Assessment of Soil Productivity Potentials in Hot Semi-Arid Northern Transition Zone of India using Riquier Index and GIS Techniques

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ABSTRACT--- ***In the present study, assessment of soil productivity was undertaken in Singhanlli-Bogur microwatershed in the hot semi-arid agro-ecological region of the northern transition zone of Karnataka, India. Nine intrinsic soil characteristics were evaluated using the parametric approach proposed by Riquier. The study revealed that there was no excellent productivity class both in terms of actual and potential productivity. In terms of actual productivity, more than half of the area (396.3 ha) which makes up 52.1% of the study area was poor in productivity, 42.6 ha (5.6 %) was extremely poor in productivity, 161.6 ha (21.3 %) showed average productivity and 144.0 ha (18.3%) was good in productivity. On the other hand, in terms of potential productivity which is the productivity that the soil is expected to show after soil improvements are done, almost half of the area (365.7 ha) which makes up 48% of the study area was average in productivity, 135.9 ha (19.9%) was poor in productivity while 242.9 ha (31.9) showed good productivity. It is expected that there will be no extremely poor productivity class in the study area after soil improvement. This is probably due to improvement in previously limiting soil characteristics. Organic matter was found to be the most limiting factor for crop production in the study area. In lowland soils especially clay soils, drainage was found to be a major limiting factor for crop production. It was suggested that the addition of organic matter through manuring, green manuring, crop rotation etc. and fertilisers, as well as improving the soil drainage conditions through excess water removal by reclamation and ridging, would increase the potential productivity of the soils. In addition, agronomic measures like sowing of close-spaced erosion-resistant crops, intercropping, strip cropping with cover management practices and mechanical measures like continuous contour trenches would improve organic matter and structure as well as conserve water and protect soils from erosion especially in the uplands.***

Keywords---- Soil Productivity, Riquier Index, GIS, Erosion, Soil Properties.

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1. INTRODUCTION

Agriculture is one of the world's most important activities supporting human life. From the beginning of civilization, man has used land resources to satisfy his needs. However, regeneration of land resources is very slow while population growth is very fast, leading to an imbalance. Potential land use assessment is likely to be the prediction of land potential for productive land use types. This is of great importance in guiding decisions on land uses in terms of their potential and conserving natural resources for future generations. Therefore, careful planning of the use of land resources is based on land evaluation, which is the process of assessing the suitability of land for alternative land uses [1].

Soil productivity is the capacity of a soil in its natural environment to produce a specific plant or sequence of plants under specific systems of management inputs [2]. [3] described actual soil productivity as the initial soil capacity to produce a certain amount of crop per hectare per annum. He defined soil potential productivity on the other hand as that productivity of soil when all possible improvements have been made. It is thus, the future potentiality of that soil taking into account physical and chemical characteristics which are modified by conservation practices or improvements and also those characteristics which are not modifiable by present day technology. According to [4], the resources should be managed in a sustainable manner so that the changes proposed to meet the needs of development are brought out without diminishing the productivity potential for future use.

Accurate estimates of future soil productivity are essential in making agricultural policy decisions and for planning the use of land from field scale to the national level, and also in determining the suitability of any soil for agricultural use. [5] reported the development of certain simulation models that could enable quantitative and qualitative estimates of crops grown under a wide range of weather and soil conditions. In addition, various approaches are also being developed which attempt to quantitatively and qualitatively relate soil properties to its productivity. These include

Riquier index, Neill index, Storie index, and Cook index [6]. Consequently, efforts by researchers have been made to key the yield of crops to a number of soil properties such as soil bulk density, available water capacity, total porosity, soil pH and nutrient storage so as to determine their influence on crop productivity.

According to [7], information on soil productivity models in many developing countries have not been fully documented in literature. In India, a good volume of information on soil productivity has been documented. Reconnaissance and detailed survey of soil resources have been carried out in several micro watersheds of Karnataka by students as well as government agencies like the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) and the Soil and Land Use Survey of India (SLUSI). However, such studies have not been undertaken in the study area. The study area is highly affected by water erosion due to high rates of deforestation and unsustainable land use practices which are further intensified by poor socio-economic conditions. In addition, the demography in this area is characterized by high poverty, rapid population growth and high illiteracy rates. As a result, this area has undergone several changes in forest/land use due to human influence, leading to degradation of soil resources. Information on soils of the study area, in respect of their characteristics, potentials and constraints is therefore required so that the precious soil resources would be put into judicious use without allowing it to degrade further. Having this view in mind, the present study was therefore undertaken in order to assess the productivity of soils of Singhanhalli-Bogur microwatershed in the northern transition zone of Karnataka, India using Riquier index and geographic information systems (GIS) techniques.

2. MATERIALS AND METHOD

2.1. Description of the study area

Singhanhalli-Bogur micro-watershed having an area of 760.6 ha (Figure 1), is located in the Decca plateau in the hot semi-arid agro-ecological region 6 and sub-region 6.4 between 15.60º to 15.70º N latitude and 74.97º to 74.98º E longitude in Dharwad taluk of Dharwad district in the northern transition zone of Karnataka, India. The study area has medium to high available water content with a length of growing period of 150-180 days. The climate is characterized by hot and humid summer and mild and dry winter. The average annual rainfall is 755.2 mm, which is distributed over May to October and annual temperature ranges from 24-28 °C with an Ustic Soil Moisture and Isohyperthermic soil temperature regimes [8]. 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 of particles 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*).

