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Soil Bulk Density as related to Soil Texture, Organic Matter Content and available total Nutrients of Coimbatore Soil

Pravin R. Chaudhari*, Dodha V. Ahire*, Vidya D. Ahire*, Manab Chkravarty and Saroj Maity****

*Microwave Research Laboratory, Z. B. Patil College, Dhule - 424002, India
**Space Application Centre, ISRO, Ahmedabad – 380015, India

Abstract- Bulk density of a soil is a dynamic property that varies with the soil structural conditions. In general, it increases with profile depth, due to changes in organic matter content, porosity and compaction. The main objective of this work was to investigate the dependence of bulk density on texture, organic matter content and available nutrients (macro and micro nutrients) for soil of Coimbatore. The relationships between some physical and chemical properties of soil such as, clay content (C), silt content (Si), sand content (S), CaCO3, organic matter content (OMC), total macro and micro nutrient content with soil bulk density (ρb) were studied for eight surface soil samples (0-15 cm). Soil bulk density showed negative relationships with all soil properties (Si, C, CaCO3, OMC, total macro and total micro nutrient content) except with sand content (S). Besides texture and OMC, the nutrient concentration was also the most effective factor that affected the bulk density of soils.

Index Terms- soil bulk density, clay content, silt content, sand content, organic matter content, total macro and micro nutrient content.

I. Introduction

Soils are composed of solids (minerals and organic matter), and pores which hold air and water. The bulk density of a soil sample of known volume is the mass (or weight) of that sample divided by the bulk volume. The "ideal" soil would hold sufficient air and water to meet the needs of plants with enough pore space for easy root penetration, while the mineral soil particles would provide physical support and plant essential nutrients. Soil bulk density is a basic soil property influenced by some soil physical and chemical properties.

Bulk density is influenced by the amount of organic matter in soils, their texture, constituent minerals and porosity. Knowledge of soil bulk density is essential for soil management, and information about it is important in soil compaction as well as in the planning of modern farming techniques.

Soil bulk density measurements are often required as an input parameter for models that predict soil processes. Such models often use bulk density measurements to account for horizon mass when aggregating soil data. Methods to measure bulk density are labor intensive and time-consuming. Thus, models have been developed to predict bulk density from soil physical and chemical data [1 - 2].

A normal range of bulk densities for clay is 1.0 to 1.6 mg/m3 and a normal range for sand is 1.2 to 1.8 mg/m3 with potential root restriction occurring at ≥ 1.4 mg/m^3 for clay and ≥1.6 mg/m^3 for sand [3].

Saxton, et. al. [4] estimated generalized bulk densities and soil-water characteristics from texture and developed a set of equations from which soil-water characteristic equations for a number of soil textural classes can be derived.

Bulk density values are required for converting gravimetric soil water content to volumetric and to calculate soil porosity which is the amount pore space in the soil [5]. Total porosity can be calculated by using bulk density and particle density of soil [6]. Soil bulk density should be used as an indicator of soil quality parameter. Akgül and Özdemir [7] studied the relationships between soil bulk density and some soil properties explained that these constants can be estimated by means of regression models.

Organic carbon influences many soil characteristics including colour, nutrient holding capacity, nutrient turnover and stability, which in turn influence water relations, aeration and workability [8]. Soil organic matter plays a key role in nutrient cycling and can help improve soil structure. The Bulk density depends on several factors such as compaction, consolidation and amount of SOC present in the soil but it is highly correlated to the organic carbon content [9 - 10].

