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Research Article

Soil Parameter Analysis of Bagmati River Basin Nepal

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Abstract

Soil parameters requires as inputs for various hydrological, soil erosion, biophysical and ecosystem models to estimate and forecast changes in climatic condition as well as in our future life conditions. Soil parameter of Bagmati River basin of Nepal is determined for its better management and fulfil demand of models. Soil samples (0-15cm and 15 -30 cm) depth were collected from 78 locations with 3 replicates, considering slope, aspect and land cover for analysis of texture, bulk density, organic matter content, electric conductivity and pH. These parameters were analysed using methods are sieve, core cutter, Walkley-Black wet combustion, electric conductivity meter and pH meter respectively. Saturated hydraulic conductivity was determined using double ring infiltrometer. Result reveals that soil distribution of the study area is consisted of twenty six different soil mapping units, mapping units 8 and 12 appear to be dominant in the area. Soil texture in both the depths varied from clay to sandy loam. The bulk density 1.523 g/cm^{-3}. Similarly, organic matter content 3.29% and 2.54%, electric conductivity 4.39 and 0.485 ms/cm of surface and sub soil respectively. Surface soil was acidic but sub soil was alkaline in nature with hydraulic conductivity 28.35 mm/hr. The highest positive correlation between is BD–pH followed by BD-SHC in both layer but highest negative correlation between BD-OC followed by EC- pH and vice versa for surface and sub soil respectively.

Keywords: *Soil, Bulk density, Organic matter, Electric conductivity, pH, Texture.*

1. Introduction

Soil is a one of the natural resources essential for the basic need for the life. It comprised of complex minerals, water, air and organic matter. It provides ecosystem services for life and acts as a water filter and a growing medium. It is the basis of our nation's agro-ecosystems which provides food, fodder and fuel (McCauley and Jacobsen, 2005). It is in the soils that we are able to observe all of the principles of biology, chemistry, and physics at work. It is the understanding of these principles which enables us to minimize the degradation and destruction of one of our most important natural resources (NRCS, 2006). Physical, chemical and physiographic properties of soil is an important component of terrestrial ecosystem. Changes in the abundance and composition of soil effects on many processes that occur in any system (Batjes, 1996). Numerous environmental, hydrological, flood and socio-economic models require soil parameters as inputs to estimate and forecast changes in our future life conditions. However, the availability of soil data is limited (Dobos *et al*, 2006). Because soil is a complex system, soil properties cannot be easily accessed directly from their reflectance spectra even under laboratory conditions (BenDor and Banin, 1994). Since under a remote sensing domain this capability could be even more problematic (Peng, 1998), neither quantitative nor semi-quantitative spatial analysis of many soil properties from reflectance data have yet received proper attention in either the point or imaging spectroscopy domain (Udelhoven *et al*, 1997). In this context field data is essential for soil scientist and researcher. Digital soil map (DSM) provides information of soil and its properties from spatially explicit soil inventories and from auxiliary landscape data (McBratney *et al*, 2003), bridging gaps between discrete soil maps and the continuous nature of soil (Burrough *et al*, 1997, Balkovic *et al* 2013). Emphasis has been given on the importance of bulk density, organic matter content, electric conductivity, pH and saturated hydraulic conductivity that plays vital role in relevant research and study.

Bulk density and total porosity are inversely related. It is most frequently used physical quantities to characterize the state of soil compaction. As density increases porosity decreases and bearing capacity increases. A balance between density, porosity, and bearing capacity needs to be achieved for civil engineering works, forest management, agricultural management water resources management etc. (Alavi *et al*, 2010). Similarly, soil organic matter is a dynamic property of soil, it influences many soil physical properties i.e. increases water retention, increases aggregate stability, decreases compaction upon mechanical stresses, often increases soil aeration, protects soil surface from erosion, modifies soil albedo. It also has a major role on soil biological properties, being the source of elements and energy for all

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soil heterotrophs. Its decomposition and mineralization sustains food webs, maintains biodiversity in soils, and ensures the recycling of carbon and other elements in terrestrial ecosystems (Adeniji *et al*, 2013, Chenu and Robert, 2014). Another property is saturated hydraulic conductivity which provides information regarding the constant rate of water infiltrates and remaining amount of precipitation run off and contributes in main stream causes flood.