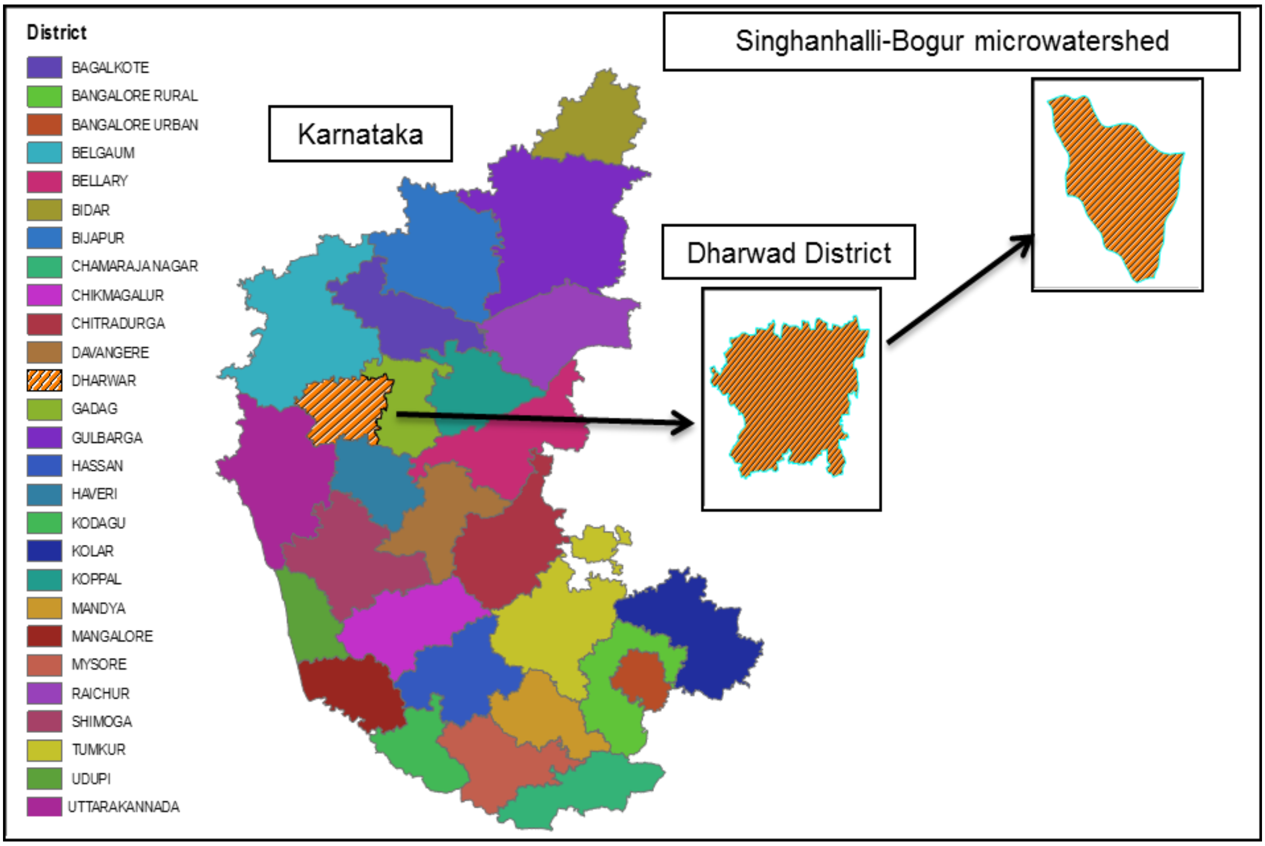

Figure 1. Map of Singhanhalli-Bogur microwatershed

2.2. Soil Survey and Laboratory Analysis

A detailed soil survey of the study area was carried out using IRS P6 LISS-IV satellite image and Survey of India Toposheet as base maps. The image and scanned Toposheet were geocoded and subset was created in ArcGIS 10.1 on a 1:12,500 scale. The area was then intensively traversed and 20 pedons locations were fixed based on soil heterogeneity resulting from variation in slope, relief, drainage and surface graveliness. At each pedon location, a fresh profile was opened and examined as per procedure outlined by [9]. Horizon-wise soil samples were collected and analyzed for important physical and physicochemical properties following standard analytical procedures. After the correlation of soil properties, the soils were classified according to "Keys to Soil Taxonomy" [10] and thereafter the soils were mapped into soil mapping units at phase level.

2.3. Soil productivity assessment

Evaluation of soil productivity is a multidisciplinary approach involving various methods, system and factors. In this study, the parametric approach proposed by [11] was used to appraise soils in terms of actual and potential productivity. This parametric system allowed the calculation of the actual productivity under present situation, and potential productivity based on anticipated ratings which could be obtained after soil reclamation. The approach is concerned basically with intrinsic soil characteristics that govern soil utilization and productive capacity and involves the calculation of a productivity index on the basis of nine factors (Table 1), viz; moisture (H), drainage (D), effective depth (P), texture/structure (T), base saturation (N), soluble salt concentration (S), organic matter content (O), mineral exchange capacity/nature of clay (A) and mineral reserves as given in equation 1. Each factor is given a numeric value from 0 to 100. The resultant index obtained by a multiplication of those factors is positioned in one of the five productivity classes.