Organic matter is different to organic carbon in that it includes all the elements (hydrogen, oxygen, nitrogen, etc) that are components of organic compounds, not just carbon. Soil organic carbon (SOC), soil organic matter (SOM) and the correlation between bulk densities are frequently used to estimate carbon pools [11]. Organic matter is an important source of nutrients for plants. Nitrogen, phosphorus and sulphur are considered macronutrients, essential micronutrients are iron, manganese, zinc, copper, boron, molybdenum, and chlorine and beneficial but not essential elements are silicon, vanadium, cobalt and nickel. Erdal Sakin [12] obtained the relationships between organic carbon, organic matter and bulk density in arid-semi arid soils in Southeast Anatolia region. Similar studies were performed by Catherine Pe´ rie´ and Rock Ouimet [13] for forest soils. T. Aşkın and N. Özdemir [14] obtained the relation of soil bulk density with soil particle size distribution and organic matter content. R. Laiho, et. al. [15] studied the variability in mineral nutrient concentrations (P, K, Ca, Mg, Fe, Mn, Zn) and bulk density within floristically defined peatland sites. E. Reintam , et. al. [16] reported the effect of bulk density on nutrient (N, P, K) assimilation and on cellular fluid pH of spring barley with different levels of fertilization.

From above discussion it was inferred that increase in organic matter decreases the bulk density of soil. On the other hand increase in organic matter also leads to change the nutrient concentration of soil. So that available nutrients in the soil may play an important role in the variation of bulk density of soil. Keeping this in mind we proposed to study the effect of texture, organic matter content and total nutrient content on bulk density of soils of Coimbatore.

II. MATERIALS AND METHODS

Study Area

Coimbatore is located at an elevation of about 411 meters. It lies between 10° 10' and 11° 30' of the northern latitude and 76° 40' and 77° 30' of eastern longitude. The mean maximum and minimum temperatures varies between 35 °C and 18 °C highest temperature ever recorded is 41 °C and lowest is 12 °C. On an average, the district gets 695 mm. of rainfall in a year. Coimbatore receives high rainfall from North East Monsoon of 444.3 mm. followed by South West Monsoon Period and hot weather period. Rainfall distribution is also good.

The soil types of a particular area play critical role is determining the fertility status and cropping pattern. Red Calcareous soil, Black soil and Red non-calcareous soil are major soil types found in Coimbatore district. Percentage distribution of Red Calcareous soil is high as compared to other soil types. The soil is predominantly black soil which is suitable for cotton crop. The soil in Coimbatore taluk is enriched with organic matter from the hill ranges. The red soils around the Anamalais are fertile. The other important causes for decline in crop production response to the application of inputs and technology is the gradual degradation of soil, the key factor for sustaining agriculture. The imbalanced fertilizer consumption, without taking into account the soil needs and soil health is proving counter productive. Therefore, soil analysis has to be taken on priority to find the status of nutrients and the requirement of fertilizers to supplement these deficiencies.

Soil Sampling and physico-chemical analyses

The aim of this study was to determine bulk density of soil samples and its relationship with the soil particle distribution, organic matter and status of nutrients of soil in Coimbatore region. Before sampling 15 mm topsoil was removed. Soil samples were collected from eight different locations at the depth of 15cm. in zigzag pattern across the required areas. Five pits were dug for each sample. A composite sample of about 2 Kg. was taken through mixing of represented soil sample. These soils were first sieved by gyrator sieve shaker with approximately 2 mm spacing to remove the coarser particles and then allowed to dry in air for 1 hour.

The proposed samples were analyzed for physico-chemical properties using standard procedures. . The nutrient concentrations and physical parameters of soil samples are represented in **Tables 1 and 2** respectively.

The *p*H and electrical conductivity of soil samples were determined in 1: 2.5, soil: water suspension [17]. Organic Matter (OM) was obtained from estimated organic carbon (OC) using the conventional conversion [18 - 19]

$$OM = 1.7 \times OC \qquad \ldots\ldots\ldots\ (1)$$

The soil bulk density was selected as dependent variables to determine statistical relationships of soil texture, organic matter content and nutrient concentrations with soil bulk density. Factors affecting bulk density are Porosity, Texture and Organic matter content. Clay soils tend to have a higher total porosity than sandy soils. However, the relationship between texture and bulk density is tenuous and depends on a variety of factors such as organic matter content and depth in the soil profile. Bulk density is closely related to the soil porosity through the following relationship [20]

