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Assessing Essential Parameters for Soil Fertility in Remote Agricultural Areas of PDUAM, Dalgaon, Darrang, Assam

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Abstract**: Soil is the upper layer of the earth's surface, consisting of a mixture of organic matter, clay, and rock particles, and it serves as the medium in which plants grow. The quality of soil plays a crucial role in agricultural activities and is vital for ensuring the safety of agricultural products. This study focuses on the assessment of soil properties within various remote areas of Pandit Deendayal Upadhyaya Adarsha Mahavidyalaya (PDUAM) located in Dalgaon, Darrang, Assam. The investigation seeks to comprehensively evaluate some of the key soil characteristics, including pH levels, electrical conductivity (EC), and some of the important ions present in the soil matrix using basic chemical laboratory experiments. By undertaking this detailed analysis, the aim is to gain an understanding of the soil fertility in these remote regions, where extensive agricultural practices are carried out. The study reveals that more than 80% of the soil samples have required pH within the fertile range. The observed conductivity value indicates the presence of sufficient soluble ions. Recognizing the pivotal role of soil in sustaining agricultural ecosystems, this study contributes to the broader discourse on optimizing agricultural practices. The findings from the assessment will not only enhance knowledge on soil health but also shall offer valuable insights for agricultural stakeholders in this area.

Keywords: Soil, pH, Conductivity, Ions, Agriculture.

1. INTRODUCTION

Soils are porous media created at the land of surface through the effects of weathering, influenced by geological, biological, and hydrological processes [1]. Soils distinguished themselves from mere weathered rock by displaying a distinct vertical layering called soil

horizon, shown in Fig. 1. This stratification is developed by the continual impact of percolating water and living organisms. Soils are considered to be open, multicomponent, biochemical systems containing solids, liquids and gases. They are open system because soil exchanges both energy and matter with the surrounding atmosphere, biosphere and hydrosphere [2]. Therefore, soil is considered to be a dynamic living system where ions and molecules consistently move from one phase to other, while interacting with each other [3].
The O horizon is the uppermost layer of the topsoil, which primarily composed of organic matters like dried leaves, grasses, small rocks, twigs, surface organisms, and fallen trees. This horizon of soil is often black brown or dark brown in color and this is mainly because of the presence of organic content, so this layer is also known as humus layer. The A-horizon or topsoil comprises a combination of organic matter and decomposed materials. The topsoil is soft and porous to hold sufficient water and air. In this layer, the seed germination occurs, giving rise to new roots which develops into a new plant. The E-horizon of the soil undergoes leaching of minerals, clay and organic matter. This layer is not present in some soils, but frequently found in older soils and forest soils. The B-horizon, also known as subsoil, lies beneath the topsoil and above the bedrock. It is comparatively harder and more compact than the topsoil, containing less humus, soluble minerals, and organic materials. C-horizon, also known as saprolite, lacks organic matter and is composed of broken bedrock. The R-horizon constitutes a compacted and cemented layer, with different rock types like basalt, granite, sandstone, limestone, quartzite, etc. [4].

