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ORIGINAL ARTICLE

Distributional Pattern and Fertility Status of Soils in the Environs of the Malaprabha River Basin, Karnataka State, India

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ABSTRACT
Soil, water, air, and plants are vital natural resources that help produce food and fiber for humans. They also maintain the ecosystems on which all life on Earth ultimately depends. Soil serves as a medium for plant growth, a sink for heat, water, and chemicals, a filter for water, and a biological medium for the breakdown of wastes. Soil interacts intimately with water, air, and plants and acts as a damper to fluctuations in the environment. Soil mediates many of the ecological processes that control water and air quality and promote plant growth. However, over time, soil resources have been continuously degraded and depleted. The degradation of soil resources has long been recognized as a primary threat to fruitful and sustainable agriculture. Moreover, ongoing climatic changes have added complexity to the challenges faced by farmers and policymakers in developing nations, particularly in India. Hence, the present study is an attempt to make an analysis of the distributional pattern and fertility status of soils in the environs of the Malaprabha River Basin, which includes an appreciation of the distributional pattern of soils, soil texture, and fertility status of soils that are necessary for the growth of green plants. In the absence of any one of these elements, a plant fails to complete its life cycle. The disorder, of course, can be corrected by the addition of those elements and by suggesting appropriate strategies considering prevailing government policies and programmes to improve the fertility status of soils in the study area.
Keywords: Natural Resources, Soil fertility, Texture, Degradation and Agriculture Development.

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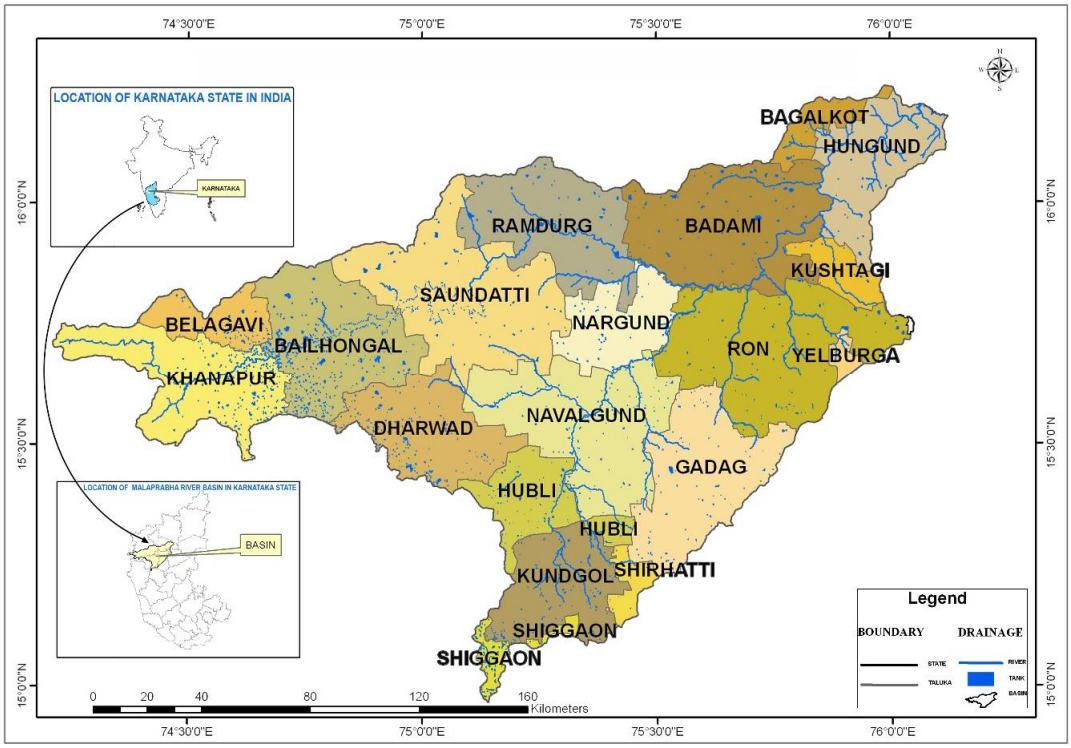
INTRODUCTION

Soils constitute the most important basic resources for agriculture [2]. It is a dynamic living entity, a medium for plant growth, and a product of the interaction of the biosphere, hydrosphere, and atmosphere with the lithosphere. It is a three-dimensional body that has depth, length, and breadth and, as such, cannot be fully comprehended from the surface. Besides climatic considerations, the texture and depth of the soil, its ingredients, salinity and alkalinity status, drainage conditions, and the position of the ground water table all go into determining the crops that would be suitable for an area and the mode and extent of irrigation to be applied to them [3]. The information on the soil profile of a region, including its morphological, physical, mechanical, and chemical properties and processes of formation, is necessary for simulating its hydrological character and also understanding its agricultural land use and production dynamics. Soils undergo rapid changes in their physical, chemical, and biological properties. The addition of inputs such as chemical fertilisers, organic manures, insecticides, and pesticides alters the properties of soil [1, 4-9]. Hence, the present study is an attempt to make an analysis of the distributional pattern and fertility status of soils in the environs of the Malaprabha River Basin, which includes an appreciation of the distributional pattern of soils, soil texture, and fertility status of soils that are necessary for the growth of green plants. In the absence of any one of these elements, a plant fails to complete its life cycle [10]. The disorder, of course, can be corrected by the addition of those elements and by suggesting appropriate strategies considering prevailing government policies and programmes to improve the fertility status of soils in the study area.