$$n = 1 - (\rho_b / \rho_s) \qquad \ldots\ldots\ldots\ (2)$$

Where, n = porosity ; ρ_b = bulk density and ρ_s = particle density

Measurement of Electrical Conductivity and pH

A pH and Electrical Conductivity of soil samples were measured by Soil Testing Kit Model 161E. A 20 gms of collected soil was weighed out into a 150 ml plastic jar and 100 ml distill water was added to it. Lid of jar was packed tightly and stirred continuously for 5 minutes. Then it was kept overnight and stirred again. Allowed to set for 15 minutes and strained sample into clean measuring cup. A pH and Electrical conductivity readings were taken.

Statistical analysis

The relationship between different soil parameters and nutrient content of soils were determined using correlation coefficient "r".

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\sqrt{n\left(\sum x^2\right) - \left(\sum x\right)^2}\sqrt{n\left(\sum y^2\right) - \left(\sum y\right)^2}} \qquad \text{--------}\ (3)$$

Where *n* is the number of pairs of data (x, y).

Simple Correlation Coefficients (r) between soil parameters and bulk density are listed in **Table 3.**

III. DISCUSSION

Texture, Bulk Density and Porosity of soil samples

The sand, silt and clay of collected samples ranges 67.25 - 90, 2 - 16.75 and 3.75 – 26.25 % respectively and these soils were categorized as sandy clay loam, loamy sand, sandy loam and sand.

Because of more percentage of sand Bulk Density and Porosity of soil samples ranging (1.25 - 1.57 Mg m^{-3}) and (0.3921 - 0.4857) respectively.

CaCO3, pH and Electrical Conductivity of soil samples

Calcium Carbonate (CaCO3) content (1.00 – 8.5 %) of soil samples showed that four samples were slightly calcareous, two samples were moderately calcareous and the remaining two were calcareous in nature. The pH (5.39 – 8.85) values indicated that two samples were acidic, four samples were alkaline and two were neutral. The values of electrical conductivity (0.1 - 0.26 ds /m) showed that all soil samples were normal i.e. non saline in nature.

Organic Carbon and Organic Matter Content of soil samples

A conversion factor of 1.72 is commonly used to convert organic carbon to organic matter as in equation (1). Organic Carbon and Organic Matter Content of soil samples varied as (0.13 – 0.78 %) and (0.22 -`1.33%) respectively.

Available Macronutrients in soil samples

According to Methods Manual of Soil Testing in India [21] the critical limits of Nitrogen (N), Phosphorus (P) and Potassium (K) for normal growth of plant were 280 kg/ha, 10 kg/ha and 108 kg/ha respectively. With this consideration the available Nitrogen content (88 - 138 kg/ha) of almost all samples was found to be very low. The Phosphorus content (6.38 - 68.47 kg/ha) of soils indicated that the one sample contain very low, two samples were contain low, three samples were contain medium and the remaining two samples were contain very high amount of Phosphorus. The available Potassium (123 - 964 kg/ha) showed that except one sample all samples were contain high amount of Potassium. All soil samples were containing adequate amount of available Calcium (Ca) (152 - 756 meq/100 gm) but low amount of Magnesium (Mg) (20 - 56 meq/100 gm).

Available Micronutrients in soil samples

According to Lindsay and Norvell [22] 4.5 ppm of Iron (Fe) is considered as the critical limit for normal growth. Considering this limit the available Fe (0.12- 5.53 ppm) indicated that five samples were containing low amount and the remaining three samples were contain high amount of Fe.

Shukla and Gupta [23] reported 3.00 ppm as the critical limit for available Manganese (Mn). The available Mn (2.31- 23.16 ppm) showed that two samples were containing low amount while six samples were contain high amount of Mn.

Lindsay and Norvell [22] suggested the critical limit of Zinc (Zn) as 0.5 to 1.00 ppm, according to which available Zn (0.43 - 2.60 ppm) showed that two samples were contain low amount and six samples were contain high amount of Zn.

