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Determination of Some Physical Properties and Electrical Conductivity of Loamy Soil with Additives

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MO and PON conceived and designed the study, acquired, analyzed and interpreted the data. Authors AB proofread the manuscript and made general recommendation and data interpretation. All authors read and approved the final manuscript.

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ABSTRACT

In this study, the electrical conductivity and physical properties of loamy soil samples with various additives is determined. The electrical conductivity meter was used to obtain the electrical conductivity and some standard methods have been adopted to obtain other properties. It is observed that the soil combined with NPK had the highest electrical conductivity with the least coming from the soil (control). It is concluded that NPK raises the electrical conductivity of the soil. This goes forth to show a measure of the amount of salts in soil (salinity of soil), which is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms which in turn influences key soil processes including the emission of greenhouse gases such as nitrogen oxides, methane, and carbon dioxide. It is recommended that soil with organic manure should be used in order to maintain low salinity and good soil health.

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Keywords: Denitrification; nitrification; nitrogen oxides saline/sodic soil; electrical conductivity (EC); soil organic carbon content (OC).

ABBREVIATIONS

EC : Electrical Conductivity
OC : Organic Carbon Content
SG : Specific Gravity
NPK: Nitrogen, Phosphorus and Potassium

1. INTRODUCTION

To evaluate the state of the soil and model soil function, soil data is used. Salinization of the soil and a decline in the amount of organic matter in the soil are the main risks to having a productive soil [1]. In conditions typical of the south-west Pacific area, soil salinity is a significant physico-chemical limitation that affects both farm-level and regional yields [2,3]. It is pertinent to note that due to land clearing, removal of native flora, and adoption of conventional agricultural practices, the amount of soil organic matter (and carbon) in Australia has significantly decreased [4,5]. However, the effects of present farming methods and management strategies on the distribution of organic matter are not as distinct as variations in the climate and soil [6,7]. Despite recent efforts to better understand the nature of the critical variables affecting the distribution of organic carbon content across Australia [8], there are still a number of important knowledge gaps regarding the fall in soil organic matter. A similar lack of soil data and knowledge makes it difficult to make appropriate assessments of soils affected by salinization [1].

Fundamental characteristics for these kinds of evaluations include soil electrical conductivity and soil organic carbon content. In the past ten years, a lot of work has gone into preserving and making soil profile data accessible for use in the future [9]. According to research to date, the distribution and occurrence of soil properties, such as electrical conductivity (EC) and soil organic carbon content (OC), are mostly explained by wide environmental impacts over varying time periods, including climate, landform, and parent material. The salinity of the soil is determined by the soil's electrical conductivity (EC). It is a crucial gauge of the health of the soil. It influences important soil activities, such as the emission of greenhouse gases like nitrogen oxides, methane, and carbon dioxide, as well as crop yields, crop compatibility, plant nutrient availability, and activity of soil microbes. A surplus of salts alters the soil-water balance, which prevents plants from growing. Arid and semiarid regions naturally produce salt-rich soils. Cropping, irrigation, and land management practices can all lead to a rise in salt levels. The quantities of nitrates, potassium, sodium, chloride, sulfate, and ammonia have been associated with EC, despite the fact that it does not directly detect particular ions or salt compounds. Calculating EC can be a quick and affordable technique to gauge how much nitrogen (N) is available for plant growth in some non-saline soils.

Numerous studies have focused on determining the electrical conductivity of soil using various testing methods. For instance, based on laboratory measurements of clean sand stone samples, [10] suggested an empirical link (the Archie's law). The Archie's law, however, only applies to sandy soil or saturated rock. Laboratory investigations conducted by McCarter [11]. Fukue et al [12] revealed that soils' electrical resistance reduces as water content rises. According to the water potential, the structures—that is, the distribution of voids, pore geometry, connectedness, and porosity—determine the ratio of air to water [13]. Connected resistivity fluctuations with the composition of pedological materials and found that macro- and meso-porosity were responsible for high and low resistivity levels, respectively. A fluid's viscosity can be excited and altered by temperature, which can then have an impact on electrical conductivity [14]. The study of Campbell [14] shows that conductivity increased by 2.02% per °C (in the range of 15-35°C) by conducting laboratory studies on 30 samples of saline and alkaline soils. Studies on problematic unsaturated soils, such as loess, lateritic soil, and expansive soil, are however, infrequently published. In many of China's south-western provinces, including Hunan, Guizhou, Yunnan, and Guangxi, lateral soil is commonly present. Typically, lateral soil is regarded as an excellent natural building material and foundation. The lateritic soil, however, has a lot of disadvantages, including shrinkage, fissures, water sensitivity, and uneven distribution. Therefore, using lateritic soil as a building material creates a number of difficult problems while building a high-speed train and a highway in these southwestern Chinese provinces. In those projects, borehole surveying, exploratory holes, trenching exploration, and pit testing are used to roughly determine the fracture depth, water volume, and distribution. These geotechnical investigations had a heavy workload, took a long period, and had little impact. An appealing approach for defining the subsurface characteristics without excavating is the electrical conductivity experiment, which can save a lot of time and work.