STUDY AREA:

The Malaprabha River Basin of Karnataka State is approximately triangular and located in the extreme western part of the Krishna basin. It lies between 15^0 05^l 02^{ll} to 16^0 20^l 19^{ll} N. latitudes and 74^0 05^l 43^{ll} to 76^0 05^l 33^{ll} E. longitudes, covering an area of 11549 sq. km, out of which 3880 sq. km are in Belgaum (33.59%), 1950 sq. km in Bagalkot (16.89%), 2739 sq. km in Dharwad (23.72%), 2657 sq. km in Gadag, 220 sq. km in Koppal, and 103 sq. km [Fig. 1]. Topographically, the Malaprabha river basin presents two important divisions, viz., the Western Ghats and the typical eastern part of the Deccan/Karnataka plateau, with distinct characteristics. The plateau has two natural subdivisions, the Semi-Malnad and the Northern Maidan, which include the northern upland, or the Deccan trap, of the state [Fig. 2]. An exhumed structure with superimposed drainage is also responsible for the sharp relief in the Kaladgi sandstones, in which Ghataprabha forms a waterfall near Gokak and the Malaprabha forms a gorge near Saundatti (Spate and Learmonth, 1967). The river Malaprabha is the most important right-bank tributary of the river Krishna.

Figure-1. Location Map of the Malaprabha River Basin, Karnataka State, India



The Benni Hall, Hire Hall, and others are the principal tributaries of the Malaprabha River [Fig. 3]. The entire river basin experiences a semi-arid type of climate, spread in the hilly, Northern dry, and Northern Transition zones of the agro-Climatic Zones of Karnataka State, and it is very warm during the summer, especially in April and May, with temperatures ranging between 35^0 and 400 °C in the eastern part of the river basin. The annual normal rainfall of the Malaprabha basin area is over 759 mm spread over 50 days, which receives monsoon rainfall as much as our nation with slight variations. Deep black cotton soils are ubiquitous in the basin area. Jowar, besides other drought-resistant inferior small millet crops, is traditionally the predominant crop. Geographically, deep black cotton soils, Unpredictable monsoonal rainfall, droughts, and famines are part of the lives of people in the study region. The present study is a natural region that occupies 6.02% of the Karnataka state. As per the 2011 census, the population of the Malaprabha River Basin is 3.38 million (5.53% of the state's total population), of which 77.66% are rural and 22.34% are urban. The dominance of rural populations makes the regional economy mainly agrarian. The basin's 68.37% of the workforce (61.75% of males and 79.55% of females), however, is still dependent on agriculture and its allied activities for their livelihood. The economic development and prosperity of the masses depend mainly on agriculture.

Figure-2. Digital Elevation Model of the Malaprabha River Basin, Karnataka State, India

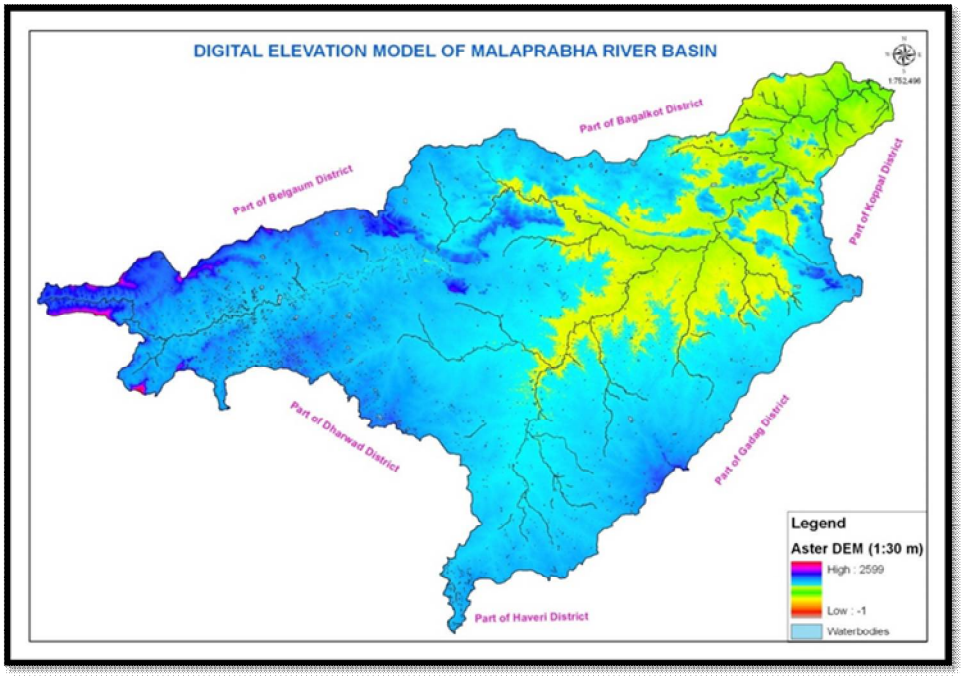
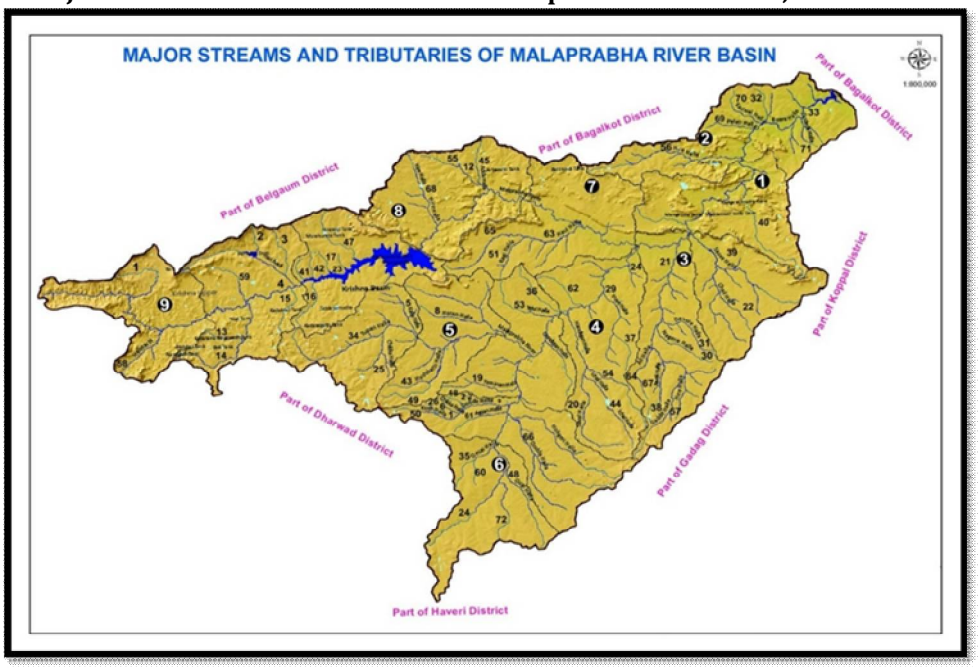