Considering 0.66 ppm as critical limit of Copper (Cu) for normal growth of plant [24] , the available Cu (0.11- 1.08 ppm) inferred that only one soil sample was contain less amount of available Cu while the remaining samples have adequate amount of available Cu.

IV. RESULTS

Relationship between bulk density and texture of soil

Effect of sand content on soil bulk density was found to be higher than that of the other soil properties. Clayey soils tend to have lower bulk densities and higher porosities than sandy soils. High degree positive correlation of bulk density was observed with sand content (r = 0.9094). While significant negative correlation of bulk density was observed with clay content (r = - 0.6332) and silt content (r = - 0.7343) of soil samples. The bulk density indirectly provides a measure of the soil porosity. Soil porosity is the ratio of the volume of soil pores to the total soil volume. Thus the bulk density of a soil is inversely related to the porosity. We also found strong negative correlation (r = - 0.8859) between porosity and bulk density of soil samples. All these correlations are shown in **Figs. 1 – 4.**

Jones [25] reported that the impact of the texture on bulk density is much, because of the organic carbon. Wagner et al. [26] estimated soil bulk density using soil texture parameters along with organic carbon content values. Bernoux, et al [27] found a correlation between texture and bulk density. Dinesh Kumar et. al. [28] indicated that soil texture specific tests would be required to determine the correct organic matter level to achieve a target bulk density to avoid the problem of compaction.

Relationship between bulk density with CaCO3, pH and Electrical Conductivity of soil samples

It was observed that the bulk density is dependent on calcareous and saline nature of soils but independent on whether the soil is acidic or alkaline. Statistical correlation studies showed significant negative correlations of bulk density with $CaCO_3$ (r = - 0.4952) content and electrical conductivity (r = - 0.6611) of soil as in **Figs. 5 and 6.** While correlation between bulk density and pH (r = - 0.2317) was negative but not so significant. However, Shaffer [29] observed highest correlation between pH and BD at 0 to 15 cm, but he did not indicate the reasons.

Relationship between bulk density and Organic Matter Content (or Organic Carbon) of soil samples

Many researchers [9-10], [12-14] obtained the relationship between organic matter and bulk density of soils and showed strong correlation between them. Curtis and Post [30] stated a reverse correlation between organic matter and bulk density. E. Sakin [31] determined the strongest correlation between bulk densities and organic matter among the data attained from the analysis results. We obtained similar results with strong negative correlation (r = - 0.8869) between organic matter and bulk density of soil samples. Thus our studies indicate that as the organic matter increases the bulk density of soil decreases (**Fig. 7)** which is required for the proper growth of the plants.

Relationship between bulk density and available Macronutrients in soil samples

We have studied the dependence of bulk density on available total primary (N+P+K) and secondary (Ca+Mg) macronutrients in the soil. It was found that the bulk density decreases as the total primary and secondary macronutrient contents in the soil increases as shown in **Figs. 8 and 9.** Statistical correlation studies showed strong negative correlation of bulk density with available total primary macronutrients (r = - 0.8615) and total secondary macronutrients (r = - 0.8119) in the soil. R. Laiho, et. al. [15] showed that the total variances of K and Mg decreases with increase in sampling depth i.e. bulk density.

Relationship between bulk density and available Micronutrients in soil samples

As that of macronutrients, the available total micronutrients (Fe + Mn + Zn + Cu) in the soil also varied bulk density of the soil. It was found that the bulk density decreases as the total micronutrient contents in the soil increases as shown in **Fig. 10.**

Statistical correlation studies showed strong negative correlation between bulk density and available total micronutrients (r = - 0.7089) in the soil. R. Laiho, et. al. [15] reported that the total variances of Fe and Zn decreases with increase in bulk density.

V. CONCLUSIONS

Following conclusions can be drawn for Coimbatore Soils -

1. Effect of sand content on soil bulk density was found to be higher than that of the other soil properties.

2. Bulk density was dependent on calcareous and saline nature of soils but independent on whether soil is acidic or alkaline.