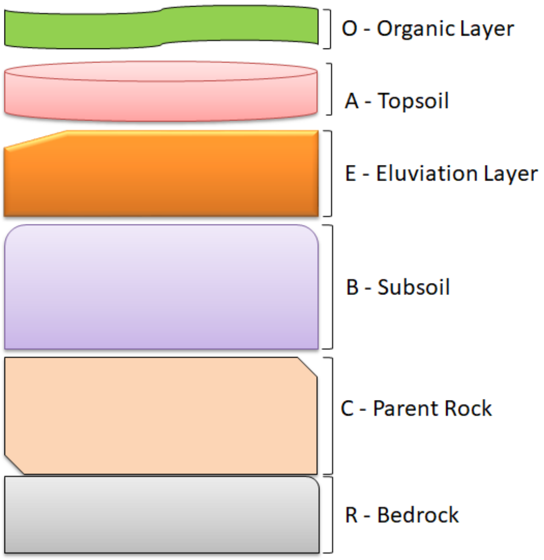

Fig. 1 Soil Layers

Soil analysis can provide important information about physical conditions, fertility status, and chemical properties that affect a soil's suitability for growing plants. Soil pH is a measure of the hydrogen ion activity in the soil. There are three types of soil such as, Neutral soil (pH = 7.0), Acidic soil (pH< 7.0) and Alkaline soil (pH > 7.0). For normal plant growth and development, moderately acidic to neutral soil pH (5.5 – 7.0) is required [5]. Changes in soil pH may affect the balance of the various nutrients, as well as their availability to plants.

Saline soil is defined to contain sufficient soluble salts to adversely affect the growth of a plant. Soil salinity reduces crop growth and affects the water uptake by the plant while causing specific ion toxicity and imbalance of nutrients. It is measured by Electrical Conductivity (EC) [6].

2. RELATED WORKS

The economic backbone of Darrang district stands on agriculture. The diverse topography and unique agro-climatic conditions has made this region suitable for cultivation. The nature of the soil in this area is sandy to sandy loam in texture and clayey in low lying areas. Sandy loam soil has good drainage capacity offering good aeration for plant roots. Similarly, clayey soil is useful for crops to retain maximum amounts of water, due to its fine particle size.

Soil fertility mainly depends on the presence of major nutrients like nitrogen, phosphorus, and potassium, as well as other nutrients like calcium, magnesium, sulfur, iron, zinc, copper, manganese *etc*. in smaller quantities. A fertile soil also needs organic matter to improve soil structure, moisture retention, nutrient retention, and an optimum pH of 6-7. The main aim of this study is to assess the soil properties of various remote areas of PDUAM, Dalgaon, Darrang, Assam, India.

A. Phospahte

Phosphorus (P) is one of the vital soil macronutrient necessary for optimum growth and development of plants. However, phosphorous is not available in free elemental state due to high reactivity. Soil P is commonly present in two forms; inorganic (Pi) or organic (Po) [7]. Inorganic P comprises of soluble and loosely bound P, Fe-P, Al-P, Ca-P, reductant soluble P, and occluded P. In contrast, organic P includes inositol P, nucleic acid, and phospholipids [8]. The relative abundance of Pi is approximately 50 to 75% of total P, in some specific cases it ranges upto 10-90% [9]. Organic P ranges from 30- 50% of the total P in soils and derived from soil organic matter, crop residues, and various manures following decomposition and mineralisation by soil microorganisms.

P has many oxidation states ranging from –III to +V. Naturally P is available in +V oxidation state in the form of H_3PO_4 which is soluble in water. It dissociates successively producing dihydrogen phosphate anions ($H_2PO_4^-$), hydrogen phosphate anions (HPO_4^{2-}) and the tetrahedral oxy-anion orthophosphate (PO_4^{3-}) [10]. HPO_4^{2-} and PO_4^{3-} ions also known as Pi; are the major mobile P forms in soil. $H_2PO_4^-$ is predominant when soil pH is less than 7.0. HPO_4^{2-} and PO_4^{3-} anions are dominant bio available P forms [11]. Less than 1% of the total P is normally dissolved in soil solution and the concentration of soluble Pi rarely exceeds 10 μM [12]. Since, soil pH plays a crucial role in determining the availability of P to crops. The maximum yield observed on P fertilizer applications is in soils with pH of 5–7 [13]. In acidic soils, P binds to Fe and Al hydroxides decreasing the level of available P. In contrast, in soils with pH > 7, P forms less soluble Ca-P precipitates, decreasing available P [14].