Figure-3. Major Streams and Tributaries of the Malaprabha River Basin, Karnataka State, India



OBJECTIVES

The present paper is an attempt to make an analysis of the distributional pattern and fertility status of soils in the environs of the Malaprabha River Basin, Karnataka State, India. In this context, the study has been undertaken with the following specific objectives:

- To study the distributional pattern of soils and their area in the environs of the river basin.
- To designate the soil texture and fertility status of soils (taluka-wise) in the talukas of the river basin and
- To suggest appropriate strategies in the light of prevailing government policies and programmes to sustain the fertility status of soils in the environs of the Malaprabha river basin.

MATERIAL AND METHODS

The present study is mainly based on secondary sources of data. Data for the present analysis has been obtained mainly from Survey Report of Soil Fertility Status of Karnataka State by the Department of Agriculture, Govt. of Karnataka in association with International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT) Patancheru, Hyderabad, Andra Pradesh in 2011, The Directorate, Department of Economic and Statistics, Bangalore, District Statistical Offices of Belgaum, Dharwad, Gadag & Bagalkot districts and District Census of Belgaum, Dharwad, Gadag and Bagalkot districts from 1971 to 2011 Census from Directorate of Census Operations, Bangalore Karnataka State; besides this, data were also collected from various government offices and websites. Presently, the taluka has been considered the smallest unit of analysis. To achieve the objectives mentioned above, relevant statistical tools like percentages, averages, variations, and others and methods of quantitative analysis have been employed. To describe the spatial pattern of soil texture and fertility status of soils in the Malaprabha river basin in 2011, all the talukas are grouped into different categories to show the existing concentration of fertility of soils in the basin area. At last, the results were presented with suitable diagrams and figures.

RESULTS AND DISCUSSIONS

Soils constitute the most important basic resources for agriculture [3]. It is a dynamic living entity, a medium for plant growth, and a product of the interaction of the biosphere, hydrosphere, and atmosphere with the lithosphere. It is a three-dimensional body that has depth, length, and breadth and, as such, cannot be fully comprehended from the surface. Besides climatic considerations, the texture and depth of the soil, its ingredients, salinity and alkalinity status, drainage conditions, and the position of the ground water table all go into determining the crops that would be suitable for an area and the mode and extent of irrigation to be applied to them [6]. The information on the soil profile of a region, including its morphological, physical, mechanical, and chemical properties and processes of formation, is necessary for simulating its hydrological character and understanding its agricultural land use and production dynamics.

Distributional Pattern of Soils in the Malaprabha River Basin:

The Regional Centre of the National Bureau of Soil Survey and Land Use Planning (ICAR), Bangalore, broadly classified the soils of the entire state of Karnataka into six major groups, such as Red, laterite, black, alluvial, brown forest, and coastal soils. The Malaprabha river basin is blessed with varied soil resources having geographical origins from different parent materials like granite, gneiss complex, Deccan trap, Dharwad schist, sandstone, and limestone sedimentary formations. The soils found in this river basin could be broadly classified into seven groups: shallow black soils, medium black soils, deep black soils under black soils, gravelly red loam soils, gravelly red clay soils, non-gravelly red loam soils, and non-gravelly red clay soils under red soils. These soils vary in depth, texture, gravelliness, and physiographic setting depending on the parent rock type and climatic conditions. By and large, black soils predominate in the north and eastern parts of the river basin, and red soils in the southern and eastern gneissic terrain.

Black Soils:

Black soils are also called regurs, black earths, and 'black cotton soils. These soils are derived from a variety of rocks, including Deccan trap, Cuddapah sediments, and even Dharwad rocks. Including the shallow, medium, and deep varieties, the black soils constitute the most important soil category in the Malaprabha river basin. Together, they occupy a major part of the basin's surface, being predominant in the northern maidan in the districts of Belagavi, Dharwad, and Gadag. The distinction between the shallow, medium, and deep black soils is made due to the profile, though several other important characteristics can also be distinguished.

Shallow Black Soils (less than 30 cm deep) occupy the highlands and upper slopes of the northern Karnataka region. They are thus more eroded and leached. They are highly susceptible to erosion. Morphologically, these soils are well-drained, grey to dark grey and dark brown, clay loam to clay, moderately alkaline, and calcareous. Due to the presence of iron oxides, their colour is brownish. The depth of black soil is very low. Some parts of the 3rd and 8th agro-climatic zones of the state, particularly the northwestern part of Belgaum, have shallow black soils.

Medium Black Soils (30–100 cm deep) commonly occur on plateau slopes and gently sloping plains, and they are moderately well drained and leached, dark brown to very dark grey, brown, cracking clay, and silty clay soils. Such soils occupy the 3rd and 8th agro-climatic zones of the state, especially the plateaus between Ghataprabha and Malaprabha valleys in Belgaum and Bagalakot districts and parts of Dharwad (Kundagol), Gadag, and Koppal districts.