Table 1. Criteria for assessing productivity of soils

Class	Description	Rating
Drainage (D)		
D1a	Marked waterlogging, water table almost reaches the surface all year round	10
D1b	Soil flooded for 2 – 4 months of the year	30

D2a	Moderate waterlogging, water table being sufficiently close to the surface to harm deep rooting plants	40
D2b	Total waterlogging of profile for 8 days to 2 months	50
D3a	Good drainage, water table sufficiently low not to impede crop growing	70
D3b	Waterlogging for brief period (flooding), < 8 days each time	90
D4	Well drained soil, deep water table (hydromorphic horizon over 120 cm depth); no waterlogging of soil profile	100
Mineral Exchange Capacity (A)		
A0	Exchange capacity of clay, < 5 $cmol.kg^{-1}$	85
A1	Exchange capacity of clay, 5 – 20 $cmol.kg^{-1}$ (probably kaolinite and sesquioxides)	90
A2	Exchange capacity of clay, 20 – 40 $cmol.kg^{-1}$	95
Reserves of weatherable mineral in B horizon (M)		
M1	Reserves very low to nil	80
M2	Reserves fair	
	M2a: Minerals derived from sands, sandy material or ironstone	85
	M2b: Minerals derived from acid rock	90
	M2c: Minerals derived from basic or calcareous rocks	95
M3	Reserves large	
	M3a: Sands, sandy materials or ironstone	90
	M3b: Acid rock	95
	M3c: Basic or calcareous	100
Soluble salt Content (S)		
S1	< 0.2 %	100
S2	0.2 – 0.4%	70
S3	0.4 – 0.6%	50
S4	0.6 – 0.8%	25
S5	0.8 – 1.0%	15
S6	1.0%	5
If Na_2CO_3 is present in the soil (alkali soil)		
S7	Total soluble salt {including Na_2CO_3} (0.1 – 0.3%)	60
S8	0.3 – 0.6%	15
S9	0.6%	5

Table 1. (contd..)

Class	Description	Rating
Soil Moisture (H)		
H1	Rooting zone below wilting point all the year round	5
H2	Rooting zone below wilting point for 9 – 11 months of the year	
	H2a: 11 months	10
	H2b: 10 months	20
	H2c: 9 months	30
H3	Rooting zone below wilting point for 6 – 8 months of the year	
	H3a: 8 months	50
	H3b: 7 months	60
	H3c: 6 months	70
H4	Rooting zone below wilting point for 3 – 5 months of the year	
	H4a: 5 months	80
	H4b: 4 months	90
	H4c: 3 months	100
H5	Rooting zone below wilting point and field capacity for most of the year	100
Slope (E)		
E1	Flat, 0 – 2%	100
E2	Slightly sloping, 2 – 6%	90
E3	Moderately sloping, 6 – 12%	70
E4	Highly sloping, 12 – 20%	50
E5	Very highly sloping, 20 – 30%	40

E6	Steeply sloping, > 30 cm	20
Texture and Structure of root zone (T)		
T1	Pebbly, stony or gravelly soil	
	T1a: Pebbly, stony or gravelly soil, > 60% by weight	2
	T1b: Pebbly, stony or gravelly soil, 40 – 60%	5
	T1c: Pebbly, stony soil, 20 – 40%	8
T2	Extremely coarse textured soil	
	T2a: Pure sand, of sand particle structure	10
	T2b: Extremely coarse textured soil (> 45% coarse sand)	20
	T2c: Soil with non-decomposed raw humus (> 30% organic matter) and fibrous structure	30
T3	Dispersed clay of unstable structure (ESP > 15%)	35
T4	Light textured soil: fS, LS, SL, cS and Si	
	T4a: Unstable structure	40
	T4b: Stable structure	50
T5	Heavy-textured soil: C or SiC	
	T5a: Massive to large prismatic structure	50
	T5b: Angular to crumb structure or massive but highly porous	80
T6	Medium-heavy soil: heavy SL, SC, CL, SICL and Si	
	T6a: Massive to large prismatic structure	80
	T6b: Angular to crumb structure, massive but slightly porous	90
T7	Soil of average, balances texture: L, SiL and SCL	100
Base saturation and pH (1:1) of A horizon (N)		
N1	Base saturation < 15% and pH 3.4 – 4.5	40
N2	Base saturation 15 – 35% and pH 4.5 – 5.0	50
N3	Base saturation 35 – 50% and pH 5.0 – 6.0	60
N4	Base saturation 50 – 75% and pH 6.0 – 7.0	80
N5	Base saturation > 75% and pH 7.0 – 8.5	100
N6	Soil excessively calcareous (> 30%)	80
Organic matter in A1 horizon (O)		
O1	Very little organic matter, less than 1%	85
O2	Little organic matter, 1 – 2%	90
O3	Average organic matter content, 2 – 5%	100
O4	High organic matter content, over 5%	100
O5	Very high organic matter content but C/N over 25	70

