American-Eurasian J. Agric. & Environ. Sci., 15 (1): 53-62, 2015
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2015.15.1.12490

Mapping of Biophysical Constraints of Soils in Semi-Arid Northern Transition Zone of India by GIS Techniques

[1]Denis M.K. Amara and [2]Parameshgouda L. Patil

[1]Department of Soil Science, School of Agriculture,
Njala University, Njala Campus, Sierra Leone, West Africa
[2]Department of Soil Science and Agricultural Chemistry, College of Agriculture,
University of Agricultural Sciences, Dharwad, 580005, Karnataka, India

Abstract: The present study was undertaken in order to identify and map soil biophysical constraints by using FAO Visual Soil and Field Assessment Methodology and GIS techniques in Singhanhalli-Bogur microwatershed in northern transition zone of Karnataka. Ten biophysical soil parameter including depth, coarse fragment/stoniness, texture, structure, tillage pan, rooting condition, surface crust, organic matter, biological activity and sodicity were assessed and interpreted for soil health. Overall, soil health status varied from poor (31.1 % of the entire study area) to medium (68.9 % of the total study area) with the level of constraints ranging from severe to moderate, respectively. Soils with severe constraints showed poor health status while soils with moderate constraints showed medium health status.

Key words: GIS · Mapping · Soil biophysical constraints · Visual soil-field assessment tool · Dharwad

INTRODUCTION

Plants require soil to obtain water and nutrients for growth and for anchorage and stability. Seeds will germinate; seedlings emerge and grow to produce a crop under a great variety of conditions. Plant growth in the context of crop production demands conditions adequate for sustainable yield of a crop which is economically worthwhile. Since soils in general are degrading due to poor management and faulty land use at a rate faster than their natural regeneration, it becomes imperative to protect them from further degradation as there is a concomitant decline in soil quality to produce healthy crops. For efficient crop production, it is important to understand the soil environment in which plants grow, to recognize the limitations of that environment and to ameliorate where possible without damaging the soil quality. Soil is one of the most important natural resources for crop production. It is estimated that the rate of soil formation is about 2.5 cm every 150 years [1]; i.e. soil is non-renewable within the human-life-span. It is in the interests of the farmer and the population as a whole, to ensure that good soil management is practised so that this resource is preserved for continued use by the current and future generations.

For satisfactory plant growth, it is essential that the soil provides a favourable physical environment for root development that can exploit the soil sufficiently to provide the plant's needs for water, nutrients and anchorage [2]. The greater degree of intervention through the engine driven mechanization has often been beneficial, improving the extent and manner of soil cultivation and enabling much greater areas to be farmed through use of irrigation and/or drainage schemes. However, such exploitation though initially improving soil physical conditions, can in time lead to deterioration in soil quality through, for example, degradation of soil structure, or increase in erosion susceptibility.

In India, the land resources available for agriculture are shrinking. Most of the soils in rainfed regions are at the verge of degradation having low cropping intensity, relatively low organic matter status, poor soil physical health, low fertility, etc. [3]. The aim of optimizing the utilization of land resources with intensification of agriculture has resulted either in the fast depletion of nutrients or occasionally in their accumulation. It is therefore important to monitor the fertility status of soils from time to time with a view to monitor the soil health. Besides natural causes, agricultural use of land is causing serious soil losses in many places across the world

Corresponding Author: Dr. Denis M.K. Amara, Department of Soil Science, School of Agriculture,
Njala University, Njala Campus, Sierra LeoneWest Africa. E-mail: denismken@yahoo.com.

including India. It is probable that the human race will not be able to feed the growing population, if the loss of fertile soils continues at the existing rate. In many states of India, hunger is compelling farmers to cultivate land that is unsuitable for agriculture and which can only be converted to agricultural use through enormous efforts and costs such as those involved in the construction of terraces and other surface treatments [4]. Identifying soil physical conditions of an area will not only provide information on the soil resources for sustainable land use planning and development but will also initiate proactive measures that would ameliorate the constraints for plant growth, mitigate soil degradation and preserve the soil quality for the future. There is an overwhelming need to manage and conserve the natural resource base with adoption of appropriate technologies that are economically viable, socially acceptable and environmentally non-degrading in all aspects [5]. In this view, the present study was carried out in order to identify and map soil biophysical constraints of the study area by GIS techniques.

Aim of the current work is to assess the soil biophysical constraints in Singhanhalli-Bogur microwatershed in northern transition zone of Karnataka using the FAO Visual Soil and Field Assessment Methodology and map the identifying units by GIS techniques.

MATERIALS AND METHOD

Description of the Study Area: Singhanhalli-Bogur micro-watershed is located between 15°31'30.30" to 15°34'49.45" N latitude and 74°50'47.46" to 74°53'35.67" E longitude in Dharwad taluk of Dharwad district in the northern transition zone of Karnataka, India (Fig. 1). The study area lies in the Decca plateau in the hot