Deep Black Soils (more than 100 cm deep) occur on the lower slopes of plateaus and nearly level plains. They are dark greyish brown to very dark grey in colour, moderately well drained, shrink-swell clay soils, and of a largely depositional nature. Parts of the 3rd and 8th agro-climatic zones of the state, mainly Naragund, Ron, and Gadag talukas of Gadag district and Navalgund, Dharwad, and Hubli talukas of Dharwad district, have deep black soils. It has a high content of calcium and potash but is deficient in nitrogen and phosphorus. Cotton and groundnuts grow well in this type.

Red soils:

Red soils are distributed in all the talukas of the Malaprabha river basin and have been derived from granite, gneisses, charnockites, sandstones, schists, quartzites, and phyllites in the semi-arid and sub-humid climates of the river basin. They are grouped into four types, such as gravelly red loam and gravelly red clay soils, non-gravelly red loam soils, and non-gravelly red clay soils, based on the texture and gravel content of the red soils. These soils are shallow to deep, well-drained to extensively drained, gravelly, or non-gravelly, and are characterized by the accumulation of clay in the subsoil.

Gravelly red loam soils occur on ridges, hills, rolling lands, and undulating uplands of the river basin. Morphologically, they are reddish brown to yellowish brown in colour, generally shallow, occasionally very deep, well drained to excessively drained, sandy loam to loamy sand, and have a high content of quartz and feldspar gravel in the surface soil and subsoil. Parts of the 3rd and 8th agro-climatic zones of the state, mainly parts of Ramadurga, Bailhongal, Saundatti talukas of Belgaum, Badami, and Hunagund talukas of Bagalakot districts, have deep black soils.

Gravely red clay soils occupy the rolling lands and uplands of the river basin. Morphologically, these soils are very shallow to deep, well to excessively drained, yellowish red, reddish brown, brown to dark red in colour, and have a loamy sand to sandy clay loam to clay subsoil with 40 to 70% gravel in the subsoil. Some parts of the 3rd agro-climatic zone of the state, particularly the south and eastern parts of the river basin, have gravelly red clay soils.

Non-gravelly red loam soils take place on ridges, rolling lands, and uplands of the river basin. Morphologically, they are dominantly very shallow to shallow, well-drained, yellowish red to reddish brown in colour, and have sandy loam to sandy clay loam and sandy clay surface soil with sandy clay loam and clay loam subsoil. Some parts of the 3rd agro-climatic zone of the state, particularly the south and eastern parts of the river basin, have non-gravelly red loam soils.

Non-gravelly red clay soils occur on rolling lands, uplands, and midlands of the river basin. Morphologically, they are yellowish red and dark red in colour, generally deep and moderately deep, well drained to excessively drained, sandy loam to sandy clay surface, with sandy clay to clay subsoil. Parts of the 3rd and 9th agro-climatic zones of the state, mainly Ramadurga, Saundatti Bailhongal, and Khanapur talukas of Belgaum and Badami and Hunagund talukas of Bagalakot districts, have non-gravelly red clay soils.

Soil Texture in the Malaprabha River Basin:

Table- 1 Distribution of Soil Texture in the Malaprabha River Basin

Sl. No.	Soil Family	Area (Sq. Km)	In %	Sl. No.	Soil Family	Area (Sq. Km)	In %
1	Clayey	512.8	4.44	7	Loamy	391.3	3.39
2	Clayey over loamy	57.4	0.50	8	Loamy Skeletal	818.5	7.09
3	Clayey Skeletal	876.1	7.58	9	Rock Out crops	618.5	5.35
4	Coarse Loamy	2.5	0.02	10	Very Fine	3751.4	32.47
5	Fine	3824.6	33.11	11	Water Bodies	231.4	2.00
6	Fine Loamy	273.4	2.37	12	Habitation	194.7	1.69
					Total Area (sq. km)	**11552.6**	**100.00**

Farming is a business, and good soil is part of a farmer's stock-in-trade. Our standard of living positively depends on agriculture, which is often determined by a combination of the physical, chemical, and biological characteristics of the soil's texture and fertility and the crops and livestock raised on them. Soil texture is one of the prime entities; it largely influences the microbiological activities and physio-chemical behavior of soils and determines the water retention and transmission properties of soils. Table- 1 and Fig. 4 and Fig.5 show the distribution of soil texture in the Malaprabha river basin. Most areas of the basin are having Fine and very fine texture of Soil. Based on texture, most of the area that falls under the fine texture category has an area of about 3824.6 sq. km (33.11%), and the very fine texture category has an area of about 3751.4 sq. km (32.47%), with rocky and water bodies accounting for a minimum of 7.35%.

Clayey skeletal (7.58%), loamy skeletal (7.09%), clayey (4.44%), others like loamy, fine loamy, clayey over loamy, coarse loamy texture (6.28%), and habitation (1.69%) are also found in some areas of the river basin.

