Assessment of Soil Physico-Chemical Parameter for Sustainable Crop Planning in a Hilly Terrain of Assam

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Abstract: **Assam state of North Eastern Region of India is surrounded by many hilly terrains which are lying barren throughout the year. In order to achieve sustainable crop production in hilly terrain with humid climate, more appropriate approach is the assessment of soil physico-chemical properties as well as soil fertility. So, the present study describes the details of topographical survey, soil sampling and analysis of physical properties at different soil profiles and find out the status of suitability of land for crop planning in the hilly terrain. The topographical survey revealed the sloppy nature of the top land surface varying the slope from 3 to 7%. And the average depth of soil on the top land was found to be only 60 cm and below which hard pan layer was encountered. So, the soil physico-chemical parameter analysis were carried out at four depth of soil profiles (0-15, 15-30, 30-45 and 45-60 cm). The soil profile analysis revealed that texture of the soils of the study site was sandy loam in nature with average sand, silt and clay percentage of 73, 11 and 17%, respectively. Average bulk density and moisture content was found to be 2g/cc and 9%, respectively. The soil water characteristics analysis revealed that the soil profile of 0-15, 15-30, 30-45 and 45-60 cm confined the field capacity and wilting point water content of 22.42, 23.11, 23.09, 23.51% and 12.44, 11.87, 12.30, 11.91%, respectively. The average pH and EC of the soil samples was found to be 5.3 and 8468.75µS, respectively. The predictive assessment of topographical survey and soil physico-chemical properties at a generic level revealed the scope for growing vegetables and horticultural crops in the hilly terrains.**

Keywords: **Hilly terrain, physical properties, chemical properties and agricultural planning.**

1. INTRODUCTION

Maintenance of soil quality is essential to sustain crop yields even under harsh environments like the humid tropics where high soil erosion, landslides and nutrient losses generally occur. Soil quality assessment has also been suggested as a tool for evaluating sustainability of soil and crop management practices [9]. Soil fertility refers to the ability of the soil to support organic life. It also refers to the inherent capacity of the soil to supply nutrient in adequate amount and in suitable proportions for crop growth and crop yield.

The physical properties of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil physical properties such as texture, bulk density and water content etc. also largely determine the soil's water and air supplying capacity to plants. Soil texture affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices [7, 8]. Soil texture is also an indicator of some other related soil features such as type of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil [12, 11].

The bulk density of soil (the mass of a unit volume of dry soil) determine the compactness and also considered as a measure of soil structure, for calculating soil pore space and as indicator of aeration status and water content [1]. Bulk density also provides information on the environment available to soil microorganisms. Soil water enhances various soil physicochemical reactions and supplies essential nutrients for plants and animals including micro and macro organisms residing in soils in order that they can carry out their own activities [13, 4]. The portion of stored soil water that can readily be absorbed by plants is said to be available water. The plant available soil water is held within a potential between field capacity (FC) and permanent wilting point (PWP).

Soil reaction (usually expressed as pH value) is the degree of soil acidity or alkalinity, which is caused by particular chemical, mineralogical and/or biological environment. Soil reaction affects nutrient availability and toxicity, microbial activity, and root growth. Thus, pH is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond so markedly to their chemical environment. Electrical conductivity (EC) is a measure of salinity. In addition to overcoming some of the ambiguities of total dissolved salts measurements, the EC measurement is quicker and sufficiently accurate for most purposes [2].

Since, the soil quality status of the hilly terrain of Assam University, Silchar has not been monitored for sustainable crop planning. So, the present study has been carried out to assess the aforementioned soil physical and chemical properties at different soil profiles of the hilly terrain which is among the non-irrigated land of the Assam state in India.

2. MATERIALS AND METHODS

2.1 Study area

One of the hilly terrains situated in the Assam University, Silchar of Cachar district and in the southern part of the Assam was considered for the study area. The study area hilly terrain of Assam University, Silchar covered total hill top area of about 10000m^2. The climate of the Silchar is warm and humid during summer where average relative humidity is 85% and in winter it is about 78%. The area receives an average of 2196 mm rainfall during the year. Soils of the zone vary from sandy type to clay soil mostly suitable for field crops including horticultural crops. The soil pH ranges from 4.6 to 5.7.