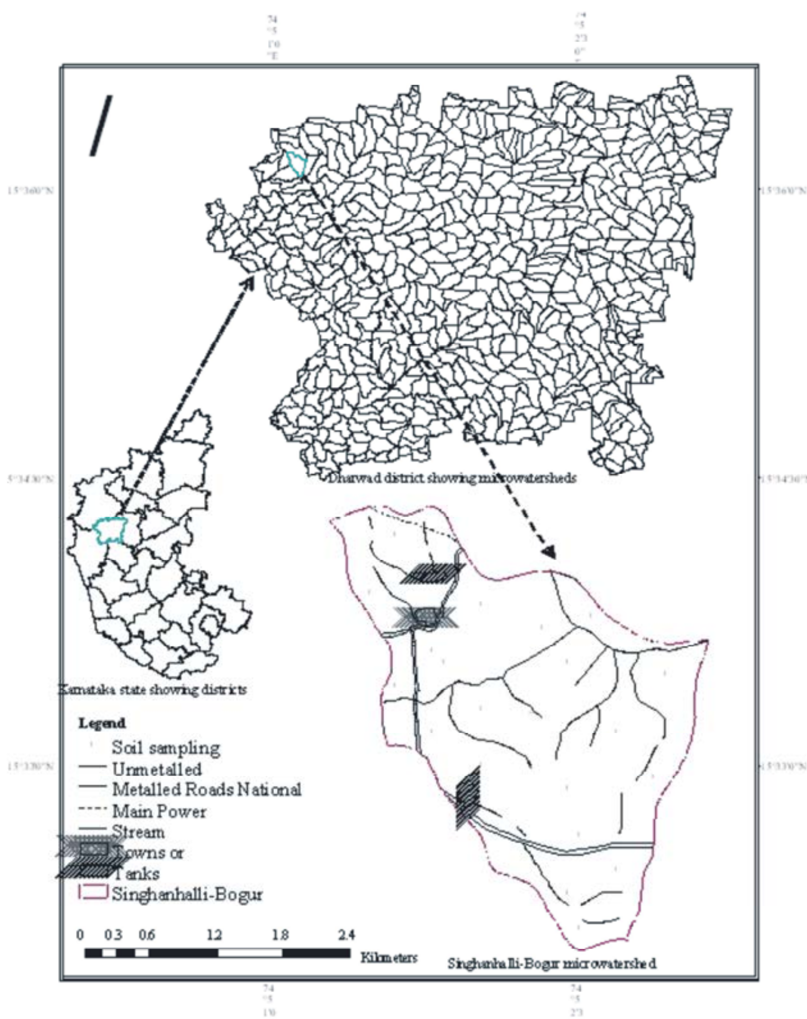

Fig 1: Map of the study area

semi-arid agro-ecological region 6 (K4D2) and sub-region 6.4, having medium to high available water content (AWC) with a length of growing period (LPG) of 150-180 days. The climate is characterized by hot and humid summer and mild and dry winter. The study area receives an annual average rainfall of 755.2 mm, which distributed over May to October and annual temperature ranging from 24 - 28 °C and having Ustic Soil Moisture and Isohyperthermic soil temperature regimes [6]. The highest elevation is 754 m above mean sea level and the relief is very gently to strongly sloping. The general slope is towards the northeast, southeast and southwest but it is more in the southwest direction. The drainage pattern is parallel. Soils are derived from chlorite schist with shale as dominant parent material containing banded iron oxide quartzite. The soils are coarse textured and shallow at the higher elevations but gradually fineness and depth increases towards the lower elevations. The main soil types are black and red soils but the red soils are in higher proportion than the black soils. The natural vegetation mainly comprised of trees and shrubs including Acacia (*Acacia auruculiformis*), Neem (*Azadirachta indica*) and Eucalyptus (*Eucalyptus sideroxylon* and *Eucalyptus regnana*).

Soil Mapping: Twenty pedons consisting of five black soil pedons and fifteen red soil pedons were characterized and based on their morphological, physicochemical and chemical properties, the soils were classified up to phase level following the "Keys to Soil Taxonomy" [7]. Fourteen soil series were identified and named after four villages, *viz*., Singhanhalli (SGH), Bogur (BGR), Mugli (MGL) and Venkatapur (VKP). The mapping units of soils are phases of soil series considering texture, depth, slope and erosion characteristics of the site. In the identification of soil mapping units of the study area, soil series, soil texture, soil depth, slope and erosion were used as inputting parameters. The fourteen series were mapped into seventeen mapping units at different phases of soil series with the help of Arc View 10.1 GIS software (Fig. 2). The mapping legend is presented as e.g., SGH-c-d4/Be1, numerator represents the name of the series (e.g., SGH-Singhanhalli), surface texture (c – clay) and depth of the soil (d4 - 75 to 100 cm) and the denominator indicates slope (B - 1 to 3 per cent) of the land and erosion status (e1 - slight).

Assessment of Soil Physical Constraints: The assessment of soil characteristics on farmer fields is preferably done without the help (or with a minimum) of instruments to avoid costs.