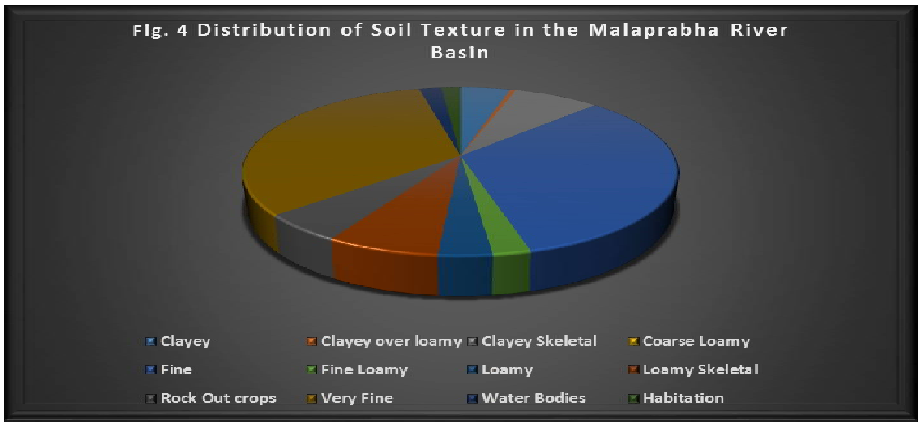
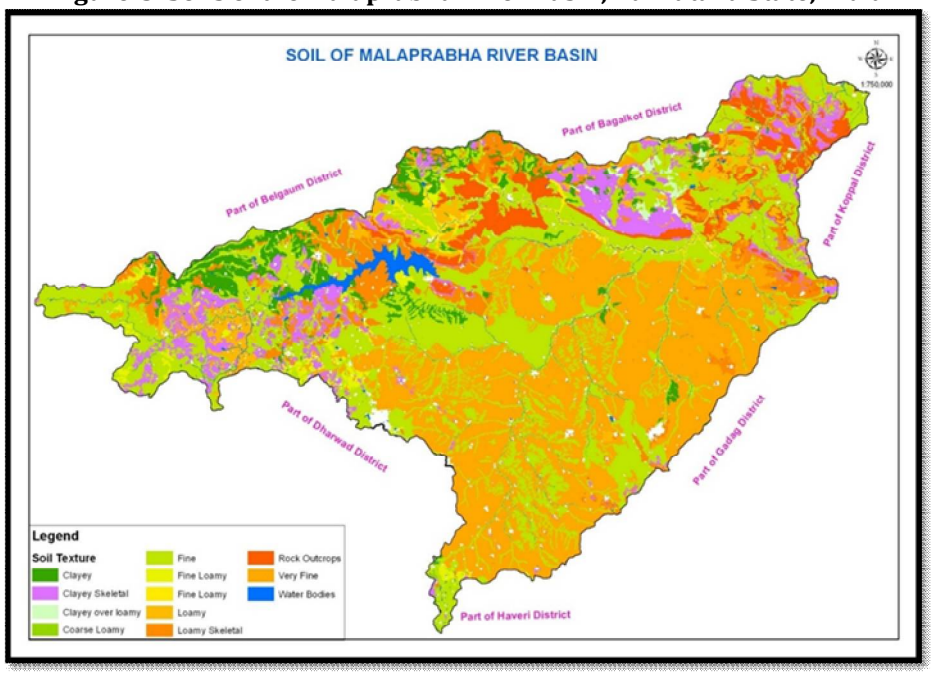


Figure-5. Soils of the Malaprabha River Basin, Karnataka State, India



Fertility Status of Soils:

Soils in the Malaprabha river basin constitute diverse orders with extreme variability in origin, parent material, water retention, and nutrient status. In addition to the parent material, climatic variables such as rainfall, temperature, and sun light influence the types and key properties of soils in a region. Accordingly, soils within the river basin show variation in terms of their physical and chemical properties. At least 16 plant food elements are necessary for the growth of green plants. In the absence of any one of these elements, a plant fails to complete its life cycle. The disorder, of course, can be corrected by the addition of that element. These 16 elements are carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, iron, manganese, zinc, copper, molybdenum, boron, and chlorine. Green plants receive carbon from carbon dioxide in the air, oxygen and hydrogen from water, and the remaining elements from the soil. Of all the plant food elements, organic carbon (nitrogen), phosphorus, and potassium play an extremely important role in plant growth.

A comprehensive survey report of the soil fertility status of the Malaprabha river basin is presented in Table 2. It explains that the chemical characteristics of soil are mainly Organic Carbon (Nitrogen), Phosphorus, Potassium, P^H, Electric Conductivity, sulphur, zinc, and Boron in the Malaprabha river basin.

Table- 2. Soils Fertility (chemical characteristics) Status of Malaprabha River Basin, 2011

Taluka	Parameter	pH	EC [dS/m]	OC [%]	Av P [ppm]	Av K [ppm]	Av S [ppm]	Av Zn [ppm]	Av B [ppm]
Khanapur	Range	4.7 -7.2	0.17 - 1.12	0.38	0.3 - 9.2	0 - 92	0.4 - 369.0	0.21 - 3.16	0.01 - 2.99
460	Mean	5.9	0.3	0.78	2.6	44	141	0.94	0.81
	% Deficient fields			**9**	**89**	**68**	**2**	**44**	**54**
Bailhongal	Range	5.4 -8.1	0.04 - 1.76	0.30 - 2.07	0.0 - 15.3	16 - 74	0.3 - 460.0	0.03 - 3.90	0.02 - 3.29
460	Mean	7	0.39	0.65	2.3	41	141.2	0.62	0.75
	% Deficient fields			**27**	**94**	**76**	**3**	**78**	**66**
Saundatti	Range	6.5 - 8.7	0.20 - 2.75	0.19 - 2.26	0.1 - 8.2	31 - 124	8.0 - 280.0	0.10 - 1.58	0.02 - 2.90
460	Mean	7.8	0.37	0.64	1.9	71	129.9	0.38	0.48
	% Deficient fields			**32**	**97**	**13**	**0**	**97**	**81**
Ramadurga	Range	6.2 - 8.3	0.14 - 2.20	0.03 - 2.62	0.1 - 9.5	9 - 169	3.9 - 408.0	0.02 - 3.48	0.01 - 2.86
460	Mean	7.4	0.4	0.67	1.9	66	160	0.59	0.57
	% Deficient fields			**26**	**95**	**38**	**2**	**74**	**78**
Badami	Range	6.3 - 8.8	0.15 - 0.89	0.18 - 1.19	0.6 - 6.2	17 - 74	4.1 - 37.2	0.51 - 3.65	0.13 - 7.45
580	Mean	7.5	0.32	0.53	2.6	43	11.5	0.79	0.68
	% Deficient fields			**49**	**98**	**67**	**57**	**64**	**73**
Hunagund	Range	6.8 - 8.7	0.11 - 1.99	0.19 - 1.18	0.6 - 6.2	18 - 74	4.2 - 39.9	0.50 - 9.56	0.18 - 12.65
660	Mean	8.1	0.34	0.63	2.6	65	10.7	0.88	0.7
	% Deficient fields			**35**	**96**	**13**	**68**	**61**	**70**
Naragund	Range	7.7 - 8.9	0.13 - 1.63	0.14 - 0.73	1.0 - 42.8	146 - 638	2.5 - 47.9	0.16 - 4.92	0.28 - 3.16
119	Mean	8.4	0.38	0.45	5.8	289	15.2	0.46	1.22
	% Deficient fields			**71**	**50**	**0**	**55**	**92**	**3**