2.2 Topographic survey and soil sampling

In order to assess the suitability of land for agriculture and classification of soils, topographical land survey was carried out using standard surveying instruments such as Global Positioning System (GPS) and Automatic Level. The total area of the hilly terrain was found about 9682.8m^2. Because of dense jungle, it was not possible to make demarcation in to different sections of the land. However, randomly, total of 16 (8 numbers in left side and 8 numbers in right side) observation points were considered for the assessment of soil parameters of the terrain. The topographical view of the study site is shown in Figure1.

The topographic characteristics such as land area, soil depth, slope and elevation of each observation points were determined using standard guidelines of land capability classification [10].

Three main factors such as depth, sampling intensity per unit area of site sampled, and the sampling design are usually considered when developing soil-sampling protocols to monitor change in major soil fertility parameters. It is noted that sampling by fixed depths, rather than by generic horizon, underestimated soil carbon losses due to cultivation [6]. So, the sampling by fixed depth was considered and collected using a soil core cutter and sampler. During collection of samples; dead plants, old manures and areas near trees were excluded.

Figure 1. A topographical view of the hilly terrain

2.3 Analysis of soil physical properties

2.3.1 Soil texture

Soil texture refers to the proportion of the soil “separates” that make up the mineral component of soil. These separates are called sand, silt, and clay. Hydrometer method was used to estimate particle size distribution without any pretreatment, except dispersion with calgon. Hydrometer method and International pipette method are used commonly to determine the particle size of the soil (Both methods are based on principle of sedimentation known as Stocks law) [3]. In the present study, hydrometer method was used to estimate particle size distribution without any pretreatment, except dispersion with calgon.

2.3.2 Bulk density

Bulk density is the proportion of the weight of a soil relative to its volume. It is expressed as a unit of weight per volume, and is commonly measured in units of grams per cubic centimeters (g/cc). Bulk density of soil was estimated by soil corer method (Brady and Weil, 2004) [5] using soil core with a known diameter (d) and height (h).

2.3.3. Moisture content

Soil water enhances various soil physicochemical reactions and supplies essential nutrients for plants and animals including micro and macro organisms residing in soils in order that they can carry out their own activities. The soil moisture content indicates the amount of water present in the soil. It is commonly expressed as the amount of water (in mm of water depth) present in a depth of one metre of soil. Moisture content of soil was calculated by oven drying method (Soil Survey Standard Test Method) using moisture box, electronic weight machine and soil core. The soil samples were collected and kept in the oven at a temperature of 105˚C for 24 hours.

2.3.4. Soil moisture characteristics

The portion of stored soil water that can readily be absorbed by plants is said to be available water. The plant can avail soil water that is held within a potential between field capacity (FC) of 0.3 bar and permanent wilting point (PWP) of 15 bar. Permanent wilting point (PWP) or wilting point (WP) is defined as the minimal point of soil moisture the plant requires not to wilt. Field capacity (FC) is the amount of soil moisture or water content held in the soil after excess water has drained away and the rate of downward movement has decreased. So, the available soil water characteristics at different potentials (0.3 bar, 1 bar, 5 bar and 15 bar) were determined using the pressure plate apparatus.

2.4 Analysis of soil chemical properties pH

By definition, 'pH' is a measure of the active hydrogen ion (H+) concentration. It is an indication of the acidity or alkalinity of a soil, and also known as "soil reaction". Soil pH was measured by "Electrometric method" using pH meter.

2.4.2 Electrical conductivity

Soil utilizes organic materials for a variety of uses, including providing plants with nutrients, aiding in irrigation, lowering evaporation rates, increasing the nutrient-holding capacity of the soil and providing food for worms, bacteria and other soil organisms. The EC was calculated with the help of a conductivity meter.

3. RESULTS AND DISCUSSION

3.1 Topographic and land characteristics

The topography and land characteristics of the study site are presented in Table 1. The topographical survey revealed that the top land surface is sloppy and undulating.