3. There was high degree reverse correlation between organic matter and bulk density of soil.

4. As that of organic matter bulk density was dependent on available macronutrients and micronutrients in the soil. It decreases as the total macronutrient or total micronutrient contents in the soil increases.

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AUTHORS

First Author – Pravin R. Chaudhari, Microwave Research Laboratory, Z. B. Patil College, Dhule - 424002, India
Second Author – Dodha V. Ahire, Microwave Research Laboratory, Z. B. Patil College, Dhule - 424002, India
Third Author – Vidya D. Ahire, Microwave Research Laboratory, Z. B. Patil College, Dhule - 424002, India
Fourth Author – Manab Chkravarty, Space Application Centre, ISRO, Ahmedabad – 380015, India
Fifth Author – Saroj Maity, Space Application Centre, ISRO, Ahmedabad – 380015, India

Correspondence Author – Dr. Pravin R. Chaudhari , Microwave Research Laboratory, Department of Physics, Z. B. Patil College, Dhule-424002 (India),
E-mail: prc_61@rediffmail.com , Contact No. : 09422757654

Table: 1 Physico-chemical analysis of soil samples

Sample No.	pH (1:2.5)	E.C. (dSm^{-1})	OC	CaCO3	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
			(%)		($kgha^{-1}$)			(meq $100g^{-1}$ soil)		(ppm)			
1	6.80	0.03	0.31	1.25	138	14.14	328	248	20	4.49	17.69	1.38	0.57
2	8.41	0.12	0.55	3.0	113	19.13	565	656	56	2.94	4.47	1.23	0.79
3	7.08	0.08	0.13	1.0	94	6.38	123	152	16	5.53	12.79	1.21	0.49
4	5.39	0.07	0.26	2.0	100	10.81	365	316	20	3.49	2.32	0.51	0.25
5	6.49	0.10	0.44	6.0	107	19.40	304	484	28	0.69	3.96	0.47	0.36
6	8.40	0.10	0.31	2.0	100	21.62	259	312	24	4.83	6.28	0.43	0.46
7	8.28	0.18	0.78	8.5	138	68.47	964	756	36	1.63	23.16	2.60	1.08
8	8.85	0.08	0.24	3.5	88	44.91	260	396	24	0.12	2.31	1.01	0.11

Table: 2 Physical Parameters of Soil Series Samples

Sample No.	Sand	Silt	Clay	Textural class	Bulk Density	Particle Density	Porosity
	(%)				($Mg\ m^{-3}$)		
1	86.00	3.25	10.50	Loamy sand	1.43	2.57	0.4436
2	67.25	5.75	26.25	Sandy clay loam	1.26	2.45	0.4857
3	89.50	2.00	7.25	Sand	1.55	2.55	0.3922
4	86.75	2.50	10.00	Loamy sand	1.45	2.45	0.4082
5	89.25	6.00	3.75	Sand	1.47	2.49	0.4096
6	90.00	2.00	7.25	Sand	1.44	2.42	0.4050
7	73.50	16.75	9.00	Sandy loam	1.25	2.43	0.4856
8	89.75	2.25	7.25	Sand	1.57	2.71	0.4207

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Table: 3 Simple correlation coefficients (r) between soil properties

Related Soil Parameters	Correlation Coefficient (r)	Level of Significance
B D - Sand%	0.9094	High degree positive
B D - Clay%	- 0.6332	Significant negative
B D - Silt%	- 0.7343	Strong negative
B D - Porosity	- 0.8859	Strong negative
B D - CaCO3	- 0.4952	Significant negative
B D - E C	- 0.6611	Significant negative
B D - pH	- 0.2317	Negative but not significant
B D - OMC	- 0.8869	Strong negative
B D - (N+P+K)	- 0.8615	Strong negative
B D - (Ca+Mg)	- 0.8119	Strong negative
B D - (Fe+Mn +Zn+Cu)	- 0.7089	Strong negative

Where B D = Bulk Density
EC = Electrical Conductivity
OMC = Organic Matter Content