Note: fS: fine Sand; LS: Loamy Sand; SL: Sandy Loam; S: Sand; C: Clay; Si: Silt; SiC: Silty Clay; cS coarse Sand

$$SPI = \frac{H}{100} * \frac{D}{100} * \frac{P}{100} * \frac{T}{100} * \frac{N}{100} * \frac{O}{100} * \frac{A}{100} * \frac{M}{100} * \frac{E}{100} * \frac{S}{100} \text{ .... (Equation 1)}$$

Where
SPI = Soil Productivity Index; H = soil moisture content; D = drainage; P = effective soil depth;
T = texture/structure; N = base saturation and pH; O = organic matter content; A = mineral reserves;
M = mineral exchange capacity; E = Slope; S = soluble salt concentration;

Each factor is rated on a scale from 0 to 100 and the resultant index of productivity, also lying between 0 and 100, is set against a scale placing the soil in one or other of five productivity classes (Table 2).

Table 2. Soil productivity classes

Soil Productivity Index	Definition	Symbol
65 – 100	Excellent	I
35 – 64	Good	II
20 – 34	Average	III
8 – 15	Poor	IV
0 - 7	Extremely Poor	V

To know the rate of improvement in the soil properties, the coefficient of improvement was calculated. The coefficient of improvement of a soil was expressed as the ratio of potential productivity to actual productivity indices multiplied by 100 as given in equation 2 below:

$$\text{Coefficient of improvement} = \frac{\text{Potential productivity rating}}{\text{Actual productivity rating}} \quad \text{...... (Equation 2)}$$

Each of the soil characteristics with associated attribute data was digitally encoded in the ArcGIS database to eventually generate the thematic maps.

3. RESULTS AND DISCUSSION

3.1. Soil productivity of study area

Soils of the study area were mapped into soil mapping units at phase level of soil classification. Accordingly, seventeen soil mapping units were identified and presented in Table 5 and depicted in Figure 2. Three mapping units (soil units 1, 4 and 9) occupying 171.96 ha (22.61%) of the study area were classified as clay soils and another three mapping units (soil units 2, 6 and 15) accounting for 87.09 ha (11.44%) of the study area were classified as clay loams. One mapping unit (soil unit 7) which occupies 40.91 ha (5.38%) of the study area was classified as sandy clay and six mapping units (soil units 3, 5, 8, 10, 16 and 17) accounting for 256 ha (33.71%) of the study area were classified as sandy loams while four mapping units (soil units 11, 12, 13 and 14) which occupy 188.13 ha (27.74%) of study area were classified as sandy clay loams.

Tables 6, 7 & 8 present the results on the productivity (actual and potential) of soils of the study area. According to the results, there was no excellent productivity class both in terms of actual and potential productivity. In terms of actual productivity, the study revealed that more than half of the area (396.3 ha) which makes up 52.1% of the study area is poor in productivity, 42.6 ha (5.6 %) has extremely poor productivity, 161.6 ha (21.3 %) has average productivity and 144.0 ha (18.3%) has good productivity (Table 8; Figure 3).

On the other hand, in terms of potential productivity which is the productivity that the soil is expected to show after soil improvements are done, almost half of the area (365.7 ha) which makes up 48% of the study area has average productivity, 135.9 ha (19.9%) has poor productivity while 242.9 ha (31.9) showed good productivity (Table 8, Figure 4).

It is expected that there will be no extremely poor productivity class in the study area after soil improvement. This is probably due to improvement in previously limiting soil characteristics after soil reclamation is done. In Table 6, it is indicated that soil units 1 & 4 are good in actual productivity. These were deep, poorly drained clay soils on very gentle slopes found in lowlands, and associated with slow to rapid permeability and slight erosion. The good productivity class is attributed to the favourable moisture condition, deep soil depth, high base saturation, high soluble salt content, appreciable mineral exchange capacity and mineral reserve status, and very gentle slope prevailing in these soils. However, these soils showed moderate limitations of drainage and organic matter probably due to the clay content. According to [12], the presence of higher amount of clay fraction at varying depths having poor internal drainage could be responsible for the less productivity of these soils.

In Table 7, it is indicated that the potential productivity of these soils will still remain good even after the major limitations (drainage and organic matter) are addressed. Soil units 2, 3, 6 & 7 were average in both actual and potential productivity. These were moderately deep to very deep, moderately drained to well drained clay loam and sandy clay soils on gentle to moderate slopes found in lowlands and undulating midlands with slow to rapid permeability and moderate erosion. Amongst the major factors including moisture, base saturation and soluble salts limiting the productivity of these soils, organic matter and mineral reserve status were identified as the most limiting factors.