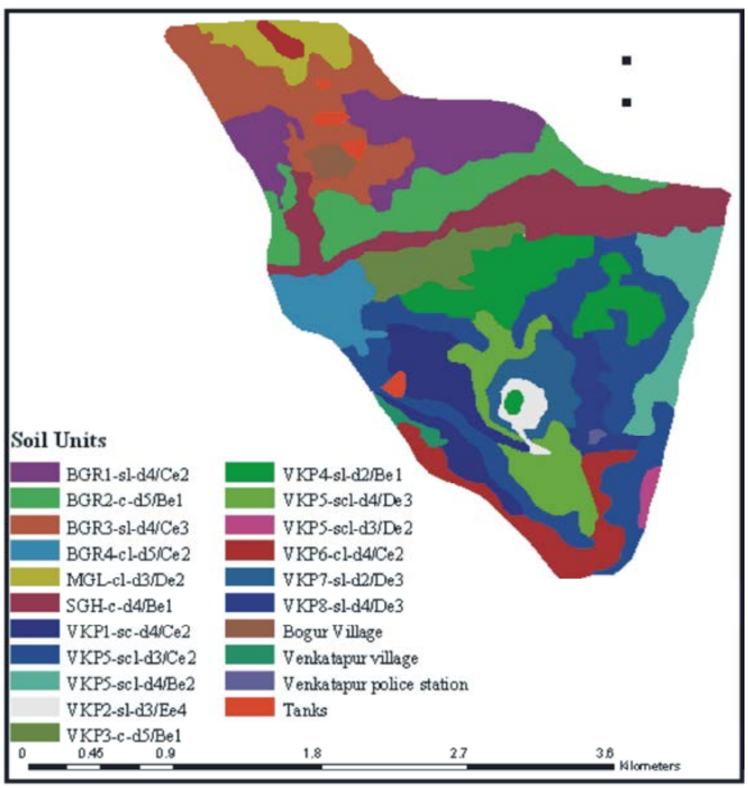

Fig 2: Soil phases map of Singhanhalli-Bogur microwatershed

In the present study, ten soil biophysical parameter including depth, coarse fragment/stoniness, texture, structure, tillage pan, rooting condition, surface crust, organic matter, biological activity and sodicity were assessed through the FAO Visual Soil and Field Assessment Methodology as described by [8, 9]. This methodology is called in short VS-FAST Methodology. It is a field-based soil assessment tool that describes and evaluates the morphological condition of soil in the field.

This technique is a more rapid and immediate method of assessment than the conventional sets of soil physical measurements commonly used. It is a simple but scientifically robust tool for assessing soil physical constraints. The scoring of the constraints was based on the scoring procedure proposed by [2, 8-10]. The scores were assigned to each of the selected soil variables of each soil mapping units and then summed to give the maximum score. The sum of scores was then used for interpretation of the overall constraint of each soil

Table 1: Rating/score for soil depth, structure, tillage pan/compaction, coarse fragments, organic matter and biological activity

Sr. No.	Class	Range	Rating/Score
Soil depth			
1.	Very shallow	<25	0
2.	Shallow	25 – 50	1
3.	Moderately deep	50 – 100	2
4.	Deep	>100	3
Soil structure			
1.	None	Soil is single grain or massive	0
2.	Weak	Poorly formed aggregates	1
3.	Moderate	Well-formed aggregates	2
4.	Strong	Very well formed aggregates	3
Tillage pan/compaction			
1.	None	No tillage pan, friable consistence* (moist) and abundant pores/voids throughout	3
2.	Slight	Slightly developed tillage pan, friable to firm consistence (moist) and many fine pores throughout but with very few large pores	2
3.	Moderate	Moderately developed tillage pan, firm consistence (moist) and moderate amount of pores but very few large pores	1
4.	Severe	Strongly developed tillage pan, with massive structure, very firm to extremely firm consistence (moist) and very few or no pores	0
Coarse fragments			
1.	None to common	0 – 15 %	3
2.	Common to many	15 – 40 %	2
3.	Many to abundant	40 – 80 %	1
4.	Dominant	> 80 %	0
Organic matter			
1.	Very low	White; value 8	0
2.	Low	Grey; value 5-7	1
3.	Medium	Dark grey to black grey; value 3-4.5	2
4.	High	Black; value 2-2.5	3
Biological activity			
1.	None	No biological features, no earthworms	0
2.	Low	Few biological features or soil biota; 1- 4 earthworms counted in spadeful	1
3.	Medium	Common biological features or biota; 4 – 8 earthworms counted in spadeful	2
4.	High	Many biological features or biota; > 8 earthworms counted in spadeful	3

* Consistence is highly dependent on current water content and also subject to individual interpretation [Source: 2, 8]

Table 2: Rating/score for soil texture, rooting condition and surface crust

Sr. No.	Class	Range	Rating/ Score
Soil texture			
1.	Sand, loamy sand	Low water and nutrient holding capacity*, good workability, high to very high infiltration rate	0
2.	Sandy loam, silt loam, heavy clay	Low to medium water and nutrient holding capacity; good workability, moderate to high infiltration rate (sandy loam and silt loam); medium to high available water holding capacity, very high nutrient holding capacity; poor workability; very slow infiltration rate (heavy clay)	1
3.	Medium clay, sandy clay loam, silty clay, sandy clay, silty clay loam	Medium to high available water holding capacity; high nutrient holding capacity; medium to poor workability, moderate to slow infiltration rate	2
4.	Loam, clay loam	Very high water holding capacity, high nutrient holding capacity, medium workability, moderate infiltration rate	3
Rooting condition			
1.	Good condition	Unrestricted root development, many (<2mm, > 50/dm^2; > 2mm, > 5/dm^2)	3
2.	Moderate condition	Horizontal and vertical root development somewhat limited; more roots between coarse structural elements than inside; common roots (<2mm, 50-200/dm^2; >2mm, > 5 - 20/dm^2)	2
3.	Poor condition	Horizontal and vertical root development clearly limited; most roots concentrated in cracks between structural units, almost no roots inside units; few roots (<2mm, 20 - 50/dm^2; > 2mm, > 2 - 5/dm^2)	1
4.	Very poor condition	Severe restriction of horizontal and vertical root development; presence of L-shaped roots, over thickening of roots or roots squashed between coarse structural units or concentrated above dense layer, no roots inside units; none to very few roots (<2mm, 0 - 20/dm^2; > 2mm, 0 - 2/dm^2)	0
Surface crust			
1.	None	No crust present	3
2.	Slight	Thin to medium crust (1 – 5 mm) on up to 20 % of the surface	2
3.	Moderate	Thin to medium crust (1 – 5 mm) present on 20 - 50 % of the surface, thick crust (> 5 mm) present in few patches	1
4.	Severe	Thin, medium and thick crust present on more than 50 % of the surface with common patches of thick crust	0