B. Nitrate

Nitrogen present in soils is in very reactive forms but in small quantities [15]. These are found in reduced inorganic forms like ammonia, and ammonium, or oxidized ones, such as nitric acid (HNO_3), nitrous acid (HNO_2), nitrate ion (NO_3^-), nitrogen oxides (NO_x), nitrous oxide (N_2O), nitrogen pentoxide (N_2O_5), and peroxyacetyl nitrate (PAN) [16]. Whereas, the organic form of nitrogen in soil includes amino acids, proteins, amines, urea, and other nitrogen containing organic molecules. Among them ammonium and nitrate ions are absorbed fastest by plants [17]. The major sources of soil NO_3^- are decomposing plant residues and animal manure, chemical fertilizers, exudates from living plants, rainfall, and lightning. These available nitrate ions are taken up by microorganisms and converted into organic forms and released back to the soil. Nitrate ions are completely soluble in water and can be easily transported by runoff and other surface water bodies to rivers or moved downward to ground water. The mobility of NO_3^- is mostly influenced by soil texture. Since NO_3^- ions do not bind to sandy particles, the coarser soil texture (sandy) can easily leach NO_3^- through soil. Therefore, NO_3^- present in those soils can contaminate the ground water under heavy rain. The lower soil pH (<5.5) reduces the rate of nitrification making deficient of NO_3^- in acid soils and ceases at pH <4.5. The optimum pH value for nitrification is between 6 to 8 [18].

C. Sulphates

Sulfur is an important component of soil derived from rock materials present in earth crust and from the atmosphere. The primary source of sulfur in the soil is minerals [19]. Some example includes gypsum ($CaSO_4.2H_2O$), ferrous sulfides (FeS and FeS_2), hydrotroilite ($FeS.nH_2O$) *etc*. In agricultural soils, S is mostly present in soil organic matter (OM), because inorganic form of S i.e. sulfate (SO_4^{2-}) easily moves through soil *via* leaching. The plants require S at an optimum concentration level of 0.1-0.5% of their dry weight, for healthy growth and development [20]. Therefore, it is necessary for crops to take up significant amounts of S from soil. In case of soils with higher concentration of OM have high potential to supply S to plants in favourable conditions of temperature and soil moisture. The S mineralization from soil OM is greater at higher soil temperature and higher content of moisture present in soil.

Sulfates are normally mobile in the substrate and are usually not absorbed above pH level of 6. This clearly implies that soil sulphate concentration is completely dependent on water management. Sulfate leaching can be partially overcome by non-specific sorption of anions. In this respect, hydrated aluminum and iron oxides, kaolinite etc. present in the soil plays significant role. Sulfate sorption directly depends on soil pH. It is found that maximum sorption observed at soil pH within 2-4 [20]. The absorption of sulfate in the soil and its availability to plants is challenged by some other ions like phosphates, molybdates, arsenates, thiocyanates, and oxalates. Among them phosphates have the greatest reducing effect as inorganic ions while oxalates can be marked as organic ion. Thus, sulphates content in soil is influenced by various factors like soil pH, atmospheric deposit, microbial processes, and discharge of sulfur along with crops, soil fertilization, and changes in water management [21].

D. Chloride

Chloride (Cl^-) anion is a dominant form of the halogen element present in soils. However, in agriculture it is considered to be toxic anion rather than a nutrient. This is due to the fact that chloride and nitrate ions are antagonistic molecules and accumulation of excessive Cl^- ion in organs in salt stress conditions. Cl^- is an essential micronutrient and required in small quantities (about 50–100 μM in the nutrient media) for healthy growth of plants [22]. It is necessary for photosynthesis, osmoregulation, turgor regulation, and elongation growth [23]. Cl^- ions travel into the roots through soil water. It also regulates activities of enzymes in the cytoplasm.

The adsorption of Cl^- ions are not possible in case of neutral and alkaline soils. The estimation of available Cl^- ions depends on crop's rooting characteristics, as well as the cropping system, soil type, precipitation or frequency of irrigation and drainage [24]. It is assumed that Cl^- ions are adsorbed on positive sites of the clay particles by electrostatic forces of attraction. The release of OH^- ions takes place during adsorption of Cl^- ions and its release finally increases pH value of the soil.