2. Study area

The study area is Bagmati river basin of Nepal. This river originates at an elevation of around 2700m in Shivpuri National park and flows towards south up to the Koshi river in Bihar state of India. The basin area of this river up to the Indo-Nepal border is about 3550km^2 at about 70m above the mean sea level. The total length of the river from its origin to the Indo-Nepal border is 170 km (Shrestha *et al* 2008). The river passes through three physiographic regions i.e. Middle Mountain, Siwalik and Terai (Jha, 2002; Dulal *et al*, 2006). Soil found in the area are sand, loamy sand, sandy loam, silt loam, silty clay loam and silty clay. The dominant soil type is loamy soil.

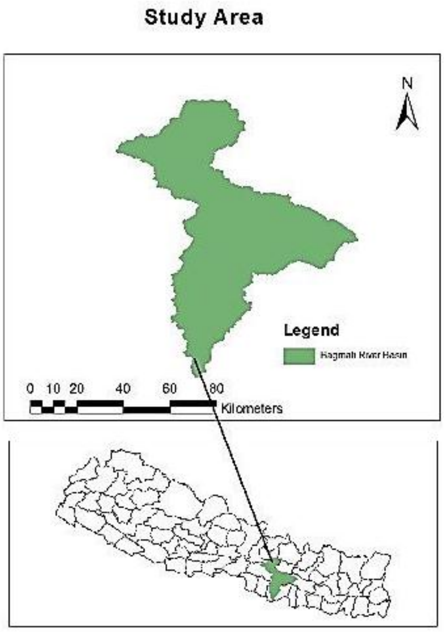

Fig.1 Map of Study area

3. Methodology

Land System map published by Department of Survey Nepal, prepared by Land Resource Mapping Project (LRMP) in 1: 50,000 scale were taken in hardcopy as sheet no. 72E/1 to 8, 72E/10 to 12, 72E/15, 72E/16, 72F/1 &72F/5 and scanned with A_0 high resolution scanner. Electronically scanned map were rectified to WGS 84. Such maps were mosaicked and digitized and final attributes table were created for soil map preparation using ESRI Arc GIS 9.3 software. Arc-hydro tool used for watershed delineation and stream network.

The study area were divided in 1km x 1km grid and each grid were treated as a unit for systematically numbering. Random table was used to select representative unit of the area. Soil map, random table and Garmin GPS was used for determination of sample site. It was collected considering slope aspect and land cover for analysis of bulk density, available organic matter, Electric conductivity, Soil pH and saturated hydraulic conductivity for determination as well as verification of soil types and its properties.

Bulk density of the soil samples were determined using core cutter method (Blake and Hartge, 1986, Jaber and Al-Qinna, 2011). Samples were taken to determine total soil water content by weight and to calculate bulk density. Bulk density were calculated from oven dry (105°C for 72 hour) soil mass and cylinder volume. The remainder of the samples were weighed, dried (31°C for 72 hour) and crushed to pass through 0.2 mm sieve for total organic matter (TOM). Which were determined following Walkley-Black wet combustion method (Nelson and Sommers, 1996; Schumacher, 2002). Total organic carbon in percentages were calculated (Frank *et al*, 1995) by dividing TOM with form factor 1.7 (Baize, 1993). Soil electric conductivity and pH analysed with help of electric conductivity meter and pH meter respectively. Saturated hydraulic conductivity was determined in field using double ring infitrometer.

3. Result and Discussion

Soil and its characteristics such as soil Bulk Density, Available Organic Matter, Saturated Hydraulic Conductivity and Stream Network Maps are as follows:

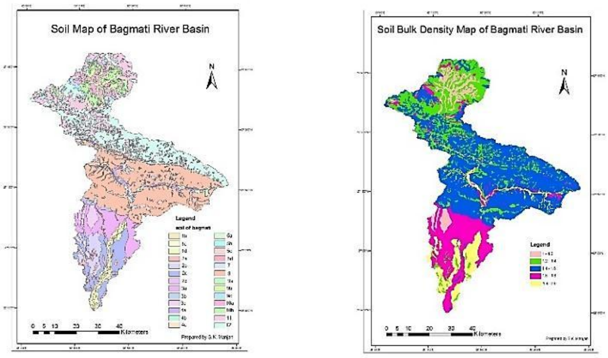

Fig.2 &3 Soil and Bulk density map of the area

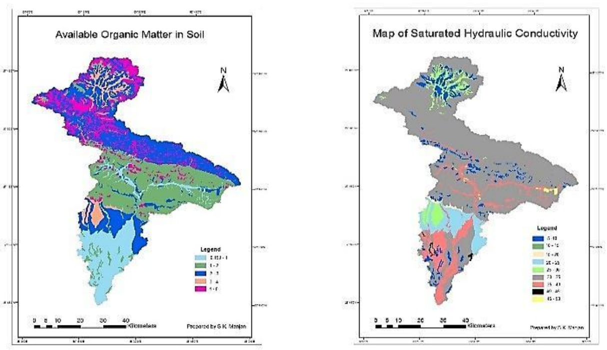

Fig.4 &5 Organic matter and Saturated hydraulic conductivity map of the area

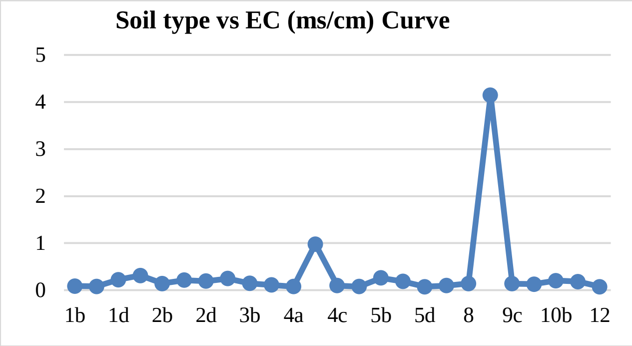

Fig.5 Soil type vs Electric conductivity map of the area

Table 1 Soil parameters analysis

Surface soil				
Analysis	Min	Max	Mean	coefficient of variation %
Bulk Density	1.04	1.99	1.52	15.82
organic matter %	0.33	8.14	3.29	60.6
Organic Carbon	0.19	4.79	1.94	60.6
Saturated Hydraulic Conductivity K (mm/hr.)	5.2	48	28.35	41.87
Clay	4.67	29.5	11.35	51.9
Silt	2.56	74.56	36.89	49.95
Sand	16.8	88.8	51.77	40.42
EC (micro seimen/ cm)	0.075	4.146	0.338	235.8
PH	4.49	8.66	6.88	17

Sub soil				
Analysis	Min	Max	Mean	coefficient of variation %
Bulk Density	1.083	2.28	1.54	19.87
organic matter %	0.23	7.67	2.54	67.97
Organic Carbon	0.13	4.51	1.496	67.97
Saturated Hydraulic Conductivity K (mm/hr.)	5.2	48	27.88	42.63
Clay	2.33	39	13.34	75.32
Silt	1.44	81.44	35.76	54.64
Sand	9.2	89.36	50.896	46.94
EC (micro seimen/ cm)	0.04	8.083	0.485	328.15
PH	3.82	8.78	6.9	19.6

Soil classification

Soil Classification is the grouping of soils with a similar range of properties into units classified by LRMP were geo-referenced and mapped. Soil map of the area is shown as fig.1. Soil type found in the area are sand, loamy sand, sandy loam, silt loam, silty clay loam and silty clay.

Soil texture

Sand content in surface soil ranged from 16.8 to 88.8 % with a mean value of 51.77% and coefficient of variation about 40%., while it ranged from 9.2 to 89.36% in sub soil with a mean value of about 50 % and coefficient of variation about 47%. However, mean of both the depth were almost similar but coefficient of variation in sub soil were more. Silt content in surface soil ranged from 2.56 to 74.56% with a mean value of 36.89% and coefficient of variation about 50%, while it ranged from 1.44 to 81.44% in sub soil with a mean value of 35.76 % and coefficient of variation about 55%, Clay content in surface soil ranged from 4.67 to 29.5 % with a mean value of 11.35% and coefficient of variation about 52%, while it ranged from 2.33 to 39 % in sub soil with a mean value of 13.34% and coefficient of variation about 75%. Shown in table 1. Though the coefficient of variation for sand, silt and clay was almost the same, it was quite lower than clay of sub soil. Based on the average as well as the maximum values, silt and clay content was found to be lower in subsoil than the surface soil. The soil texture in both the depths varied from loamy sand to silty loam.