Table- 2. Soils Fertility (Chemical Characteristics) Status of Malaprabha River Basin, 2011

Taluka	Parameter	pH	EC [dS/m]	OC [%]	Av P [ppm]	Av K [ppm]	Av S [ppm]	Av Zn [ppm]	Av B [ppm]
Ron	Range	6.4 - 9.6	0.08 - 1.52	0.04 - 0.82	0.0 - 82.8	51 - 810	0.8 - 121.9	0.12 - 7.98	0.10 - 6.98
339	Mean	8.3	0.26	0.28	5.6	193	6.8	0.4	0.85
	% Deficient fields			**92**	**70**	**0**	**87**	**94**	**30**
Gadag	Range	6.0 - 9.4	0.05 - 5.53	0.08 - 1.01	0.0 - 32.8	34 - 621	1.0 - 49.3	0.06 - 2.42	0.10 - 9.62
256	Mean	8.3	0.25	0.4	4.6	183	4.8	0.42	0.99
	% Deficient fields			**74**	**68**	**1**	**93**	**91**	**32**
Dharwad	Range	5.1 - 8.9	0.04 - 1.55	0.30 - 1.99	0.2 - 207.0	39 - 2044	2.5 - 118.2	0.28 - 4.58	0.18 - 2.58
270	Mean	6.9	0.24	0.84	15.9	193	11.8	1.12	0.7
	% Deficient fields			**6**	**34**	**1**	**65**	**27**	**47**

Hubli	Range	5.3 - 9.1	0.04 - 1.87	0.21 - 1.47	0.2 - 80.0	36 - 2344	1.4 - 715.0	0.28 - 24.30	0.10 - 12.48
320	Mean	7.4	0.25	0.67	7.2	180	10.7	1.12	0.84
	% Deficient fields			**18**	**56**	**4**	**83**	**36**	**50**
Navalgund	Range	5.6 - 9.2	0.07 - 1.08	0.17 - 0.84	0.2 - 30.6	86 - 1781	2.3 - 61.0	0.24 - 3.28	0.26 - 3.54
180	Mean	8.3	0.3	0.44	4.3	321	6.9	0.59	1.14
	% Deficient fields			**71**	**74**	**0**	**89**	**80**	**6**
Kundagol	Range	6.3 - 9.3	0.03 - 1.17	0.27 - 0.91	0.2 - 75.8	46 - 603	2.5 - 70.2	0.32 - 4.10	0.36 - 5.16
200	Mean	8.1	0.22	0.48	8.1	243	6	0.73	0.91
	% Deficient fields			**63**	**55**	**1**	**94**	**69**	**12**
MRB	Mean	**99.4**	**4.02**	**7.46**	**65.4**	**1932**	**656.5**	**9.04**	**10.64**
4764	**% Deficient fields**			**573**	**976**	**282**	**698**	**907**	**602**
	Average	**7.65**	**0.31**	**0.57**	**5.03**	**148.62**	**50.50**	**0.70**	**0.82**
				44	**75**	**22**	**54**	**70**	**46**

Sources: Survey Report of Soil Fertility Status of Karnataka State by the Department of Agriculture, Govt. of Karnataka in association with International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT) Patancheru, Hyderabad, Andra Pradesh in 2011 [6].

Organic carbon or nitrogen induces vegetative development in plants by imparting a healthy green colour to the leaves. It also controls, to some extent, the efficient utilisation of phosphorus and potassium. Its deficiency retards growth and root development, turns the foliage yellowish, hastens maturity, causes the shrivelling of grains, and lowers the crop yield. Table 2(A) presents the spatial distribution of organic carbon (N) status of soils in the talukas of the Malaprabha river basin and comparatively with the status of Karnataka state. It revealed the fact that 38.46% of the talukas (52% of the state soil), namely Ron (0.28%), Gadag (0.40%), Navalgund (0.44%), Naragund (0.45%), and Kundagol (0.48%), are deficient (< 0.5%), and 61.54% of the talukas (48% of the state soil), namely Badami (0.53%), Hunagund (0.63%), Saundatti (0.64%), and Bailhongal (0.65%) Ramadurga (0.67%), Hubli (0.67%), Khanapur (0.78%), and Dharwad (0.84%) are sufficient (> 0.5%) category groups for the organic carbon status of soils in the river basin.