Studies reveals that nitrification in acidic soil (pH 5.0-5.5) is reduced by Cl^- ions and low osmotic potential of the soil solution [25]. It is observed that Cl^- ion functions as an inhibitor of nitrification in soil at pH 5.5 but not at pH 6.6. In contrast the impact is quite less within pH range of 6.5-7.0. Thus, it is found that antagonistic Cl^- anion-anion competition with nitrate and phosphate regarding cellular uptake hamper growth and yield.

E. Ammonium

Plants take up nitrogen in the form of ammonium (NH_4^+) or nitrate ions (NO_3^-) [26]. Improved production of crops depends on NH_4^+ and NO_3^- ratio has been reported. These ions are made available to the soil by the process of nitrogen fixation, nitrification and mineralization [27]. Nitrate however leaches away very easily due to weak binding with the negatively charged soil particles. Ammonium thus emerges to be the efficient form of nitrogen but this is partly lost due to oxidation to nitrate [28]. 2:1 type clay minerals like illite, vermiculite and montmorillonite have strong tendency for ammonium fixation. NH_4^+ exists in equilibrium with NH_3, which is pH dependent and finally converted to nitrate; called nitrification. Nitrification may occur within a pH range of 5.5 -10, the optimum value is pH of 8.5. However, nitrification has also been reported at a pH of 3.8 [29]. Other factors affecting nitrification are temperature, soil matrix, moisture and aeration. Ammonia volatilisation is a major concern in context of reduced nitrogen availability to plants. Besides leaching, runoff and denitrification, soil pH is found to be an important factor in volatilisation process. NH_3 volatilization is more in soils with pH>7 and is less in soils with pH=5-7. In certain cases, crops have been found to prefer for ammonium and nitrate depending on the soil pH. In acidic soils, crops utilized nitrate and in alkaline soils, crops preferred for an increased presence of ammonium [30].

F. Calcium

Calcium is the third abundant element in plant tissue and is involved in various functions like cell division, cell elongation, etc [31]. Plants take up Calcium and Magnesium in their ionic forms (Ca^{2+} and Mg^{2+} respectively). Calcium and magnesium ions in soil are mainly due to weathering of rocks and minerals. Calcium enters the soil by degradation of minerals like calcite ($CaCO_3$), limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). Calcium may also enter the soil due to atmospheric deposition of soot and ash. Dicotyledonous plants require more calcium (0.5% to 2.0% of dry matter) than monocotyledonous plants (0.3 to 1.25%) [32]. Usually, calcium is found abundantly in soil except for acidic soils where calcium has to be added as soil amendment. The amount of Ca in soil depends on weathering and soil nature. Leached humid tropics contain 0.1 to 0.3% of Ca, calcerous soils may contain <1% to 25% of Ca.

G. Magnesium

Magnesium is another important macronutrient that is used by plants for different physiological functions. It is present in chlorophyll and helps to collect photons in photosystem I and photosystem II and helps to maintain the structure of ribosomes [33]. Magnesium enters into soil through decomposition of rocks containing various primary and secondary minerals. Some primary mineral sources include ferromagnesian minerals like olivine, pyroxene, amphibole, mica etc. Examples of secondary mineral sources are magnesite, dolomite, talc and serpentine group [34]. Also 90-98% of the magnesium in soil is bound to lattice structure of minerals, so it is not available to plants directly [35]. Plants take up magnesium in the form of Mg^{2+} but since it has very low ionic radius and large hydrated radius as compared to other cations, so Mg^{2+} binds weakly to the negatively charged soil colloids and the root cell borders [36]. Highly weathered, acidic and coarse soils are deficit of magnesium due to its large hydrated radius [37]. In alkaline soils magnesium carbonate and gypsum formed hinders the availability of magnesium and in calciferous soils, uptake of magnesium is affected by the presence of Ca and bicarbonates. Magnesium deficiency in soil may occur due to crop removal, leaching, erosion, interaction with other ions etc.