* Water holding capacity and nutrient holding capacity not only depend on the quantity of clay but also the type of clay. Therefore the rating is a relative one, valid within a region with similar dominant clay type. [Source: Modified from 2, 8, 19]

Table 3: Rating/score for sodicity

Sr. No.	Class	Description of sodicity signs	Rating/Score
1.	None	No signs of sodicity, also not in nearby areas, see below; depth of groundwater > 2m	3
2.	Slight	Sodicity: in shallow pit soil structure is weak; in close-by areas some puddles of surface water are coloured black by dispersed organic colloids (slick spots); upon drying, black crusts are formed	2
3.	Moderate	Sodicity: waterlogging is a common surface feature; some puddles of surface water are coloured black by dispersed organic colloids (slick spots); upon drying, black crusts are formed; hard setting surface, but when worked soil becomes easily dusty when dry; corrosion of road furniture such as steel posts, road signs, guard rail is an increasing problem; tunnel/pipe erosion is visible in some degraded areas. Crops sensitive to high sodium saturation (e.g. beans) perform poorly; tolerant crops (e.g. cotton do not appear to be affected.	1
4.	Severe	Sodicity: in shallow pit the top of the B-horizon is visible in the form of well-defined vertical columns or prisms, having a rounded top with lighter colour and smooth, shiny and well defined sides; soil structure in topsoil is poorly developed.; waterlogging is a common surface feature; puddles of surface water are frequently coloured black by dispersed organic colloids (slick spots); upon drying, black crusts are formed; hard setting surface, but when worked soil becomes very dusty when dry; corrosion of road furniture such as steel posts, road signs, guard rail is a severe problem; tunnel/pipe erosion is visible in some degraded areas.	0

[Source: 8]

mapping unit. The criteria for rating/scoring the selected soil variables of each soil mapping units are presented in Tables 1, 2 and 3.

RESULTS AND DISCUSSION

Depth: Effective soil depth is defined as the depth of the soil at which root growth of grasses or crops is strongly inhibited. Rooting depth being plant specific, it is recommended that the representative species of grasses and cereals are used to indicate the effective rooting depth of the soil [11].

The depth of soils in the study area was observed to vary from shallow to deep (Tables 4, 5). Two mapping units VKP4-sl-d2/Be1 and VKP7-sl-d2/De3 were shallow ranging between 25 to 50 cm. Depth limitations to crop production on these mapping units were observed to range from moderate to severe. In nine mapping units (MGL-cl-d3/De2, BGR1-sl-d4/Ce2, VKP1-sc-d4/Ce2, VKP2-sl-d3/Ee4, VKP5-scl-d4/De3, VKP5-scl-d3/De2, VKP6-cl-d4/Ce2 VKP8-sl-d4/De3 and VKP5-scl-d3/Ce2), the soils were moderately deep (50 to 100 cm), whereas in SGH-c-d4/Be1, BGR2-c-d5/Be1, BGR3-sl-d4/Ce3, BGR4-cl-d5/Ce2, VKP3-c-d5/Be1 and VKP5-scl-d4/Be2, the soil were deep (>100 cm). In the moderately deep and deep soils, the depth was not a constraint for crop production.

Structure: Soil structure is even more difficult to assess than effective soil depth. For fast soil assessment purposes, the complete description in terms of grade, size and type of aggregates requires too much experience or is too much subject to individual interpretation; therefore only grade is considered [2, 8, 12].

Table 4: Soil physical constraints of study area

		Rating/score of constraint										
Sr. No.	Soil mapping unit	Depth	Structure	Tillage pan	Texture	Coarse fragment	Rooting condition	Organic matter	Biological activity	Surface crust	Sodicity	Maximum score
1	SGH-c-d4/Be1	3	3	2	2	3	3	3	1	3	3	26
2	MGL-cl-d3/De2	2	2	3	3	2	3	2	0	3	3	23
3	BGR1-sl-d4/Ce2	2	2	2	1	1	3	2	1	2	3	19
4	BGR2-c-d5/Be1	2	3	2	2	3	3	3	1	3	3	25
5	BGR3-sl-d4/Ce3	3	2	2	1	1	3	2	0	3	3	20
6	BGR4-cl-d5/Ce2	3	2	3	3	2	3	1	0	3	3	23
7	VKP1-sc-d4/Ce2	3	2	2	2	2	3	1	1	2	3	21
8	VKP2-sl-d3/Ee4	2	1	3	1	2	2	1	0	3	3	18
9	VKP3-c-d5/Be1	2	3	2	2	3	3	2	0	3	3	23
10	VKP4-sl-d2/Be1	3	2	3	1	2	3	1	1	2	3	21
11	VKP5-scl-d4/De3	1	2	3	2	2	3	3	0	3	3	22
12	VKP5-scl-d3/De2	2	2	3	2	2	3	1	1	0	3	19
13	VKP5-scl-d3/Ce2	2	2	2	2	2	3	1	0	1	3	18
14	VKP5scld4/Be2	3	3	3	2	2	3	2	1	3	3	25
15	VKP6-cl-d4/Ce2	2	2	3	3	2	3	2	1	3	3	24
16	VKP7-sl-d2/De3	2	1	2	1	2	3	1	0	1	3	16
17	VKP8-sl-d4/De3	2	1	3	1	2	3	1	0	2	3	18