Table- 2(A): Organic Carbon (Nitrogen) Status of Soils in the talukas of Malaprabha River Basin

Category	Range of Parameter (in %)	% of State Average	No. of Talukas	% of Talukas	Name of the Taluka (0.28% to 0.84%)
Deficient	**< 0.5**	**52**	**5**	**38.46**	Ron (0.28%), Gadag, (0.40%), Navalgund (0.44%), Naragund (0.45%) & Kundagol (0.48%)
Sufficient	**> 0.5**	**48**	**8**	**61.54**	Badami (0.53%), Hunagund (0.63%), Saundatti (0.64%), Bailhongal (0.65%) Ramadurga (0.67%), Hubli (0.67%), Khanapur (0.78%) & Dharwad (0.84%)
		100	**13**	**100**	**0.57 % (Less= 6 + More=7)**

Note: The data created for the study with reference to Table-2

Phosphorus influences the vigour of plants and improves the quality of crops. It induces the formation of new cells, promotes root growth, and accelerates leaf development, the emergence of ears, and the formation and maturation of grins. The below Table 2(B) depicts the spatial distribution of the available phosphorus status of soils in the talukas of the Malaprabha river basin. This is another important element whose deficiency is widespread and constrains the productivity of crops in the river basin. Based on the information, deficiency of phosphorus status is a serious observable fact; 61.54% of the talukas like Saundatti (1.9), Ramadurga (1.9), Bailhongal (2.3), Badami (2.6), Hunagund (2.6), Khanapur (2.6), Navalgund (4.3), and Gadag (4.6) are deficient (< 5 ppm), and the remaining 38.46% of the talukas, namely Ron (5.6), Naragund (5.8), Hubli (7.2), Kundagol (8.1), and Dharwad (15.9) are sufficient (> 5 ppm) category of the available phosphorus status of soils in the river basin.

Table- 2(B): Available Phosphorus Status of Soils in the talukas of Malaprabha River Basin

Category	Range of Parameter (ppm)	% of State Average	No. of Talukas	% of Talukas	Name of the Taluka (1.9 to 15.9)
Deficient	**< 5**	**41**	**8**	**61.54**	Saundatti (1.9), Ramadurga (1.9), Bailhongal (2.3) Badami (2.6), Hunagund (2.6), Khanapur (2.6), Navalgund (4.3) & Gadag, (4.6)
Sufficient	**> 5**	**59**	**5**	**38.46**	Ron (5.6), Naragund (5.8), Hubli (7.2), Kundagol (8.1) & Dharwad (15.9)
		100	**13**	**100**	**5.03 (Less= 8 + More=5)**

Note: The data created for the study with reference to Table-2

Potassium enhances the endurance and ability of plants to resist disease, insect attack, and cold. It is essential for starch formation and translocation of sugar and is especially useful for starch-rich crops like sugarcane, potatoes, etc. Table 2(C) shows the spatial distribution of the available potassium status of soils in the talukas of the Malaprabha river basin. Based on existing information, deficiencies of potassium are not a serious fact, except in Bailhongal (41), Badami (43) and Khanapur (44); all other talukas (76.92%) have sufficient (> 50 ppm) potassium status in the soils in the river basin.

Table- 2(C): Available Potassium Status of Soils in the talukas of Malaprabha River Basin

Category	Range of Parameter (ppm)	% of State Average	No. of Talukas	% of Talukas	Name of the Taluka (41 to 321)
Deficient	**< 50**	**23**	**3**	**23.08**	Bailhongal (41), Badami (43) & Khanapur (44)
Sufficient	**> 50**	**77**	**10**	**76.92**	Hunagund (65), Ramadurga (66), Saundatti (71), Hubli (180), Gadag, (183), Dharwad (193) Ron (193), Kundagol (243), Naragund (289) & Navalgund (321)
		100	**13**	**100**	**148.62 (Less= 8 + More=5)**

Note: The data created for the study with reference to Table-2

Also, important to plant growth is the chemical balance of the soil, i.e., its P^H value, which indicates the degree of salinity, alkalinity, normality, etc. The P^H value of soil, i.e., whether the soil is acidic, alkaline, or normal, plays an important role in plant growth. Soil acidity exceeding a particular limit is injurious to plant growth. The availability of certain nutrients, particularly phosphorus, calcium, and magnesium, decreases with an increase in acidity. Lime must be added as an amendment to reduce acidity and bring it to a normal level. Table 2(D) depicts the spatial distribution of the P^H status of soils in the talukas of the river basin. Based on the P^H status of soils, except Khanapur (7.69%), all other talukas (92.31%) lie in the normal (6.5 to 8.5) category; they are included under acidic (< 6.5), and none of the talukas are observed in the alkaline (> 8.5) category group of the river basin.

Table-2(D): P^H Status of Soils in the talukas of Malaprabha River Basin

Category	Range of Parameter	% of State Average	No. of Talukas	% of Talukas	Name of the Taluka (5.9 to 8.4)
Acidic	**< 6.5**	**39**	**1**	**7.69**	Khanapur (5.9),
Normal	**6.5 to 8.5**	**59**	**12**	**92.31**	Dharwad (6.9), Bailhongal (7.0) Ramadurga (7.4), Hubli (7.4), Badami (7.5), Saundatti (7.8), Hunagund (8.1), Kundagol (8.3), Navalgund (8.3), Ron (8.3), Gadag, (8.3) & Naragund (8.4)
Alkaline	**> 8.5**	**2**	**--**	**--**	**--**
		100	**13**	**100**	**7.65 (Less= 5 + More=8)**

Note: The data created for the study with reference to Table-2

The Electric conductivity of soluble salt in the root zone also prevents plant growth. The soluble salts mainly consist of chlorides and sulphates of sodium, calcium, and magnesium. Table 2(E) presents the spatial distribution of the electric conductivity status of soils in the talukas of the Malaprabha river basin. It observed the fact that, while most of the talukas are in the normal (< 0.8 dS/m) category, others, like critical to salt-sensitive crops (0.8 to 1.6 dS/m**)**, critical to salt-tolerant crops (1.6 to 2.5 dS/m), and injurious (> 2.5 dS/m) categories, are noticed in the electric conductivity status of soils in the river basin. In addition to that, elements like available sulphur, zinc, and boron also play an important role in plant growth.