Bulk density

Bulk density of the surface soil ranged from 1.036 to 1.999 gram per cubic centimeter (gcm-3) with a mean value of 1.523 gcm-3 and coefficient of variation 15.8%. While it ranged from 1.083 to 2.283 gcm-3 in sub soil with a mean value of 1.535 gcm-3 and coefficient of variation about 20% shown in table 1 and map 2. The bulk density found in both layer are almost same but surface layer was dominated by sub layer. It is due to presence of more organic matter in surface soil.

Organic Matter

Organic matter content of the surface soil ranged from 0.328% to 8.143% with mean value of 3.294273% and 1.03% coefficient of variation. In case of sub soil, organic matter content ranged from 0.2261 to 7.667 % with mean value of 2.543506 % and 1.155492% coefficient of variation. Organic matter was considerably lower in sub soil than surface soil.

Electrical conductivity

Electrical conductivity of the surface soil ranged from 0.075 to 4.146 milliseimens per centimeter (ms/cm) with a mean value of 4.390827 ms/cm and coefficient of variation 2.36 ms/cm, while in surface soil ranged from 0.04 to 8.083 ms/cm with a mean value of 0.485056 ms/cm and coefficient of variation 3.28 ms/cm. though maximum electrical conductivity was in sub soil but on average more floating particle was in surface soil.

Soil pH

Soil pH of the surface soil ranged from 4.49 to 8.66 with a mean value of 6.877 and coefficient of variation 17%, while it ranged from 3.823 to 8.78 in sub soil with a mean value of 6.9 and coefficient of variation about 20%. Variation in pH was lesser in surface soil than sub soil. According to classification of soil reaction suggested by (Brady, 1985) about 37% soil sample were alkaline in 30 % were neutral and 33% acidic reaction.

Saturated hydraulic conductivity

Saturated hydraulic conductivity provides information regarding the constant rate of water infiltrates and

Table 2 Pearson correlation coefficient (r) between soil parameters

Related soil parameter	Surface soil Correlation coefficient (r)	Sub-surface soil Correlation coefficient(r)	Level of significant
Bulk Density - sand %	0.375258	0.164146	Positive
Bulk Density – Organic Matter %	-0.7646	-0.55	Significantly negative
Bulk Density –Electric Conductivity	-0.3911437	-0.3058	negative
Bulk Density -pH	0.825	0.801	
Bulk Density –saturated hyd. cond.	0.473537	0.423964	Significantly positive
Organic Carbon%- Electric Conductivity	0.286796648	0.321592	positive
Organic Carbon –pH	-0.57	-0.37916	Moderately negative
Electric Conductivity – pH	-0.60486	-0.64184	Moderately negative
Saturated hyd. Cond. - EC	0.055946672	0.056296	Slightly positive effect

remaining amount of precipitation run off which contributes in main stream causing flood. Saturated hydraulic conductivity of soil in the area is found as minimum 5.2 mm/hr. and maximum 48 mm/hr. with a mean value of 28.35 mm/hr. and coefficient of variation about 42%.

Relationship between bulk density and texture of soil

The simple correlation coefficient (r) between bulk density with soil parameters are given in Table 2. It was observed that the bulk density is dependent on texture of the soil. As the sand content of the soil sample increases the bulk density increases. Positive correlation of bulk density was observed with sand content as 0.375 and 0.164 for surface soil and sub soil respectively.