Table 5: Interpretation of soil physical constraints

		Interpretation										
Sr. No.	Soil mapping unit	Depth	Structure	Tillage pan	Texture	Coarse fragment	Rooting condition	Organic matter	Biological activity	Surface crust	Sodicity	Overall interpretation of constraint
1	SGH-c-d4/Be1	Deep	Strong	Slight	c	None to common	Good	High	Low	None	None	Medium
2	MGL-cl-d3/De2	Moderately deep	Moderate	None	cl	Common to many	Good	Medium	None	None	None	Medium
3	BGR1-sl-d4/Ce2	Moderately deep	Moderate	Slight	sl	Many to abundant	Good	Medium	Low	Slight	None	Poor
4	BGR2-c-d5/Be1	Moderately deep	Strong	Slight	c	None to common	Good	High	Low	None	None	Medium
5	BGR3-sld4/Ce3	Deep	Moderate	Slight	sl	Many to abundant	Good	Medium	None	None	None	Medium
6	BGR4-cl-d5/Ce2	Deep	Moderate	None	c	Common to many	Good	Low	None	None	None	Medium
7	VKP1-sc-d4/Ce2	Deep	Moderate	Slight	sl	Common to many	Good	Low	Low	Slight	None	Medium
8	VKP2-sl-d3/Ee4	Moderately deep	Weak	None	sl	Common to many	Moderate	Low	None	None	None	Poor
9	VKP3-c-d5/Be1	Moderately deep	Strong	Slight	c	None to common	Good	Medium	None	None	None	Medium
10	VKP4-sl-d2/Be1	Deep	Moderate	None	sl	Common to many	Good	Low	Low	Slight	None	Medium
11	VKP5-scl-d4/De3	Shallow	Moderate	None	scl	Common to many	Good	High	None	None	None	Medium
12	VKP5-scl-d3/De2	Moderately deep	Moderate	None	scl	Common to many	Good	Low	Low	Severe	None	Poor
13	VKP5-scl-d3/Ce2	Moderately deep	Moderate	Slight	scl	Common to many	Good	Low	None	Moderate	None	Poor
14	VKP5-scl-d4/Be2	Deep	Strong	None	scl	Common to many	Good	Medium	Low	None	None	Medium
15	VKP6-cl-d4/Ce2	Moderately deep	Moderate	None	cl	Common to many	Good	Medium	Low	None	None	Medium
16	VKP7-sl-d2/De3	Moderately deep	Weak	Slight	sl	Common to many	Good	Low	None	Moderate	None	Poor
17	VKP8-sl-d4/De3	Moderately deep	Weak	None	sl	Common to many	Good	Low	None	Slight	None	Poor

The data in Tables 4 and 5 revealed that structure was a serious constraint in three mapping units of Venkatapur series: VKP2-sl-d3/Ee4, VKP7-sl-d2/De3 and VKP8-sl-d4/De3 where soils were weak. The weak structural nature of these soils might be attributed to the poorly formed aggregates resulting from low organic matter content. In the mapping units MGL-cl-d3/De2, BGR1-sl-d4/Ce2, BGR3-sl-d4/Ce3, BGR4-cl-d5/Ce2, VKP1-sc-d4/Ce2, VKP4-sl-d2/Be1, VKP5-scl-d4/De3, VKP5-scl-d3/De2, VKP6-cl-d4/Ce2 and VKP5-scl-d3/Ce2, the soil structure was moderate, whereas in SGH-c-d4/Be1, BGR2-c-d5/Be1, VKP3-c-d5/Be1 and VKP5-scl-d4/Be2, the structure was strong. The moderate and strong structure could be attributed to the well-formed aggregates having high aggregate stability, resulting from the high organic matter content of these soils.

Tillage pan/Compaction: Slightly developed tillage pan were observed in the mapping units SGH-c-d4/Be1, BGR1-sl-d4/Ce2, BGR2-c-d5/Be1, BGR3-sl-d4/Ce3, VKP1-sc-d4/Ce2, VKP3-c-d5/Be1, VKP7-sl-d2/De3 and VKP5-scl-d3/Ce2 (Tables 4 and 5). This might be due to the friable to firm consistence (moist) and many fine pores throughout but with few large pores [12]. Tillage pans impede the movement of water, air and plant roots through the soil. The presence of a tillage pan is both a negative indicator of soil condition and a symptom of unsustainable land management practices. The cumulative effect includes increased risk of water logging (as water tends to lie on top of compacted layers) and erosion (as the loosened topsoil can easily detached from compacted subsoil) as well as yield reduction and crop losses (through shallow and "right-angle" root systems, less able to survive dry lands [13]. In all the other mapping units, no tillage pans were observed. This might be due to the abundant macro pores/voids throughout the pedons [8, 9].

Texture: Texture has important effects on a soil's water holding capacity, aeration and porosity, workability, hydraulic conductivity, compaction potential, resistance to root penetration, nutrient holding capacity (CEC) and resistance to acidification [10]. According to the results shown in Tables 4 and 5, the texture of the mapping units, *viz*., BGR1-sl-d4/Ce2, BGR3-sl-d4/Ce3, VKP2-sl-d3/Ee4, VKP4-sl-d2/Be1, VKP7-sl-d2/De3 and VKP8-sl-d4/De3 was sandy loam. The sandy loam texture of these soils might lead to low to medium water and nutrient holding capacity, good workability and moderate to high infiltration rate [2]. Texture is intimately related to the mineral composition, the specific surface area and the soil pore space. It affects practically, all of the factors governing plant growth. Soil texture influences the movement and availability of soil moisture, aeration, nutrient availability and the resistance of the soil to root penetration. It also influences physical properties related to the soil's susceptibility to soil degradation, such as aggregate stability [9, 14].