Analyzing soil water content, which is likely the easiest to identify soil feature, is crucial for agricultural planning. For calculating land atmospheric interaction, water balance, infiltration, and deep percolation or recharge, knowledge of the water content in near-surface soil is essential. For maximizing crop yields, achieving high irrigation efficiencies, reducing yield loss from salinization and waterlogging, and timing irrigation, survey data is essential. Clay content, water content, and salinity are all factors that affect the electrical conductivity of soil [15].

Recent advances in artificial intelligence and other techniques have brought previously unheard-of attention to the study of the salinity content of the soil in diverse dry parts of the world [16–21]. To our knowledge, no study has examined the electrical conductivity of loamy soil with different organic and inorganic manures, which are frequently utilized by farmers to increase agricultural yields.

The structure of this study is as follows. In Section 2, we outline the resources used and the methodology followed for the research. We presented the results in section 3, and in section 4, we discussed the findings from section 3. The research is finished with a summary of our findings in section 5.

2. MATERIALS AND METHODS

2.1 Materials

Small containers, Plates, Table spoon, 100-mL graduated cylinder, a rod for stirring, which is longer than the graduated cylinder, manure (organic and inorganic), and loamy soil, Drying oven, Dryers, glass electrode containing pH meter, glass beaker (100ml), Digital conductivity meter, glass rod.

2.2 Methods

2.2.1 Determination of the Porosity

The test is done with a mixture of soil and the manure in equal ratio which is what is required for standard test. A mixture of other soil maybe added. The sample is put into the graduated cylinder to approximately half of the graduated cylinder when that has been done, the sample is poured out and the record is taken. 70ml of water is put into the graduated cylinder and the sample that was set aside is slowly added. The mixture is stirred with the rod to break-up lumps; this is left for about five (5) minutes so as to allow escape of bubbles. The volume of sample/water mixture is recorded.

The volume of solids in the tested samples is calculated:

$$Volume\,of\;solids\left(mL\right)=-70mL\,water+Volume\,of\;sample\,/\,water\,mixture \tag{1.1}$$

Total pore space volume calculation:

$$Volume\,of\;pore\,space\left(mL\right)=-Volume\,of\;solids\left(mL\right)+Volume\,of\;packed\,sample \tag{1.2}$$

Determine the porosity:

$$Porosity\,of\;sample=\frac{Volume\,of\;pore\,sample\left(mL\right)\times 100\%}{Volume\,of\;packed\,sample\left(mL\right)} \tag{1.3}$$

Compare the porosity of manure, soil and manure-soil mixture (and optional other types of soil, with and without compost added).

2.2.2 Moisture content

5-10g of previously grounded sample was weighed out. The sample was placed in drying oven at 105^{0}C for at least 12hrs. The sample was allowed to dry up in the dryer. The sample was reweighed with precaution not to expose it to the atmosphere. The moisture content is calculated as follows:

$$Moisture\,content\,(\%) = 100\,\frac{(B-A)-(C-A)}{(B-A)} \tag{1.4}$$

Where:

A= weight of clean, dry scale pan(g)
B= weight of scale pan + wet sample(g)
C= weight of scale pan + dry sample(g)

2.2.3 Determination of specific gravity

$$Specfic\ gravity = \frac{W_3 - W_1}{W_2 - W_1} \tag{1.5}$$

Where W_1, is the recorded weight for an empty specific gravity bottle (SG) bottle. W_2 is the recorded weight for empty SG bottle filled to the mark with distilled water. W_3, is the recorded weight for empty SG bottle filled to the mark with oil sample.