3. METHODOLOGY

A. Materials And Instruments

All materials and solvents were acquired from commercial sources and were used as supplied, unless mentioned other-wise. Reagents used for different laboratory experiments were of analytical grade. Water used for the experiments was pure distilled water. pH measurements of aqueous soil suspensions were performed by using Impact’s digital pH meter consisting of an electrode (code=170841081) and a display unit. Conductivity was measured in aqueous soil suspensions by using “Electronics India’s Digital Conductivity Meter 601”.

B. Sample Collection

1) Choice of Area:

In this study, we choose some areas of Dalgaon and Mangaldoi constituency of Darrang district, Assam, India where extensive agricultural activities are carried out. The samples collected from eight villages which are; Padupuri, Jogipara, Niz Shyamabari, Shyamtilla, Simaluguri, Duliapara, Daipam, and Dhekerigaon.

2) Choice of Soil:

Three different types of soil samples were chosen for our study from above specified area; (i) Inorganic soil sample (only inorganic fertilizers/pesticides are used during cultivation), (ii) organic soil sample (only organic substances are used) & (iii) uncultivated lands (not used for cultivation from a long time). There are total no of 41 samples collected from these specified areas.

3) Soil Layers:

Samples were collected from different layers ranging from 0-2, 2-4, 4-6, & 6-8 inches from the soil surface. The layering of soil was done by using a scale by digging a hole. Immediately, samples were collected, packed in clean polythene bags and labelled accordingly. Since, 41 no of soil samples were chosen; therefore all total 164 ($41\times4 = 164$) samples are there for study in the laboratory.

The soil samples were then undergoing pre-treatment of grinding to fine powder and drying under sunlight prior to further analysis.

4) pH and Conductivity Measurement:

10 g of dried soil sample is dissolved in 50 mL of distilled water followed by frequent stirring. After keeping the solution for 2 hours, the soil water suspension is poured into another beaker for pH measurement by using digital pH meter. The same suspension is used for conductivity measurement using the digital conductivity meter.

5) Analysis of Soluble Ions:

Soil extract is prepared by adding 10g of soil in 50 mL of distilled water followed by continuous stirring for 30 minutes. The suspension is allowed to stand for another 2 hours followed by filtration 2-3 times to get clear solution. The volume of the filtrate is reduced to 20 mL by heating and used for analysis of different ions; Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}, Ca(II), Mg(II) & NH_4^+. Few drops of $AgNO_3$ was added to acidified soil extract (by adding dil.HNO_3) to test the presence of Cl^- ions. Curdy white precipitate insoluble in dil HNO_3 but soluble in NH_4OH solution indicates the presence of Cl^- ions. Similarly, few drops of $BaCl_2$ solution was added to soil extract to detect the presence of SO_4^{2-} ions. Heavy white precipitate implied the presence of SO_4^{2-} ions. To detect the presence of NO_3^- ions, equal volume of freshly prepared $FeSO_4$ solution was added to soil extract; followed by cooling under tap water and dropwise addition of conc. H_2SO_4. Formation of brown ring confirms the presence of NO_3^- ions. PO_4^{3-} ions presence confirmed by changing soil extract colour to yellow on addition of equal amounts of conc. H_2SO_4 and ammonium molybdate, followed by boiling. Addition of Nessler's reagent under alkaline addition confirms the presence of NH_4^+ ions by formation brown precipitate. Soluble Ca(II) and Mg(II) ions present in the soil extract were determined by complexometric titration using EDTA in the presence of suitable indicators (Patton and Reeder's indicator & Erichrome black T).

4. RESULT AND DISCUSSION

The pH measurement of aqueous soil suspensions of different soil samples collected from various regions within the studied area, categorized into different ranges at room temperature (~ 25 °C) is given in Table 1 (Supporting Document). From the pie chart (Fig. 2), it was clear that most of the studied area exhibited a pH range between 6 and 7 i.e. 67%, whereas 21% of the studied area displayed pH values exceeding 7 while 12% of the samples demonstrated pH values below 7. This distribution indicates that the soil in the area tends to be slightly acidic to moderately alkaline.