In the mapping units SGH-c-d4/Be1, BGR2-c-d5/Be1, VKP1-sc-d4/Ce2, VKP3-c-d5/Be1, VKP5-scl-d4/De3, VKP5-scl-d3/De2, VKP5-scl-d3/Ce2 and VKP5-scl-d4/Be2, the texture of soils varied from clay to sandy clay and sandy clay loam. Soils of these textural classes are capable of having medium to high available water holding capacity, high nutrient holding capacity, medium to poor workability and moderate to slow infiltration rate [8]. On the other hand, the texture of the mapping units MGL-cl-d3/De2, BGR4-cl-d5/Ce2 and VKP6-cl-d4/Ce2 was clay which could be related to the very high water holding capacity, high nutrient holding capacity, medium workability and moderate infiltration rate [2].

Coarse Fragments: The results in Tables 4 and 5 indicated that the coarse fragments in the mapping units BGR1-sl-d4/Ce2 and BGR3-sl-d4/Ce3 were many to abundant ranging between 40 to 80 per cent. The presence of coarse fragments with diameter less than 2 mm influences the nutrient status, water movement, rooting volume, use and management of the soil [8, 10]. In the mapping units MGL-cl-d3/De2, BGR4-cl-d5/Ce2, VKP1-sc-d4/Ce2, VKP2-sl-d3/Ee4, VKP4-sl-d2/Be1 VKP5-scl-d4/De3, VKP5-scl-d3/De2, VKP6-cl-d4/Ce2, VKP7-sl-d2/De3 VKP8-sl-d4/De3, VKP5-scl-d3/Ce2 and VKP5-scl-d4/Be2, coarse fragments were common to many ranging between 15 to 40 per cent, whereas in SGH-c-d4/Be1, BGR2-c-d5/Be1 and VKP3-c-d5/Be1, coarse fragments were not common ranging between 0 to 15 per cent. The common to many and abundant coarse fragments in these mapping units might be due to the nature of parent material as well as the abrasive effect of run-off which remove the finer soil particles from surface layer, thereby leaving coarser fragments [2, 9].

Rooting Condition: The ease of root penetration, size and abundance, local concentration and sudden change of orientation of roots are dependent on texture, coarse fragments, tillage pan, structure, etc., [9]. The root system (size, abundance, orientation etc.) were examined from the sides of the pedons. Overall, there were no signs of unrestricted root developments (Tables 4 and 5).

The study revealed that rooting condition in all the mapping units was good, thus indicating unrestricted root development. On the contrary, the rooting condition of non-cultivable land (VKP2-sl-d3/Ee4) was moderate, thus indicating that horizontal and vertical root developments were somewhat limited. The unrestricted root development in this mapping unit could be attributed to the texture, moderate coarse fragments, slightly developed tillage pan and moderate to strong structure of the soils [2, 8].

Organic Matter: The content of organic matter of mineral soils can be estimated from the colour of a soil. This estimation is based on the assumption that the soil colour is due to a mixture of dark coloured organic substances and light coloured minerals [2]. Generally, the darker the soil the higher the organic matter content [10]. In the present study, the soils from surface layers which were dried due to the increased temperature and lack of water in these soils were moistened in order to assess their organic matter content. All the soils were tested for organic matter content under moistened state.

According to the results shown in Tables 4 and 5, the study revealed that the organic matter content of soils ranged from low to high. The mapping units *viz*., SGH-c-d4/Be1, BGR2-c-d5/Be1, BGR3-sl-d4/Ce3 and BGR4-cl-d5/Ce2 were low in organic matter, indicating a severe constraint. The low organic matter content of these soils might have resulted to the grey colour and value of 5 to 7. In addition, the low organic matter could have deleterious effects on other soil properties such as leading to increased aggregate strength and bulk density, decreased water infiltration and water holding capacity and decreased aggregate stability [15, 16]. In the mapping units BGR1-sl-d4/Ce2, VKP3-c-d5/Be1, VKP4-sl-d2/Be1, VKP5-scl-d4/De3, VKP8-sl-d4/De3 and VKP5-scl-d3/Ce2, organic matter content was high. This might have resulted to the dark grey to black grey and black colours with value 2 to 5 of these soils [8, 9, 12].

Biological Activity: Soil biota is the very "life" of the soil [8]. Their presence in large numbers throughout the soil profiles is conducive to a good condition of the soil (porosity, aeration and infiltration/water movement, soil fertility etc.). If not visible directly, their presence may be inferred from biological features such as open or in-filled large burrows (krotovinas), termite or ant channels and burrows, other insect nests, worm casts and channels [10]. In the present study, biological constraint was assessed based on the presence of earthworms, termite holes, etc. The results in Tables 4 and 5 indicated that in the mapping units MGL-cl-d3/De2, BGR3-sl-d4/Ce3, BGR4-cl-d5/Ce2, VKP2-sl-d3/Ee4, VKP3-c-d5/Be1, VKP5-scl-d4/De3, VKP7-sl-d2/De3, VKP8-sl-d4/De3 and VKP5-scl-d3/Ce2, there was no physical presence of biological activity, where no visible biological features were found. In the mapping units SGH-c-d4/Be1, BGR1-sl-d4/Ce2, BGR2-c-d5/Be1, VKP1-sc-d4/Ce2, VKP4-sl-d2/Be1, VKP5-scl-d3/De2, VKP6-cl-d4/Ce2 and VKP5-scl-d4/Be2, a low biological activity was observed. The reason might be due to the few termite holes that were visible in these pedons [8, 9, 12].