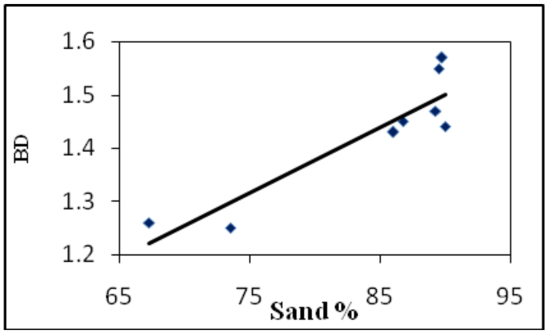

Figure 1: Variation of Bulk Density with Sand % content in soil samples

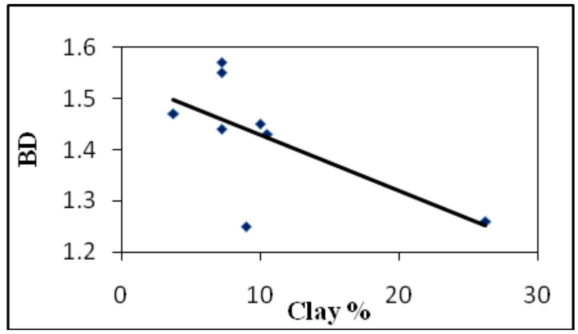

Figure 2: Variation of Bulk Density with Clay % content in soil samples

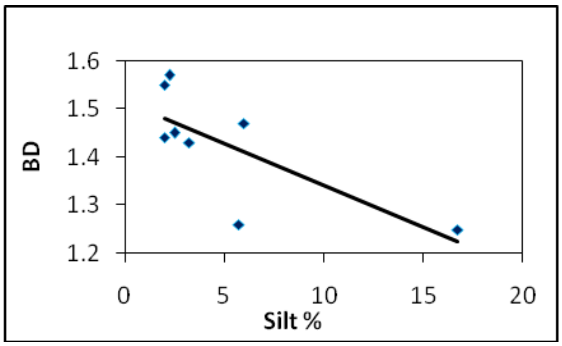

Figure 3: Variation of Bulk Density with Silt % content in soil samples

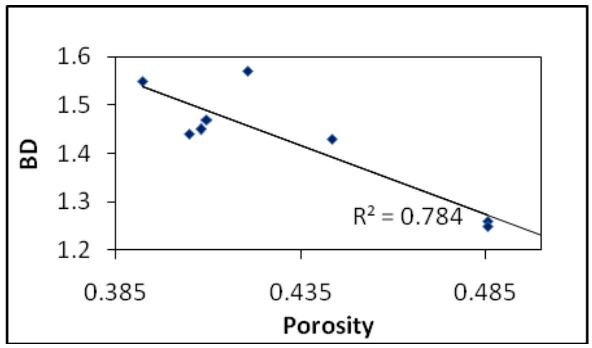

Figure 4: Variation of Bulk Density with Porosity of soil samples

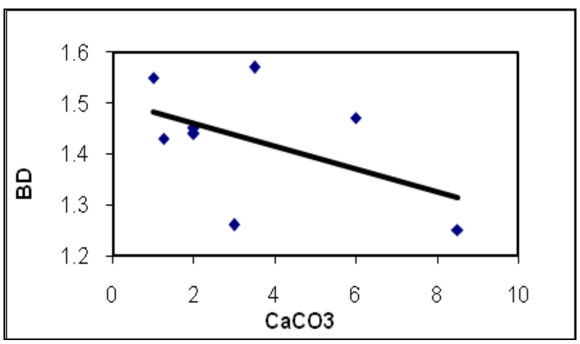

Figure 5: Variation of Bulk Density with CaCO3 in soil samples