2.2.4 Determination of Ph

In a beaker, weigh 20 g of the sample. Add 50ml of distilled water, whisk thoroughly for about 5 minutes, then let sit for 30 minutes. The pH meter should be turned ON and let 15 minutes to warm up. Use a standard buffer with a pH of 7 to standardize the glass electrode and a buffer with a pH of 4 or 9.2 to calibrate it. While continuously swirling, dip the electrodes into the beakers containing the sample water suspension. Change the pH meter to pH reading mode while recording pH, wait 30 seconds, and then record the pH value to the nearest 0.1 unit. After recording, switch the pH meter to standby mode. The electrodes should be taken out of the sample suspension and cleaned with distilled water. After each determination, rinse the electrodes, and before the next one, gently wipe them dry using filter paper. After every ten, standardize the glass electrodes. When not in use, immerse the electrodes in distilled water, and make sure the reference electrode is always in contact with saturated potassium chloride solution and solid potassium chloride crystals. Toluene is added in three to four drops in typical buffer solutions to stop the growth of mould.

2.2.5 Measurement of electrical conductivity (EC) in soil

With the aid of the standard KCL solution, calibration is done on the conductivity cell and cell constant is ascertained. For conductivity measurements, the soil water suspension (20 gm:50 ml) that was made for pH analysis can also be utilized. Allow the soil water suspension in the beaker to settle for a further 30 minutes after recording the pH (the total interval of intermittent shaking was 1 hour). After calibration, submerge the conductivity cell in the soil water suspension's supernatant liquid. Read the test solution's conductivity within the appropriate conductance range, the cell should be taken out of the soil suspension, cleaned with distilled water, and then dipped into a beaker of the same water. The unit of EC is dS.m^{-1}. When not in use, submerge the conductivity cell in distilled water. During the test, note the temperature of the soil water suspension.

3. RESULTS

In this study, the electrical and physical properties of various samples have been obtained. Table 1 shows the numerical values of these properties and Figs. (1-5) shows the comparative bar chart of the various properties.

Table 1. Electrical conductivities and physical parameters of the soil samples

Sample	pH	Electrical Conductivity (μS/cm)	Moisture Content (%)	Porosity (%)	Density (g/ml)
Soil (Control)	6.6	25.8	22.5	75.8	0.631
Soil + NPK	6.6	480.9	28.3	82.9	1.193

Sample	pH	Electrical Conductivity (μS/cm)	Moisture Content (%)	Porosity (%)	Density (g/ml)
Soil + Poultry dung	7.4	116.6	34.5	80.4	0.567
Soil + Cow dung	7.5	386.6	44.9	67.8	1.458
Soil + Urea	7.3	35.7	45.2	75.2	1.553