Table 1. Topography and land characteristics of the study site

Sites	Obser-vation points	Elevation (m) w.r.t. MSL	Slope (%)	Range of soil depth (cm)	Topography and class	Drainage type and class
Left Side	(A)	36.5	2.85		Gently sloping to gently undulating B_2	Moderately well drained C_3
	(B)	36.27	2.04			
	(C)	35.85	4.17			
	(D)	35.77	3.53	25-50		
	(E)	35.72	3.31			
	(F)	35.81	2.60			
	(G)	35.83	2.22			
	(H)	35.84	1.98			
Right Side	(A)	36.32	2.57		Moderately sloping to gently undulating B_3	Moderately well drained C_3
	(B)	35.59	8.67			
	(C)	35.37	7.96			
	(D)	34.87	9.11	50-90		
	(E)	34.24	10.00			
	(F)	34.27	7.91			
	(G)	34.67	5.67			
	(H)	34.59	5.31			

It was observed that left side of terrain has an average land slope of about 3% and so the land is gently sloping to undulating (class B_2 type). However, average land slope of right side of terrain was found to be 7% and which is moderately sloping to gently undulating (Class B_3 type). The drainage systems of both the sides were found to be moderately well drained which indicates that it is a class C_3 type (Land Capability Classification, Agriculture Handbook, United States Department of Agriculture, 1958). The average soil depth in the study area was found 60 cm. So, further sampling and analysis were carried out using the individual samples from four profile depths (0-15, 15-30, 30-45 and 45-60cm).

3.2 Soil physical properties status

Soil samples collected from average 8 locations and 4 depths of profile in the study site were used to determine the soil texture, bulk density, moisture content, soil moisture characteristics.

According to USDA textural classification triangle, it was found that the soils of the study site are sandy loam in nature with average sand, silt and clay percentage of 73%, 11% and 17%, respectively, indicating the coarse nature of the soil and the low water retention characteristics. The depth wise average soil texture status of the study site is presented in Table 2.

Table 2. Depth wise average soil texture status of the study site

Sites	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Soil Type
Left	0-15	20	10	70	Sandy loam
	15-30	16	6	78	Sandy loam
	30-45	12	12	76	Sandy loam
	45-60	10	12	78	Sandy loam
Right	0-15	16	12	72	Sandy loam
	15-30	20	10	70	Sandy loam
	30-45	20	12	68	Sandy loam
	45-60	20	12	68	Sandy loam

The depth wise wet and dry bulk density, moisture content of the study site are presented in Table 3. The average bulk density was found to be 2g/cc. The average moisture content was found to be 9% which implies available soil water is held within a potential between field capacity (FC) and permanent wilting point (PWP). The moisture content was found in decreasing trend with the increase in the soil depth and vice versa. It was observed that soils with high amount of clay have higher amount of water than soils with low amount of clay content.

The variations of the soil water characteristics are presented in Figure 3. The soil water content at field capacity and wilting points at 0-15, 15-30, 30-45 and 45-60 cm profile were observed to be 22.42, 23.11, 23.09, 23.51% and 12.44, 11.87, 12.30, 11.91% respectively. Soil water content at FC and PWP were found to be increasing with depth for the soil may be due to variation in topography and land use all affect the distribution of soil moisture and different management practice. Soils with high amount of clay have higher amount of water both at 1/3 and 15 bars than soils with low amount of clay content.

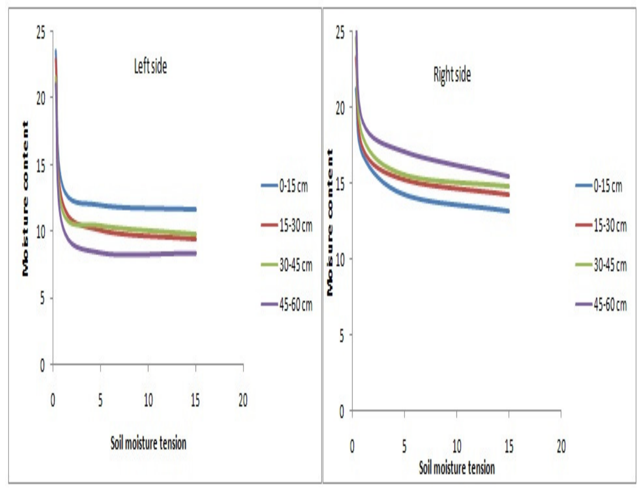

Figure 2. Depth wise soil moisture characteristic in the study site.