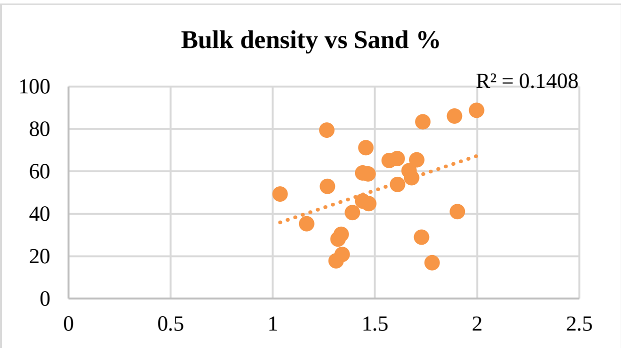

Fig.6 Correlation of BD vs Sand % of surface soil

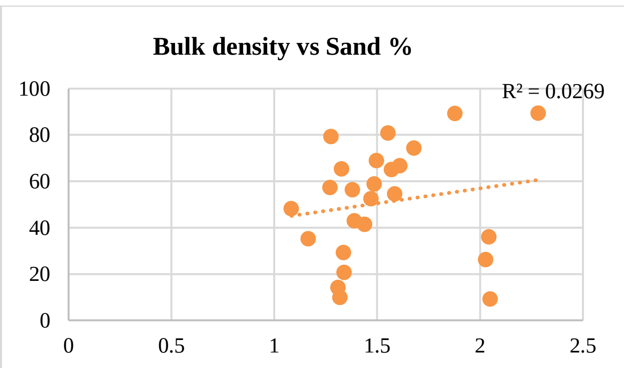

Fig.7 Correlation of BD vs Sand % of sub soil

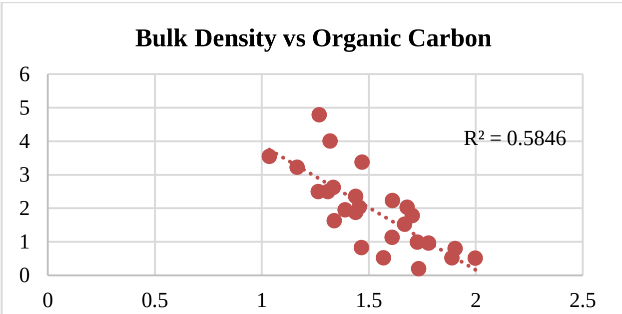

Fig.8 Correlation of BD vs OM of surface soil

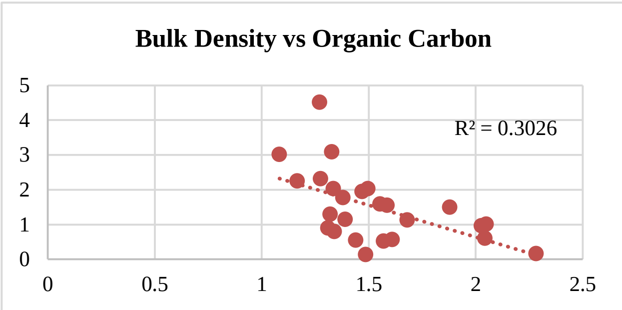

Fig.9 Correlation of BD vs OM of sub soil

Relationship between bulk densities with organic matter content in soil samples

It was obtained significantly negative correlation between bulk density and total organic matter content of the soil samples as -0.7646 and -0.55 for surface soil and sub soil respectively, which indicate that as the organic matter increases the bulk density of soil decreases. The bulk density bears an inverse relationship with the soil organic matter (White, 1987). Similar results were reported by many researchers (Askin and Ozdemir, 2003; Morisada *et al.*, 2004; Leifeld *et al.*, 2005; Perie and Ouimet, 2007; Sakin, 2012).

Relationship between bulk density and Electrical conductivity of soil samples

It was observed that correlation between BD and electrical conductivity were -0.39 and -0.31 for surface and sub soil respectively. It implies that relation between bulk density and electrical conductivity are negative correlation on both the layer. It shows that BD does not effect on EC.

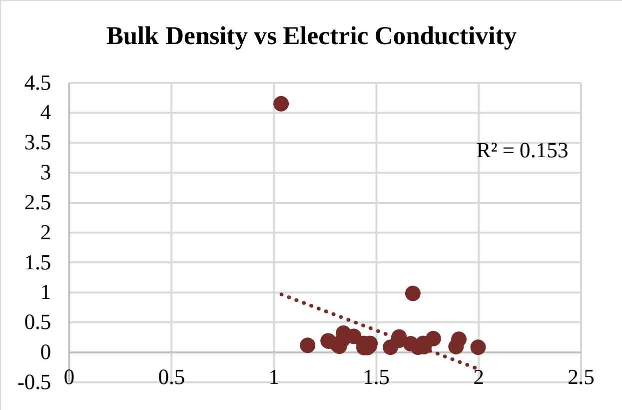

Fig.10 Correlation of BD vs EC of surface soil

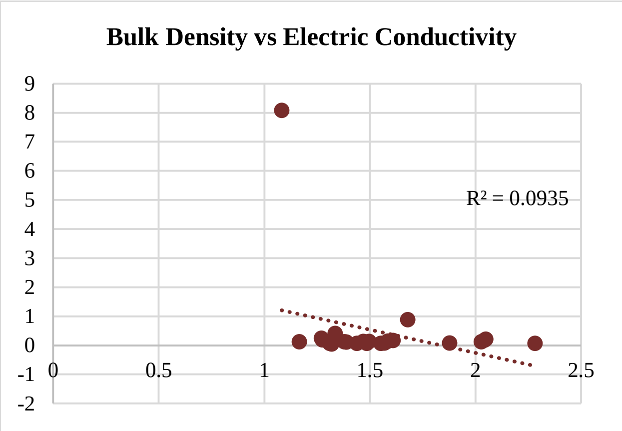

Fig.11 Correlation of BD vs EC of sub soil

Relationship between bulk density and pH of soil samples

Statistical correlation studies showed significant positive correlations of bulk density with soil pH as 0.825 and 0.801 for surface and sub soil respectively. It shows that acidic soil have less BD than alkaline soil.