Table 5. Soil unit description of Singhanhalli-Bogur microwatershed

Soil Unit No.	Description	Area	
		ha	%
1	Deep, moderately drained clay soils on very gentle slopes in lowlands, associated with moderately rapid permeability and slight erosion.	78.49	10.32
2	Moderately deep and moderately well-drained clay loam soils on moderate slopes in undulating midlands, associated with moderately rapid permeability and moderate erosion.	22.08	2.90
3	Deep and well-drained sandy loam soils on gentle slopes in undulating midlands, associated with rapid permeability and moderate erosion.	70.91	9.32

4	Very deep, moderately drained clay soils on very gentle slopes in lowlands, associated with slow permeability and slight erosion.	65.51	8.61
5	Deep, well-drained sandy loam soils on gentle slopes in undulating midlands, associated with rapid permeability and severe erosion.	73.18	9.62
6	Very deep, well-drained clay loam soils on gentle slopes in lowlands, associated with rapid permeability and moderate erosion.	27.72	3.64
7	Deep and well-drained sandy clay soils on gentle slopes in lowlands, associated with slow permeability and moderate erosion.	40.91	5.38
8	Deep and well-drained sandy loam soils on steep slopes in uplands, associated with rapid permeability and very severe erosion.	10.22	1.34
9	Deep and moderately drained clay soils on very gentle slopes in lowlands, associated with moderately rapid permeability and slight erosion.	27.96	3.68
10	Moderately deep and well-drained sandy loam soils on very gentle slopes in uplands, associated with moderately rapid permeability and slight erosion.	59.46	7.82
11	Deep and well-drained sandy clay loam soils on moderate slopes in lowlands, associated with rapid permeability and severe erosion.	41.35	5.44
12	Moderately deep and moderately well-drained sandy clay loam soils on moderate slopes in undulating midlands, associated with moderately rapid permeability and moderate erosion.	109.5	14.4
13	Deep and moderately well-drained sandy clay loam soils on very gentle slopes in lowlands, associated with rapid permeability and moderate erosion.	33.82	4.45
14	Moderately deep and moderately well-drained sandy clay loam soils on gentle slopes in undulating midlands, associated with rapid permeability and moderate erosion.	3.46	0.45
15	Deep and moderately well-drained clay loam soils on gentle slopes in undulating midlands, associated with rapid permeability and moderate erosion.	37.29	4.90
16	Moderately deep, moderately well-drained sandy loam soils on moderate slopes in uplands, associated with moderately rapid permeability and severe erosion.	22.34	2.94
17	Deep and moderately well-drained sandy loam soils on moderate slopes in undulating midlands, associated with rapid permeability and severe erosion.	20.29	2.67