The pH of soil serves as a crucial indicator of soil fertility, influencing the solubility and bioavailability of nutrients. As per reports, soil nitrates and ammonium are available to plants in a relatively wider range of pH from 6.0-8.0. However, as pH increases beyond 7, the availability of phosphate tends to decrease. The elevated soil pH observed in certain samples could potentially be attributed to the excessive use of fertilizers [5].

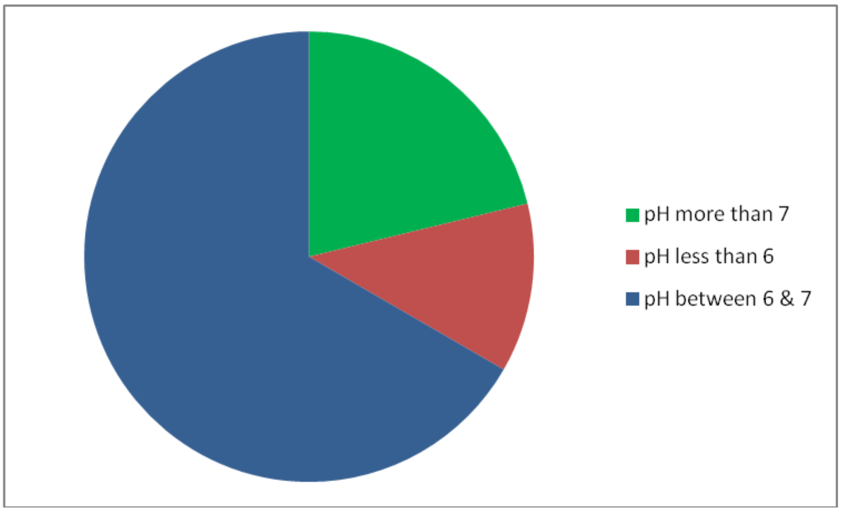

Fig. 2 ph Obtained for Different Soil Samples

Electrical conductivity values can vary with concentration of salts in the soil. Amount and timing of rainfall, irrigation practices and internal soil drainage systems affects the salts in the soil. Cations (Ca^{2+}, Mg^{2+}, K^+, Na^+, and NH_4^+) and anions (SO_4^{2-}, Cl^-, NO_3^-, and HCO_3^-) present in soil conduct electrical current. Thus, conductivity determines the concentration of dissolved ions present in soil; a measure of soil salinity which affects growth of plants. A soil is considered as saline if the conductivity equals or exceeds 4 (dS/m) at 25°C. Table 2 (Supporting Document), shows the electrical conductivity (EC) measurement of aqueous soil suspensions at room temperature (~ 25°C) and were found to be less than 4 (dS/m). Usually a soil EC value in the range of 0-1.5 dS/m is good for plant growth and activity of microbes in the soil. The investigation suggests that all the soils from studied regions are nonsaline. Pie diagram shows that 76.22% of soil samples under study have conductivity less than ≈ 0.250mS/cm which might be due to presence of higher proportion of Ca^{2+}, Mg^{2+}, Cl^- and PO_4^{3-} ions. 20.73% has conductivity in the range of ≈ 0.250mS/cm – 0.750mS/cm and 3.05% shows conductivity above ≈ 0.750mS/cm (Fig 3). The investigations also stresses on the fact that the uncultivated lands (like Simaluguri Sample 4) also has EC value within the suitable range for crops. So these uncultivated lands need to be explored for agriculture if other parameters are favourable. One however needs to ascertain first that the EC value is not mainly due to nitrates or even a trace amount toxic elements like Mn, Cd, Se etc. because in that case it will pose serious health hazards to animals, plants and human beings.