3.3. Soil chemical properties status

The observed pH and EC of different soil samples of the study site is also shown in Figure 3 and 4, respectively. The EC of the soil samples were found to be in the range of 4000 to 13600 Micro Siemen (µS). It has been found from the graph that the EC is highest at the soil profile 15-30 cm in left side of terrain and is decreasing with the increase in the depth. The EC of the soil in right side of terrain is almost similar in all the places.

The average pH and EC of all the soil samples were found to be 5.3 and 8468.75µS, respectively which indicate that the soil is strongly acidic in nature and about 50% of applied fertilizer may be available to plants. The pH was found to be more in the upper surface of both the fields as compared to other layers.

Table 3. Depth wise status of bulk density and moisture content the study site.

Observation Points	Depths (cm)	Dry Bulk Density (g/cc)	Wet Bulk Density (g/cc)	Moisture Content (%)	Dry Bulk Density (g/cc)	Wet Bulk Density (g/cc)	Moisture Content (%)
		Left side of terrain			Right side of terrain		
A	0-15	1.83	2.06	12.23	1.59	1.91	20.47
	15-30	1.85	2.02	9.64	1.62	1.83	12.93
	30-45	1.87	2.06	10.50	1.72	1.90	10.17
	45-60	2.17	2.22	2.21	1.84	1.96	6.51
B	0-15	1.35	1.58	16.58	1.42	1.73	21.89
	15-30	1.61	1.72	7.28	1.60	1.81	13.16
	30-45	1.75	1.87	6.69	1.58	1.76	11.38
	45-60	2.32	2.45	5.52	2.14	2.27	5.83
C	0-15	1.58	1.90	19.85	1.59	1.94	22.45
	15-30	1.85	1.96	6.33	1.83	1.96	7.34
	30-45	1.65	1.76	7.04	1.93	1.98	2.96
	45-60	2.26	2.39	5.67	1.96	2.01	2.55
D	0-15	1.66	1.93	16.80	1.53	1.88	22.71
	15-30	1.80	1.92	6.85	1.74	1.85	6.74
	30-45	1.78	1.87	4.71	1.91	1.98	3.61
	45-60	1.89	1.97	4.02	1.99	2.03	2.12
E	0-15	1.78	2.01	12.72	1.57	1.85	17.43
	15-30	1.92	2.05	6.61	1.72	1.84	6.93
	30-45	1.95	2.03	3.94	1.83	1.90	3.95
	45-60	1.99	2.06	3.31	1.95	2.02	3.17
F	0-15	1.58	1.89	19.72	1.59	1.91	20.40
	15-30	1.78	1.90	6.73	1.84	1.96	6.54
	30-45	1.88	1.97	4.57	1.83	1.90	3.55
	45-60	1.95	2.02	3.33	1.98	2.03	2.17
G	0-15	1.63	1.92	17.46	1.59	1.89	18.59
	15-30	1.78	1.89	6.29	1.88	2.00	6.48
	30-45	1.89	1.96	3.33	1.85	1.94	4.48
	45-60	1.93	1.99	3.16	1.95	2.01	2.87
H	0-15	1.49	1.86	24.87	1.57	2.01	20.20
	15-30	1.75	1.87	6.91	1.74	2.01	6.91
	30-45	1.83	1.91	4.37	1.84	2.01	4.02
	45-60	1.87	1.94	3.36	1.93	2.01	2.96

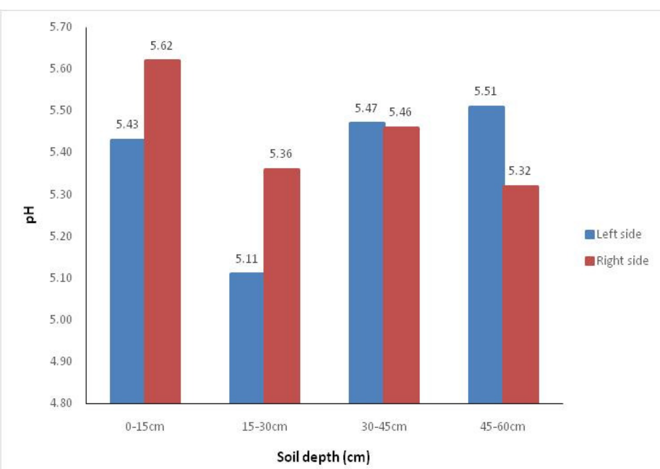

Figure 3. Depth wise average pH status observed in the study site.