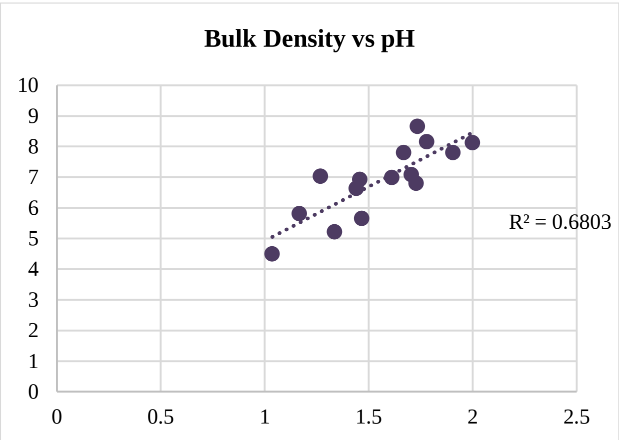

Fig.12 Correlation of BD vs pH of surface soil

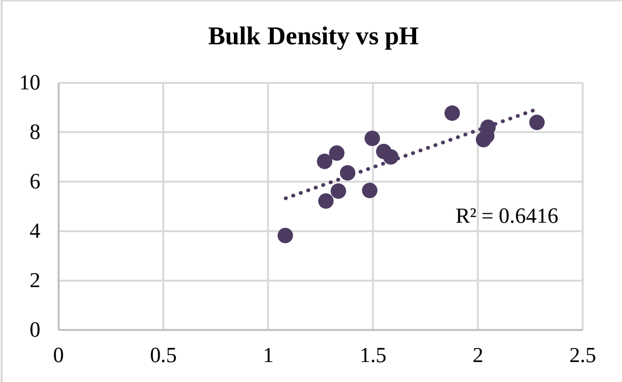

Fig.13 Correlation of BD vs pH of sub soil

Bulk density –saturated hydraulic conductivity.

It was analysed in both the layer it is significantly positive correlated, which indicate that as the bulk density increases the saturated hydraulic conductivity increases.

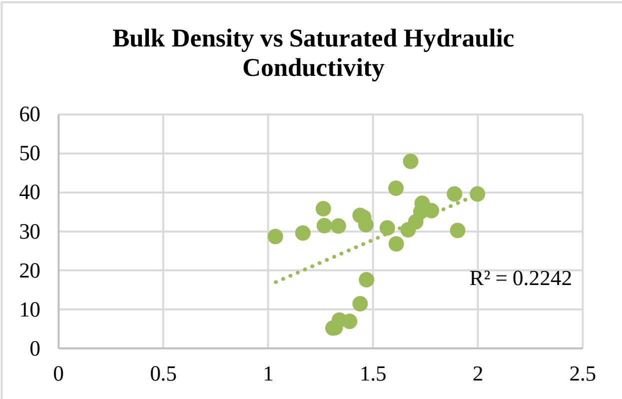

Fig.14 Correlation of BD vs Saturated hydraulic conductivity of surface soil

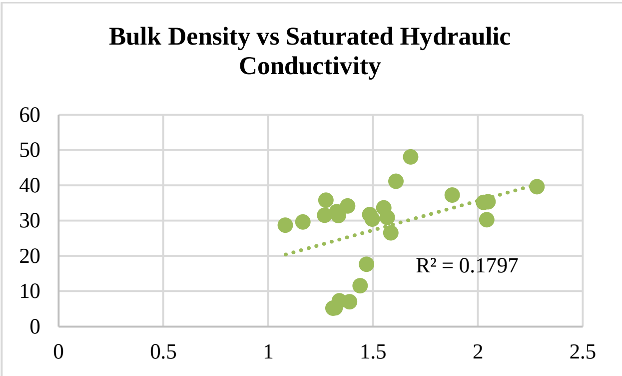

Fig.15 Correlation of BD vs Saturated hydraulic conductivity of sub soil

Organic carbon –Electric conductivity

It was analysed that organic matter had positive correlation (r = 0.29 & 0.32) with electric conductivity but negative correlation (r= -0.57 & -0.38) with pH. It shows that incensement of organic matter in soil increase electric conductivity but decrease soil pH and vice versa.