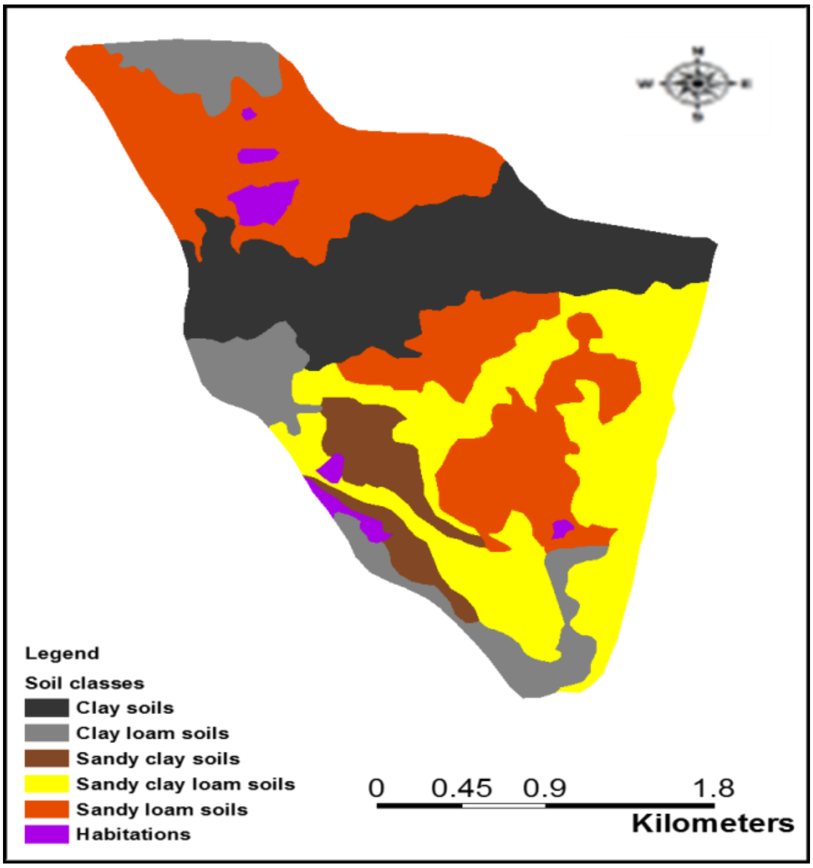

Figure 2. Soil map of Singhanhalli-Bogur microwatershed

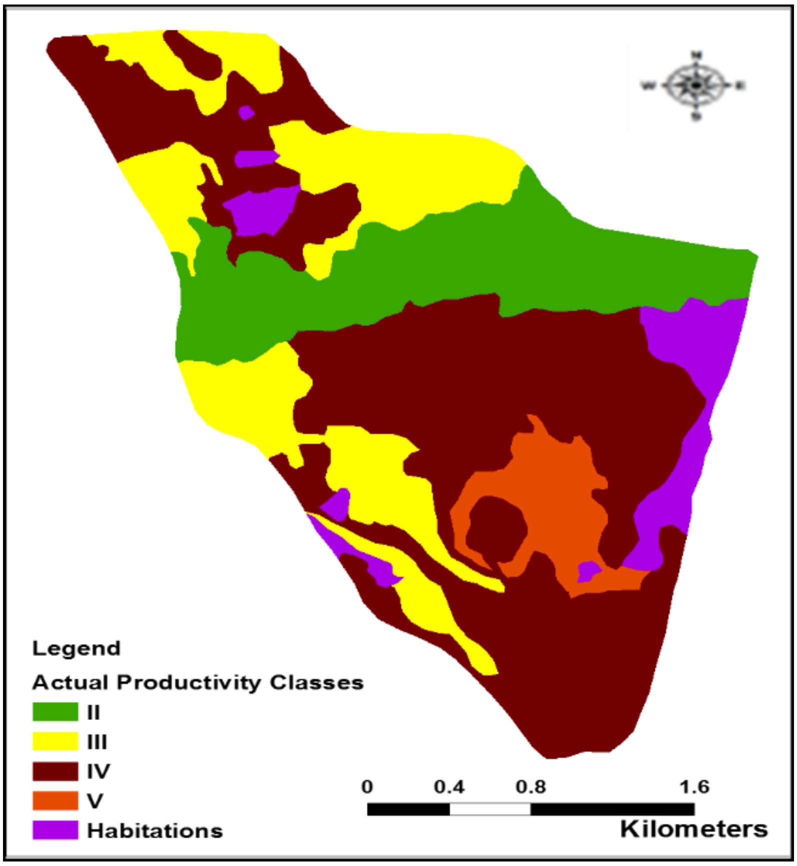

Figure 3. Actual soil productivity map of Singhanhalli-Bogur microwatershed

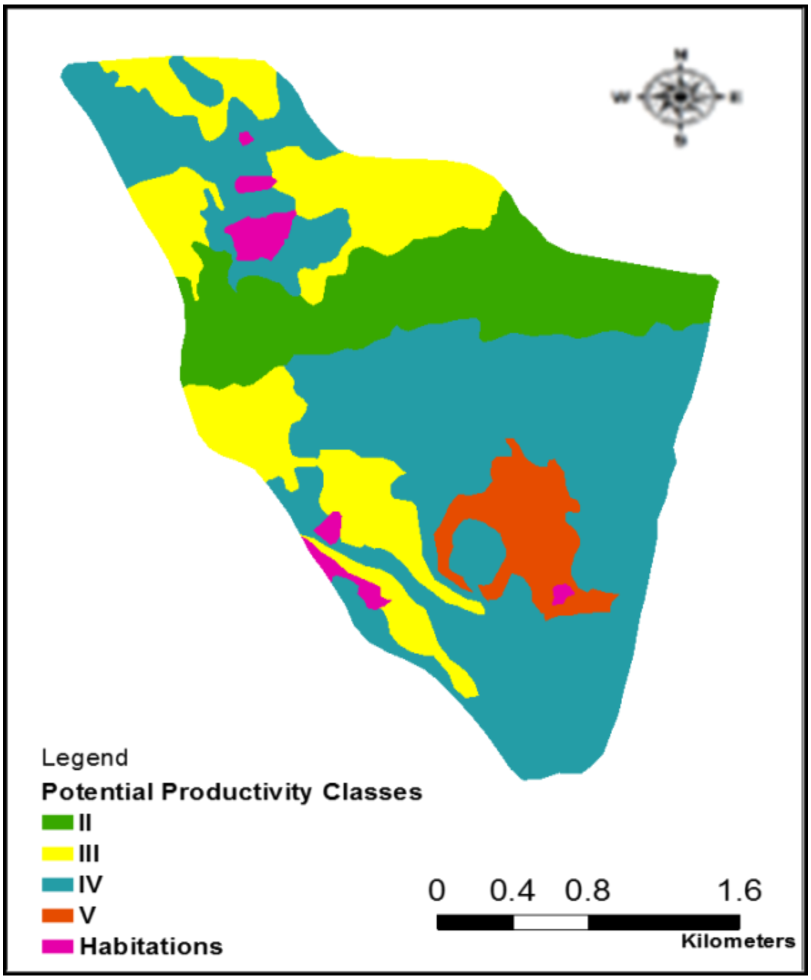

Figure 4. Potential soil productivity map of Singhanhalli-Bogur microwatershed

Soil units 5, 8, 9, 10, 11, 12, 13, 14 & 15 were poor in actual productivity. These were moderate to deep, moderately drain to well drained clay loam and sandy clay loam soils with moderate to rapid permeability found on very gentle to steep slopes located in lowlands, undulating midlands and uplands having slight to severe erosion. The major limitations of these soils were soil moisture, depth, texture, base saturation, organic matter, slope and mineral reserve status. The poor productivity could be attributed to the identified moderate to severe limitations. However, the data in Table 7 revealed that these soils showed greater scope for improvement in terms of potential productivity after soil management issues are addressed. Soil units 5, 8, 11, 12, 14 and 15 were rated "average" while soil unit 9 was rated "good" but it was observed that soil units 10 and 13 would still remain rated as "poor" in potential productivity even after improvement in the major limiting factors is done. This indicates that the low mineral reserve and mineral exchange capacity coupled with limiting texture and soluble salt status would still be an issue of great concern for crop production in these soils and hence, would therefore require major soil improvement efforts that might be difficult for farmers to undertake due to the poor economic status of farmers in the study area as noted by [8].