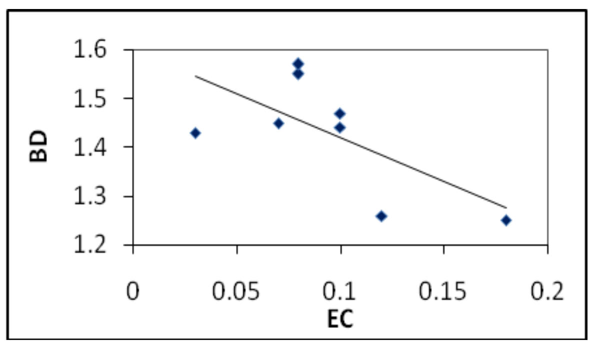

Figure 6: Variation of Bulk Density with Electrical Conductivity of soil samples

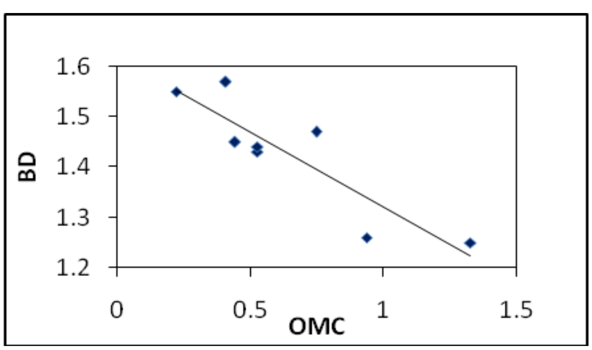

Figure 7: Variation of Bulk Density with Organic Matter Content of soil samples

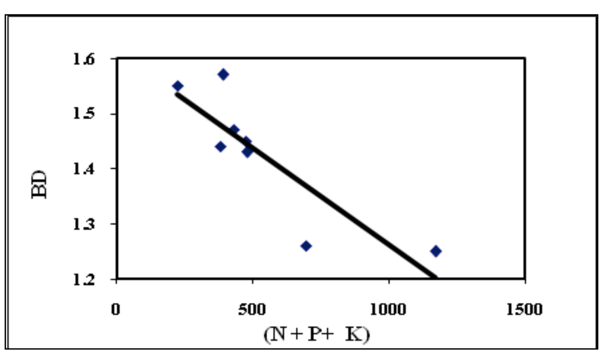

Figure 8: Variation of Bulk Density with (N+P+K) in soil samples

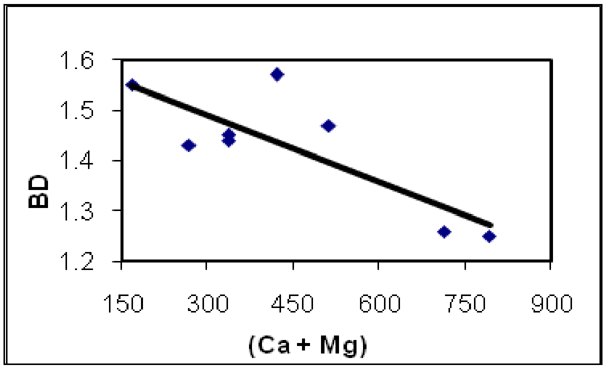

Figure 9: Variation of Bulk Density with (Ca + Mg) in soil samples

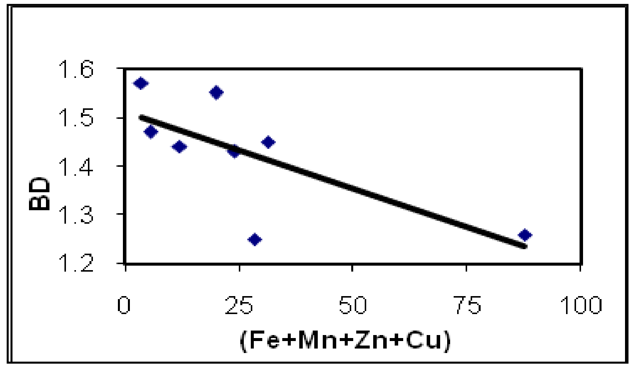

Figure 10: Variation of Bulk Density with (Fe+Mn+Zn+Cu) in soil samples