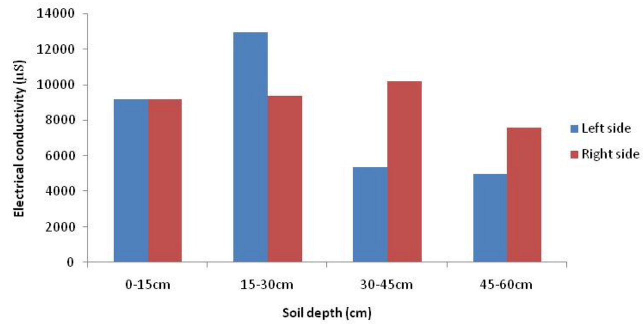

Figure 4. Depth wise average EC status observed in the study site.

4. AGRICULTURAL PLANNING

The development of plants and measures to achieve greater and more efficient output from agriculture; a sound agriculture policy should be able to reconcile three basic needs: the production of food and agricultural products, protection of the environment and the maintenance of the agricultural farm. The hilly terrain is not suitable for the cultivation of rice as it is a well drained land and rice requires lot of water during its plantation period. However, low water requirement crops like carrot, maize, tomato, sweet potato, peas and flowers like roses, cosmos, marigold, hibiscus and calendula are suitable for cultivation. Based on the basic research with the specific parameters of soil, the crop planning for sustainable agriculture in a hilly terrain is proposed and presented in the Table 4.

Table 4. Sustainable agricultural planning of the study site.

Sites	Soil							Crop
	Type	Texture (Avg)	Bulk density (g/cc) (Avg)	MC (%) (Avg)	Soil water Characteristics (Avg)	Soil pH (Avg.)	Soil EC(µS) (Avg.)	
Left side	2-4% slope, gently sloping to gently undulating moderately well drained	Sandy loam	1.82	8.52	21.03 (FC) 8.38 (WP)	5.36	8300	Tomato, Maize, Sweet Potatoes, Radish, rose, calendula, cosmos, marigold, pineapple etc.
Right side	3-10% slope, Moderately sloping to gently undulating well drained	Sandy loam	1.77	9.48	25.98 (FC) 15.43 (WP)	5.33	8637.5	Tomato, Maize, Sweet Potatoes, Radish, rose, calendula, cosmos, marigold, pineapple etc.

Agricultural intensification without adequate restoration of soil fertility may threaten the sustainability of agriculture. Quantitative estimation of plant nutrient depletion from soils is useful for comprehending the state of soil degradation and for devising corrective measures.

5. CONCLUSIONS

Soil physical properties also largely determine the soil's water and air supplying capacity to plants. Many soil physical properties change with changes in land use system and its management such as intensity of cultivation, the instrument used and the nature of the land under cultivation, rendering the soil less permeable and more susceptible to runoff and erosion losses. So, the present study was carried out assess soil physical and chemical properties of a hilly terrain situated in Assam University, Silchar and surrounded by many low hills of Assam state. The physical properties such as soil texture, bulk density, moisture content, soil moisture characteristics and chemical properties such as pH, EC of the soil samples were determined using standard methods.

The land topographical survey and soil characteristics study revealed that the study site is coming under sloppy (3-7%) land. The soil is sandy loam with acidic in nature. Average bulk density and moisture content was found to be 2g/cc and 9%, respectively. The soil water content at field capacity and wilting points at 0-15, 15-30, 30-45 and 45-60 cm profile were observed 22.42, 23.11, 23.09, 23.51% and 12.44, 11.87, 12.30, 11.91% respectively. The findings provide the logistic and basic information for a sustainable agricultural planning in the study site. However, for increasing the yield of the crops to be grown in the hilly terrain a detailed fertility status with available nutrients are also to be studied.

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