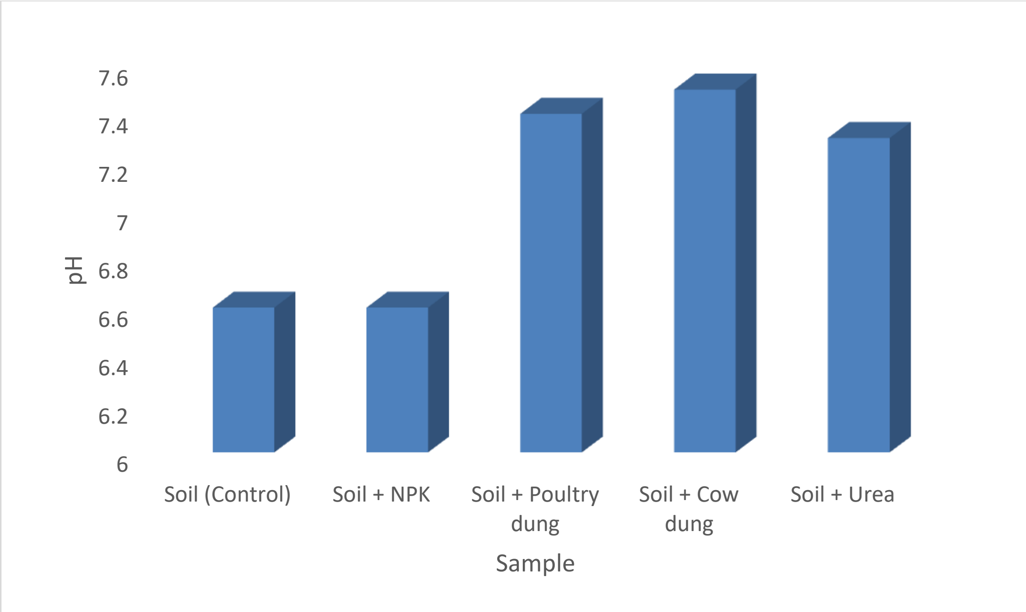

Fig. 1. pH of samples

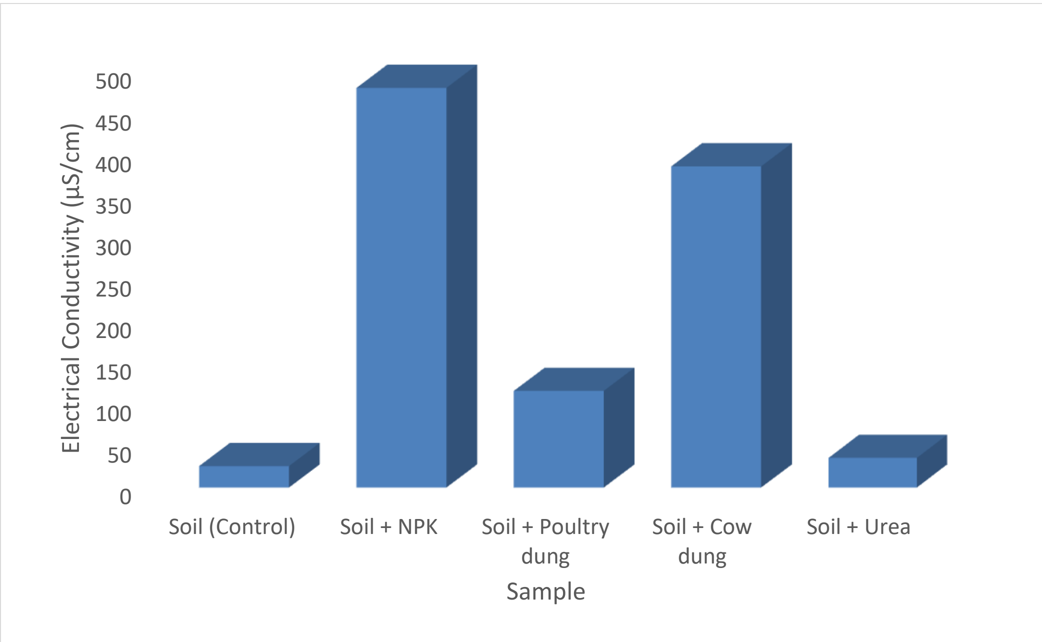

Fig. 2. Electrical Conductivity of samples

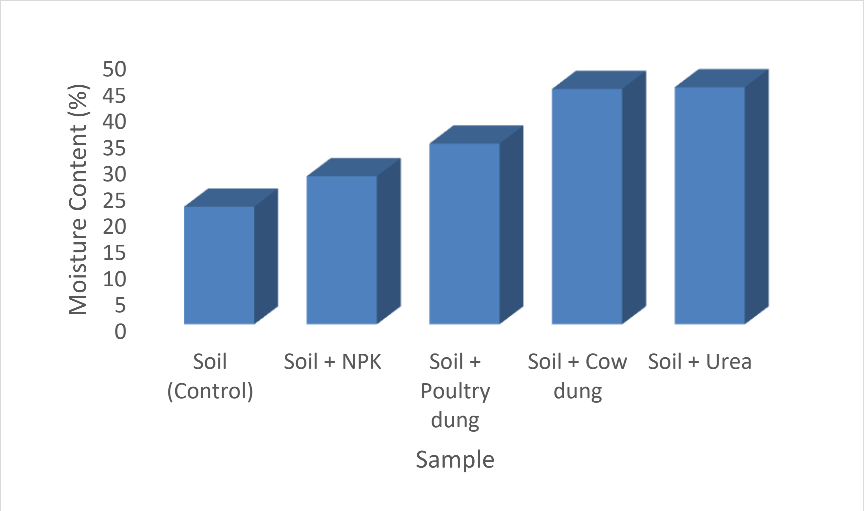

Fig. 3. Moisture Content of samples

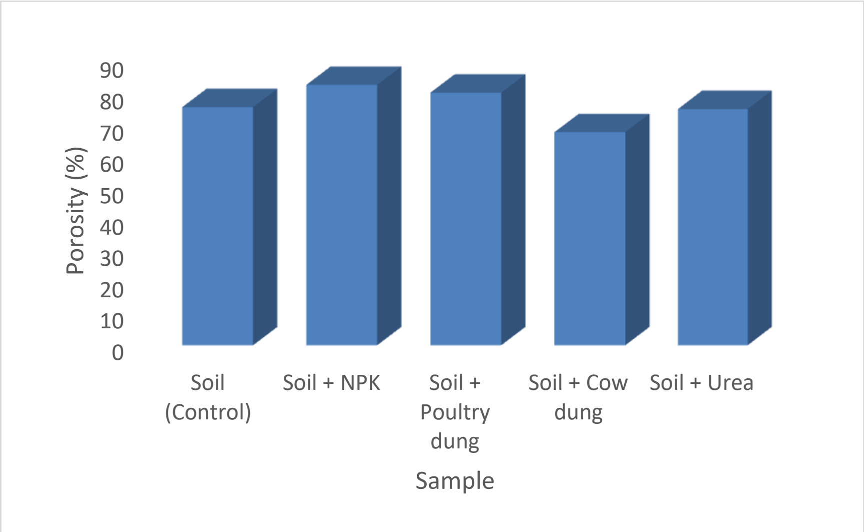

Fig. 4. Porosity of samples

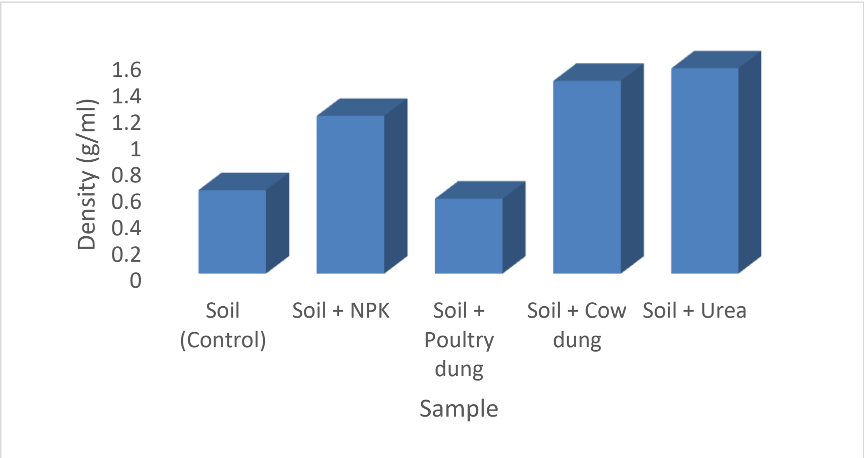

Fig. 5. Soil Density of samples

4. DISCUSSION

Fig. 1 shows a bar chart of pH of the five samples. Comparatively, it's seen that the soil combined with cowdung had highest pH followed by soil plus poultry droppings, soil plus urea, soil (control) and soil plus NPK in that order. Fig. 2 shows the bar chart of electrical conductivity for soil samples. The soil combined NPK had the highest electrical conductivity with soil plus cowdung coming next, followed by soil plus poultry droppings, soil plus urea and soil. Fig. 3 shows the bar chart of Moisture content (%) for soil samples. The soil combined with urea had the highest moisture content, followed by soil plus cowdung, soil plus poultry, soil plus NPK and soil (control) respectively. Fig. 4 shows the bar chart of porosity (%) of samples. The porosity of the soil samples was found to increase in the following order: soil plus NPK (highest), soil plus poultry, soil (control), soil plus urea and soil plus cow dung. Fig. 5 shows the bar chart soil density of samples. The sample with the highest density was found to be soil combined with urea, followed by; soil plus cowdung, soil plus NPK, soil (control) and soil plus poultry.

5. CONCLUSION

In this study, we determine the electrical conductivity, moisture content, density, pH and porosity of the loamy soil samples. Several methods have been used to obtain these properties. It is observed that the soil combined with NPK had the highest electrical conductivity with the least coming from the soil (control). It is concluded that NPK raises the electrical conductivity of the soil. This goes to show a measure of the amount of salts in soil (salinity of soil). It is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms which influence key soil processes including the emission of greenhouse gases such as nitrogen oxides, methane, and carbon dioxide.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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