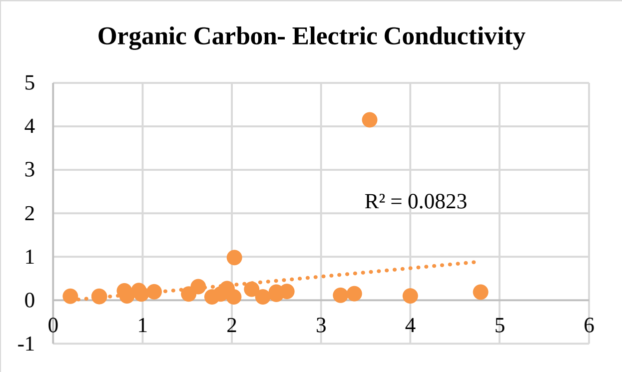

Fig.16 Correlation of Organic carbon vs Electric conductivity of surface soil

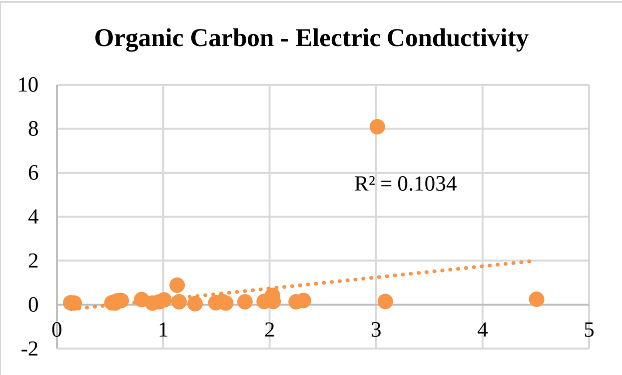

Fig.17 Correlation of Organic carbon vs Electric conductivity of sub soil

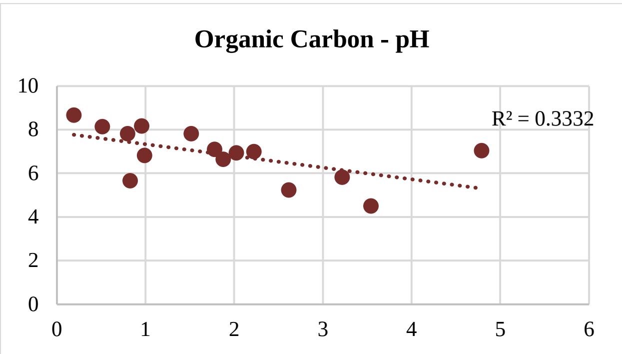

Fig.18 Correlation of Organic carbon vs pH of surface soil

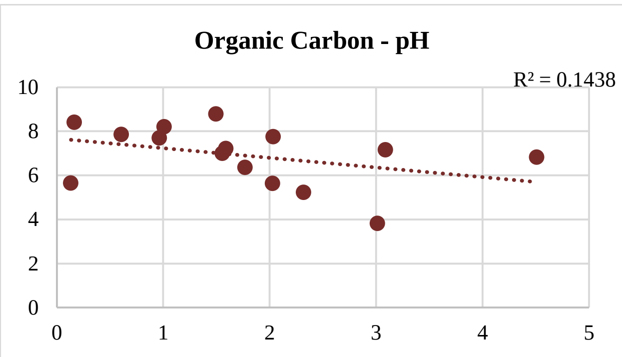

Fig.19 Correlation of Organic carbon vs pH of sub soil

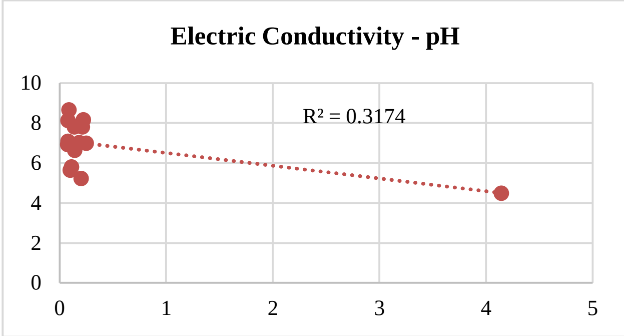

Fig.20 Correlation of Electric conductivity vs pH of surface soil

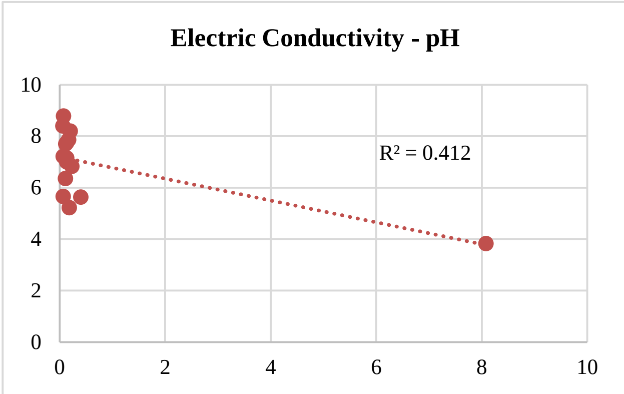

Fig.21 Correlation of Electric conductivity vs pH of sub soil

Saturated hydraulic conductivity - Electric conductivity

It was analysed that Electric conductivity and saturated hydraulic conductivity had slightly positive correlation as 0.056. It implies that there is no any relation between each other.

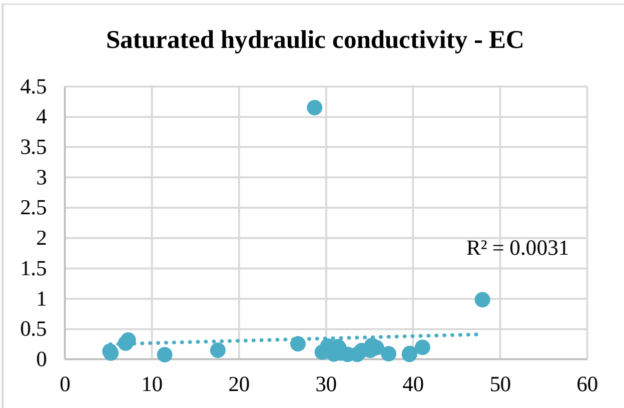

Fig.22 Correlation of Saturated hydraulic conductivity vs Electric conductivity of surface soil

Local soils data are normally unavailable in Asia, Africa and South America (Gijsman *et al*, 2007). But, soil data are essential inputs for various types of hydrological model ie. SWAT (Soil and Water Assessment Tool) model (Setegn *et al*, 2008), VIC (variable infiltration capacity) model (Zhou *et al* 2004), Soil erosion model ie. RUSLE (George *et al* 2013) Biophysical models ie. LPJ (Lund–Postdam–Jena) Dynamic Global Vegetation Model (Sitch *et al*, 2003), EPIC (Environmental Policy Integrated Climate) model (Williams *et al*, 1989, Guerra *et al*, 2004) and Ecosystem models ie. Savanna (Ellis and Coughenour, 1998). In such condition determined soil parameters ie. Texture, Bulk Density, Organic Matter, Electric conductivity, pH and Saturated hydraulic conductivity can be used by researchers and scientists.

Conclusions

The present study has attempted to produce a digital map and basic parameter of Bagmati River Basin on the basis of field data collection and lab analysis result. It is found that soil distribution of the study area is consisted of twenty six different soil mapping units, mapping units 8 and 12 appear to be dominant in the area, having sand, loamy sand, sandy loam, silt loam, silty clay loam and silty clay, had bulk density 1.523 g/cm^{-3}. Similarly, organic matter content 3.29% and 2.54%, electric conductivity 4.39 and 0.485 ms/cm of surface and sub soil respectively. Soil shows 37%, 30 % and 33% soil are alkaline, neutral and acidic in nature with hydraulic conductivity 28.35 mm/hr. The highest positive correlation between is BD –pH followed by BD-SHC in both layer but highest negative correlation between BD-OC followed by EC- pH and vice versa for surface and sub soil respectively. The result is believed to assist as input for various modelling in the area and providing solutions of the problem in the area. A significant contribution is made towards solving the problem of paucity of quantitative and accurate soil data. Thus, it tends to serve as soil metadata.

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