed an increased to decreasing trend with depth [20].

4. CONCLUSION

The current investigation demonstrates that the soils are severely lacking in nutrients and have a low fertility condition. One of the primary causes of decreased production is a lack of knowledge and awareness among farmers, as well as the failure to implement sustainable crop management practices, such as comprehensive soil health management. Now a day there is a growing need for balanced fertilization and site-specific fertilizer recommendations according to the crop type, yield level, and soil conditions. With the obligatory need for intensification of crop production, the demand for crops for readily available soil nutrients increases. Strengthening and locating the best sources of amendments for enhancing the fertility of issue soils, which will also offer more than one nutrient to reduce crop production costs, may be used to improve problem soil and create wealth from low fertile lands.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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