Soil units 16 & 17 were rated "extremely poor" in actual productivity and "poor" in potential productivity due to severe limitations of soil moisture, soil depth, soil texture and structure, base saturation, soluble salts, slope and mineral reserve status. These were severely eroded, moderately deep to deep, well drained sandy loam soils with rapid permeability found on moderate slopes and located in undulating midlands and uplands. Upland soils located on moderate to high slopes have been reported to have extremely poor to poor productivity due to major limitations of shallow rooting depth and low organic matter [13]. Therefore, by providing supplementary irrigation, addition of organic matter and fertilizers and taking suitable measures for erosion control, the productivity of these soil units would be improved in the long term [14]. According to [15], the addition of NPK fertilizers and poultry manure to such soils would raise their base saturation, CEC and organic matter and hence increase their productivity.

Table 6. Actual productivity rating of soils of the Singhanhalli-Bogur microwatershed

Soil Unit No.	Soil moisture (H)	Drainage (D)	Soil depth (P)	Texture/ Structure (T)	Base saturation (N)	Soluble salts (S)	Organic matter (O)	Mineral exchange capacity (A)	Slope (E)	Mineral reserves (M)	Productivity index (%)	Productivity class
1	100	70	100	80	100	100	85	100	90	90	39	Good
2	90	100	80	90	80	100	85	90	70	85	24	Average
3	100	100	90	90	80	100	85	85	90	90	34	Average
4	100	70	100	80	100	100	85	100	90	90	39	Good
5	90	100	90	50	80	100	85	100	90	90	17	Poor
6	80	100	100	90	80	70	85	90	90	85	27	Average
7	80	100	90	90	80	70	85	95	90	85	22	Average
8	80	70	80	90	60	70	85	85	90	85	13	Poor
9	80	100	100	80	100	70	85	95	90	85	19	Poor
10	80	100	80	50	80	70	85	85	90	85	10	Poor
11	70	100	90	100	80	70	85	90	70	85	18	Poor
12	70	100	80	100	80	70	90	90	70	85	17	Poor
13	70	100	80	50	80	50	90	90	90	85	8	Poor
14	70	100	90	100	80	50	90	95	90	85	19	Poor
15	70	100	90	90	80	50	90	95	90	85	17	Poor
16	70	100	80	50	80	50	90	95	70	85	7	Extremely poor
17	70	100	90	50	80	50	90	85	70	85	7	Extremely poor

Table 7. Potential productivity rating of soils of the Singhanhalli-Bogur microwatershed after soil improvement

Soil Unit No.	Soil moisture (H)	Drainage (D)	Soil depth (P)	Texture/ Structure (T)	Base saturation (N)	Soluble salts (S)	Organic matter (O)	Mineral exchange capacity (A)	Slope (E)	Mineral reserves (M)	Productivity index (%)	Productivity class
1	100	90	100	80	100	100	100	100	90	90	58	Good
2	100	90	80	90	80	100	100	90	70	85	28	Average
3	100	100	90	90	80	100	100	85	90	90	45	Good
4	100	90	100	80	100	100	100	100	90	90	58	Good
5	100	90	90	50	80	100	100	100	90	90	26	Average
6	100	90	100	90	80	70	100	90	90	85	31	Average
7	100	100	90	90	80	70	100	95	90	85	33	Average
8	100	100	80	90	60	70	100	85	90	85	20	Average
9	100	90	100	80	100	70	100	95	90	85	37	Good
10	100	100	80	50	80	70	100	85	90	85	15	Poor
11	100	100	90	100	80	70	100	90	70	85	27	Average
12	100	100	80	100	80	70	100	90	70	85	24	Average
13	100	100	80	50	80	50	100	90	90	85	11	Poor
14	100	100	90	100	80	50	100	95	90	85	26	Average
15	100	100	90	90	80	50	100	95	90	85	24	Average
16	100	100	80	50	80	50	100	95	70	85	9	Poor

17	100	100	90	50	80	50	100	85	70	85	9	Poor

Table 8. Productivity classes in study area

Productivity class			Actual productivity (productivity before soil improvement)		Potential productivity (productivity after soil improvement)	
Index range	**Definition**	**Symbol**	**Area (ha)**	**%**	**Area (ha)**	**%**
65 – 100	Excellent	I	nil	nil	nil	nil
35 – 64	Good	II	144	18.3	242.9	31.9
20 – 34	Average	III	161.6	21.3	365.7	48.0
8 – 19	Poor	IV	396.3	52.1	135.9	19.9
0 -7	Extremely poor	V	42.6	5.6	nil	nil

3.2. Coefficient of improvement

The coefficient of improvement in soil characteristics (Table 9) was expressed as the ratio of potential productivity to actual productivity. According to the results, the coefficient of improvement of soils of the study area was in the order of 1.9 (for soil unit 9), 1.5 (for soil units 1, 4, 5, 7, 8, 10 & 11), 1.4 (for soil units 12, 13, 14, 15, 16 & 17), 1.3 (for soil unit 3) and 1.2 (for soil units 2 & 6). Soil unit 9 showed the maximum scope for improvement as the productivity index increased from 19% (poor productivity) to 37% (good productivity) after suitable improvement measures (including favourable soil moisture, increased solubility of salts, addition of organic matter, etc.) have been applied. Similarly, soil units 5, 8, 10 & 11 which are poor in actual productivity offered a moderate scope for improvement to potential productivity classes ranging from average to good after suitable improvement measures have been applied. The least scope for soil improvement in the study area was shown by soil units 2 and 6 due to their low organic matter content, mineral exchange capacity and mineral reserve status. The results therefore indicate that undertaking suitable and appropriate soil management programmes will greatly increase the productivity of soils of the study area.