Physical Soil Crusts: Two main categories of soil surface crusts can be distinguished *viz*., 1) Physical and chemical crusts and 2) Biological soil crusts. Physical and chemical crusts are inorganic features such as platy surface crusts or salt crusts. Biological soil crusts are formed by living organisms and their by-products, creating a crust of soil particles bound together by organic materials [8]. Physical crusts are essentially a consequence of a change in land cover, usually man-induced and are as such not part of the original ecosystem, while biological crusts are a part of the semi-arid and arid ecosystems in which they develop and thrive. Therefore, the presence/appearance of physical soil crusts may be interpreted as a sign of land degradation (negative effects on water infiltration), whereas in the case of biological crusts it is rather their poor condition or disappearance (facilitating erosion) that is indicative of land degradation [9, 10].

In the present study, soil surface crust was assessed in terms of physical crust. According to the results stated in Tables 4 and 5, the status of physical soil crusts in the mapping unit VKP5-scl-d3/De2 was severe. This might be due to change in land cover resulting to thin, medium and thick crust present on more than 50 per cent of the soil surface with common patches of thick crust. In the mapping units VKP7-sl-d2/De3 and VKP5-scl-d3/Ce2, the physical soil crusts status was moderate which could be attributed to the moderate change in land cover, hence resulting to thin to medium crust (1 to 5 mm) present on 20 to 50 per cent of the surface, thick crust (more than 5 mm) present in few patches [12, 17].

On the contrary, the physical soil crusts status of the mapping units BGR1-sl-d4/Ce2, VKP1-sc-d4/Ce2, VKP4-sl-d2/Be1 and VKP8-sl-d4/De3 was slight. This could be attributed to the good land cover protecting the surface. In SGH-c-d4/Be1, MGL-cl-d3/De2, BGR2-c-d5/Be1, BGR3-sl-d4/Ce3, BGR4-cl-d5/Ce2, VKP2-sl-d3/Ee4, VKP3-c-d5/Be1, VKP5-scl-d4/De3, VKP6-cl-d4/Ce2 and VKP5-scl-d4/Be2, there were no visible physical soil crusts [8, 9].

Sodicity: The results shown in Tables 4 and 5 revealed that soils of the study area were free of high sodium concentrations and hence, could be classified as non-sodic soils.

Interpretation of Soil Physical Constraints for Soil Health: The above ten soil biophysical parameters were assessed by creating classes and assigning a score (weighting factor) to each class. The aggregation was done by adding the scores per class (Table 6) and comparing the total score of each parameter as suggested by [10]. Based on the above assessment, the study revealed that the soil health status of soils of the study area ranged from poor to medium. The soil health status of about 236.7 ha area representing 31.1 per cent was poor, whereas 523.9 ha area representing 68.9 per cent showed soil health that was medium (Fig. 3).

Soil health status of the mapping units BGR1-sl-d4/Ce2, VKP2-sl-d3/Ee4, VKP5-scl-d3/De2, VKP7-sl-d2/De3, VKP8-sl-d4/De3 and VKP5-scl-d3/Ce2 was poor, indicating very severe constraints. These constraints were due to depth (moderately deep), weak structure due to poorly formed aggregates, presence of slightly developed tillage pans with friable to firm consistence (moist) and many fine pores throughout but with few large pores, sandy loam texture with low to medium water and nutrient holding capacity and good workability and moderate to high infiltration rate, presence of common to many coarse fragments; medium organic matter and low biological activity [8, 10, 18]. On the other hand, the soil health status of the mapping units SGH-c-d4/Be1,

Table 6: Interpretation for soil physical constraints (field level) for soil health

Si. No.	Maximum Rating/Score	Interpretation of soil health	Soils belonging to this soil health class	% of study area
1.	≥36	Very good	Nil	0
2.	29 – 35	Good	Nil	0
3.	12 – 28	Medium	SGH-c-d4/Be1, MGL-cl-d3/De2, BGR2-c-d5/Be1, BGR3-sld4/Ce3, BGR4-cl-d5/Ce2, VKP1-sc-d4/Ce2, VKP3-c-d5/Be1, VKP4-sl-d2/Be1, VKP5-scl-d4/De3, VKP5-scl-d4/Be2 and VKP6-cl-d4/Ce2	68.9
4.	11 - 20	Poor	BGR1-sl-d4/Ce2, VKP2-sl-d3/Ee4, VKP5-scl-d3/De2, VKP5-scl-d3/Ce2, VKP7-sl-d2/De3 and VKP8-sl-d4/De3	31.1
5.	≤10	Very poor	Nil	0

[Source: Modified from 8, 10]