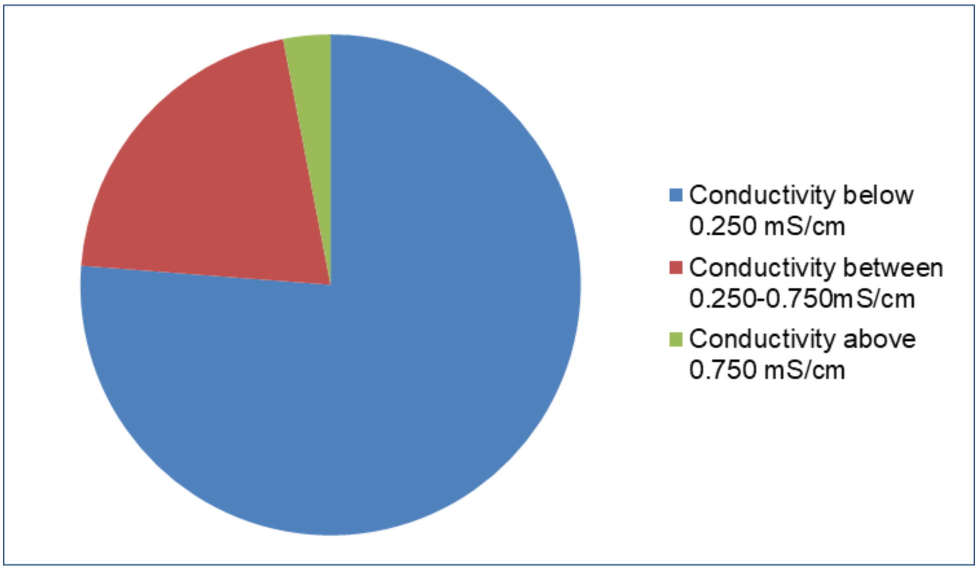

Fig. 3 EC obtained for different soil samples

The analysis of soluble ions present in aqueous soil extracts of different soil samples was shown in Table 3 (Supporting Document). It was observed that except for one organic soil sample of Simaluguri (in 4-6 inch), all other samples showed the presence of Cl^- in all the layers. One of the inorganic soil sample collected from Padupuri showed the absence of SO_4^{2-} in all the measured layers, whereas rest of the inorganic samples of showed the presence of SO_4^{2-}. Absence of SO_4^{2-} was detected in the important layers of soil (0-2 inch and 2-4 inch) of some areas like Padupuri, Duliapara and Shyamtila. The absence of SO_4^{2-} might be due to higher pH, leaching, excess PO_4^{3-} or less organic matter. PO_4^{3-} was found to be present in all the samples. But the absence of NO_3^- was observed in samples from Simaluguri, Padupuri, Daipam, Shyamtila, Shyambari, Duliapara. These areas were found to be devoid of NO_3^- in all measured layers which are of important to agriculture. The absence of NO_3^- may be due to pH or leaching by running water from any source or soil. The analysis of cations like Ca^{2+}, Mg^{2+} and NH_4^+ showed their presence in all of the samples. The qualitative analysis of the samples done showed that the area under investigation contains some of the essential elements needed for plant growth. However further study on quantifying the ions have to be done to ascertain the requirement of soil supplement in the area.

5. CONCLUSION

In this study, pH and electrical conductivity of various samples were evaluated from the nearby areas of PDUAM, Dalgaon. Additionally, qualitative analysis of ions was also conducted for the collected samples. The pH investigations revealed a prevalent range of 6 to 7 and the electrical conductivity was found to be less than 4 (dS/m) in the studied area. The analysis of soluble ions indicated the predominance of Cl^-, SO_4^{2-} and PO_4^{3-} ions in the majority of samples, with the notable absence of NO_3^- in a few samples. Additionally, Ca^{2+}, Mg^{2+} and NH_4^+ were present in all the samples. The qualitative examination reveals the presence of essential elements for plant growth in the investigated area. However, a more indepth quantitative study is essential to precisely assess the soil's ion composition and determine the necessity for soil supplementation in the region.

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