Table 9. Coefficient of improvement of soils in Singhanhalli-Bogur microwatershed

Soil Unit No.	Coefficient of improvement
1	1.5
2	1.2
3	1.3
4	1.5
5	1.5
6	1.2
7	1.5
8	1.5
9	1.9
10	1.5
11	1.5
12	1.4
13	1.4
14	1.4
15	1.4
16	1.4

17	1.4

4. CONCLUSION

Actual productivity of soils of the study area varies from extremely poor to good with almost half of the area falling below the average.Organic matter was found to be the most limiting factor for crop production. In addition, drainage was a major limiting factor in lowland soils especially the clay soils. However, there are scopes for productivity to be increased if some soil improvement strategies are undertaken. This would be of immense benefit for the farmers especially in improving their livelihood as majority of farmers in the study area depends on their lands as the only source of income for their family. Therefore, an appropriate soil management approach including choosing appropriate crops, rotation of crops, addition of organic matter through manuring, green manuring and fertilisers, in combination with affordable engineering technologies like contour trenches are to be taken up in order to conserve water and protect the soils especially in the uplands. This will help to address the inherently low productivity of soils in the study area. Agri-horticulture may be practiced on undulating midlands having well drained sandy clay loams. In addition, there are presently no watershed development programmes in the study area. Therefore, an integrated watershed development approach is needed in order to protect the limited forests and erosion-prone areas. For such programme to be successful, it must be implemented with people's participation especially focusing on site-based land use planning, harvesting and recycling of excess run-off, rehabilitation of denuded areas and resource conserving land uses such as silvi-pastoral, horti-pastoral, agro-horticultural and other suitable multi-tier and high density plantation systems.

5. REFERENCES

[1] Fresco, L.O., Huizing, H., Keulen, H.V., Luning, H.A. and Schipper, R.A. (1994) Land Evaluation and Farming Systems Analysis for Land Use Planning. FAO Working Document.

[2] Karlen, D.L., Mausbach, M.J., Doran, J.W., Cline, R.G., Harris, R.F. and Schuman, G.E.(1997) Soil Quality: A concept, definition, and framework for evaluation. *Soil Sci. Soc. Am. J.* 61(1): 4-10.

[3] Riquier, J. (1974) A summary of parametric methods of soil and land evaluation. In: *Approaches to land classification, Soils Bulletin 22* (ed. FAO) FAO, Rome.

[4] Kanwar, J.S. (1994) In management of land and water resources for sustainable agriculture and environment. *Diamond JubileeSymposium,* Indian Society of Soil Science, New Delhi.

[5] De wit, C.T. and Van Keulen, H. (1987) Modelling production of field crops and its requirements. *Geoderma* 40: 253-265.

[6] Gantzer, C.J. and McCarty, T.R. (1987) Predicting corn yields on a clay pan using a soil productivity index. Trans ASAE. 30: 1347-1352.

[7] Anikwe, M.A. and Obi, M.E. (2000) Evaluation of an index model for quantifying the productivity of soils in south eastern - Nigeria, using maize as a test Crop. *J. Agric. Eng*. 45: 81-86.

[8] Amara Denis, M.K., Patil, P.L., Dasog, G.S. and Manjunath, M.V. (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.

[9] Soil Survey Staff (2009) Soil Survey manual. USDA publishers (India), Jodhpur.

[10] Soil Survey Staff (2012) "*Keys to Soil Taxonomy*"United States Department of Agriculture Natural Resource Conservation Service, 12th Edition, Washington D.C., USA.

[11] Riquier, J., Luis Brama, D. and Cornet, J.P. (1970) A new system of soil appraisal in terms of actual and potential productivity. FAO Soil Resources, Development and Conservation Service, Land and Water Development Division, FAO, Rome, 38 pp.

[12] Ogunkunle, A.O. (1993) Soil in land suitability evaluation: an example with oil palm in Nigeria. *Soil Use and Manag*. 9:35-40.

[13] Nasre, R.A., Nagaraju, M.S.S., Srivastava, R., Maji, A.K. and Barthwal, A.K. (2014) Characterization, Classification and Evaluation of Soils of Karanji Watershed, Yavatmal District of Maharashtra for Land Resource Management using Geospatial Technologies. *J. Indian Soc. Soil Sci.* 61(4): 275-286.

[14] Sumithra, K.N., Budihal, S.L., Patil, S.G., Bellakki, M.A. and Desai, B.K. (2013)Productivity potentials of Timanhal micro-watershed soils. *Karnataka J. Agric. Sci.* 26(1): 40-45.

[15] Agber, P.I. and Ali, A. (2012)Evaluation of the productivity of soils in Makurdi, Southern Guinea Savanna, Nigeria, using Riquier index. *J. Env. Sci. and Water Res.* 1(5): 100 – 104.