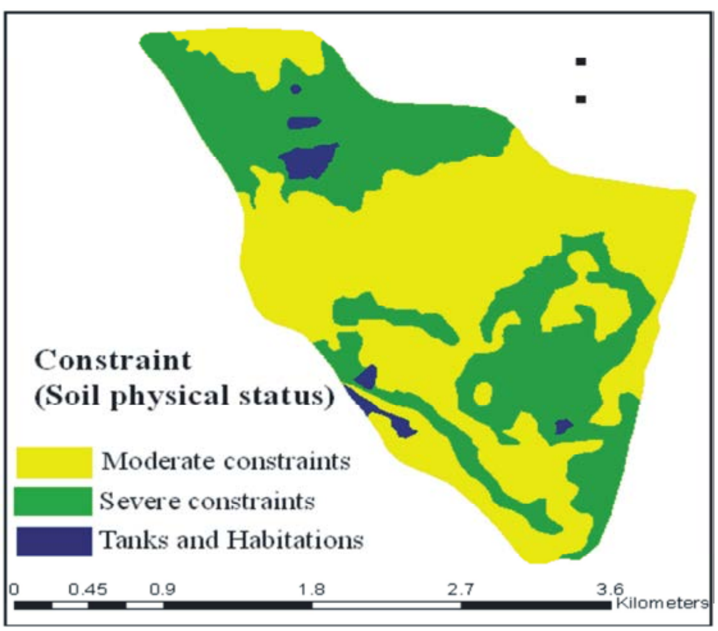

Fig 3: Status of soil physical constraints in Singhanhalli-Bogur microwatershed

MGL-cl-d3/De2,BGR2-c-d5/Be1,BGR3-sl-d4/Ce3,BGR4-cl-d5/Ce2, VKP1-sc-d4/Ce2, VKP3-c-d5/Be1, VKP4-sl-d2/Be1,VKP5-scl-d4/De3,VKP6-cl-d4/Ce2 and VKP5-scl-d4/Be2 was medium, indicating moderate to severe constraints. These moderate to severe constraints were due to depth (moderately deep to deep), moderate to strong structure due to well formed aggregates, presence of moderately developed tillage pan with firm consistence (moist) and moderate amount of pores but very few large pores, good texture having medium to high available water holding capacity, high nutrient holding capacity, medium to poor workability and moderate to slow infiltration rate, presence of common to many coarse fragments, medium organic matter and low biological activity [8, 10, 18].

CONCLUSION

The soil health status of the study area varied from poor to medium due to moderate to severe soil physical constraints resulting from shallow depth, poor aggregate stability, moderately developed tillage pan, high content of coarse fragments and medium organic matter. The poor health status of soils in the study area is likely to reduce crop yield even below the economic threshold. Hence, appropriate soil and water conservation measures focusing on farmers' participation should be adopted as an ameliorating mechanism to the present situation.

REFERENCES

1. Friend, J.A., 1992. Achieving soil sustainability. J. Soil Water Conserv, 47: 156-157.
2. FAO, 2006. World reference base for soil resources. FAO World Soil Resources Report 103. Rome, Italy.
3. GOI, 2009. Union Budget and Economic Survey. Ministry of Finance, Government of India, New Delhi.
4. Ajai, A.S., P.S. Dhinwa, S.K. Pathan and K. Ganesh Raj, 2009. Desertification/land degradation status mapping of India. Current Sci., 97: 10.
5. FAO, 2008. Feeding the World and Sustainable Management of Natural Resources Fact sheets. Rome, Italy.
6. Amara Denis, M.K., P.L. Patil, G.S. Dasog and M.V. Manjunath, 2013. Rainfall Erosivity (R-Factor) Estimation for Singhanalli-Bogur Microwatershed in Northern Transition Zone of Karnataka. Res. J. Agric. Sci., 4(5/6): 644-647.
7. Soil Survey Staff, 2012. Keys to Soil Taxonomy, United States Department of Agriculture Natural Resource Conservation Service, 12th Edition, Washington D.C., USA.
8. McGarry, D., 2005. A methodology of a Visual Soil – Field Assessment Tool. Natural Resources Sciences, Queensland Government, Australia.
9. Shepherd, G., Stagnari, F., Pisante, M. and J. Benites, 2008. Visual Soil Assessment for Annual Crops, Food and Agriculture Organization of the United Nations, Rome, Italy.
10. FAO, 2007. Land degradation assessment in Drylands (LADA), Biophysical indicator toolbox (Pressure/State). Technical Report 2, Rome, Italy.
11. FAO, 1997. Land quality indicators and their use in sustainable agriculture and rural development. Land and water Bulletin 5, FAO, Rome, Italy.
12. FAO, 2005. Draft proposed indicators for Land Degradation Assessment in Drylands. FAO, Rome, Italy.
13. Shepherd, T.G., 2000. Visual Soil Assessment, Field Guide for Cropping and Pastoral Grazing on Flat to Rolling Country. Horizons.mw/Landcare Research, Vol. 1: 84. Palmerstone North, New Zealand.
14. FAO, 2000. Manual on integrated soil management and conservation practices, Land and Water Bulletin 8, FAO, Rome, Italy.
15. Matson, P.A., W.J. Parton, A.G. Power and M.J. Swift, 1997. Agricultural intensification and ecosystem properties. Science, 277: 504-509.
16. Li, F.R., L.Y. Zhao, H. Zhang, T.H. Zhang and Y. Shirato, 2004. Wind erosion and airborne dust composition in farmland during spring in Horqin Sandy Land of eastern Inner Mongolia, China. Soil and Tillage Res., 75: 121-130.
17. FAO, 2003. Data sets, indicators and methods to assess land degradation in Drylands. Report of the LADA e-mail conference, 9 October – 4 November 2002. World Soil Resources Report 1000, FAO, Rome, Italy.
18. Stocking, M.A. and N. Murnaghan, 2001. Handbook for the field assessment of land degradation, Earthscan Publications Ltd., London.
19. Tongway, D., 1994. Rangeland soil condition assessment manual. CSIRO, Division of wildlife and ecology, Canberra, Australia.