Table- 2(E): Electric Conductivity Status of Soils in the talukas of Malaprabha River Basin

Category	Range of Parameter (dS/m)	% of State Average	No. of Talukas	% of Talukas	Name of the Taluka (0.22 to 0.40)
Normal	**< 0.8**	**96**	**13**	**100**	Kundagol (0.22), Dharwad (0.24) Gadag, (0.25), Hubli (0.25), Ron (0.26), Khanapur (0.30), Navalgund (0.30), Badami (0.32), Hunagund (0.34), Saundatti (0.37), Bailhongal (0.39), Naragund (0.38) & Ramadurga (0.40)
Critical to Salt Sensitive Crops	**0.8 to 1.6**	**3**	**--**	**--**	--
Critical to Salt Tolerant Crops	**1.6 to 2.5**	**0.5**	**--**	**--**	--
Injurious	**> 2.5**	**0.5**	**--**	**--**	--
		100	**13**	**100**	**0.31 (Less= 7 + More=6)**

Note: The data created for the study with reference to Table-2

The following tables (2(F) to (2(H)) represent the spatial distribution of available sulphur, zinc, and boron status of soils in the talukas of the Malaprabha river basin. Sulphur availability is considered sub-optional in most of the soils where oilseeds and pulses are grown. The Gadag (4.8), Kundagol (6.0), Ron (6.8), and Navalgund (6.9) talukas are observed as deficient (< 10 ppm) (30.77%), and the others, namely Hubli (10.7), Hunagund (10.7), Badami (11.5), Dharwad (11.8), Naragund (15.2), Saundatti (129.9), Khanapur (141.0), Bailhongal (141.2), and Ramadurga (160.0) talukas, are noticed in the sufficient (>10 ppm) category of the sulphur availability status of soils in the river basin.

Table- 2(F): Available Sulphur Status of Soils in the talukas of Malaprabha River Basin

Category	Range of Parameter (ppm)	% of State Average	No. of Talukas	% of Talukas	Name of the Taluka (4.8 to 160.0)
Deficient	**< 10**	**52**	**4**	**30.77**	Gadag, (4.8), Kundagol (6.0), Ron (6.8) & Navalgund (6.9)
Sufficient	**> 10**	**48**	**9**	**69.23**	Hubli (10.7), Hunagund (10.7), Badami (11.5), Dharwad (11.8), Naragund (15.2), Saundatti (129.9), Khanapur (141.0), Bailhongal (141.2) & Ramadurga (160.0)
		100	**13**	**100**	**50.50 (Less= 9 + More=4)**

Note: The data created for the study with reference to Table-2

Zinc deficiency has been most reported in the talukas of the Malaprabha river basin. Table 2(G) shows the fact that 61.64% of the talukas are deficient and 38.46% of talukas are sufficient in terms of the available zinc status of soils in the river basin. The deficient (< 0.75 ppm) category comprises Saundatti (0.38), Ron (0.40), Gadag (0.42), Naragund (0.46), Navalgund (0.59), Ramadurga (0.59), Bailhongal (0.62), and Kundagol (0.73) talukas, while Badami (0.79), Hunagund (0.88), Khanapur (0.94), Hubli (1.12), and Dharwad (1.12) talukas are incorporated under the sufficient (> 0.75 ppm) category of the available zinc status of soils in the river basin.

Table- 2(G): Available Zinc Status of Soils in the talukas of Malaprabha River Basin

Category	Range of Parameter (ppm)	% of State Average	No. of Talukas	% of Talukas	Name of the Taluka (0.38 to 1.12)
Deficient	**< 0.75**	**55**	**8**	**61.54**	Saundatti (0.38), Ron (0.40), Gadag, (0.42), Naragund (0.46), Navalgund (0.59), Ramadurga(0.59), Bailhongal (0.62) & Kundagol (0.73)
Sufficient	**> 0.75**	**45**	**5**	**38.46**	Badami (0.79), Hunagund (0.88), Khanapur (0.94), Hubli (1.12) & Dharwad (1.12)
		100	**13**	**100**	**0.70 (Less= 7 + More=6)**

Note: The data created for the study with reference to Table-2

The deficiency of Boron is not critically reported in the talukas of the Malaprabha river basin. Table 2(H) explains the fact that 84.62% of the talukas are included under the sufficient (< 0.58 ppm) category. This category comprises Badami (0.68), Dharwad (0.70), Hunagund (0.70), Bailhongal (0.75), Khanapur (0.81), Hubli (0.84), Ron (0.85), Kundagol (0.91), Gadag (0.99), Naragund (1.22), and Navalgund (1.14) talukas, while 15.38% of talukas like Saundatti (0.48) and Ramadurga (0.57) are sufficient (> 0.58 ppm) for the available zinc status of soils in the river basin.

Table- 2(H): Available Boron Status of Soils in the talukas of Malaprabha River Basin

Category	Range of Parameter (ppm)	% of State Average	No. of Talukas	% of Talukas	Name of the Taluka (0.48 to 1.14)
Deficient	**< 0.58**	**62**	2	15.38	Saundatti (0.48) & Ramadurga (0.57)
Sufficient	**> 0.58**	**38**	11	84.62	Badami (0.68), Dharwad (0.70), Hunagund (0.70), Bailhongal (0.75), Khanapur (0.81), Hubli (0.84), Ron (0.85), Kundagol (0.91), Gadag, (0.99), Naragund (1.22) & Navalgund (1.14)
		100	**13**	**100**	**0.82 (Less= 7 + More=6)**

Note: The data created for the study with reference to Table-2

CONCLUSIONS

The soils of the talukas of the Malaprabha river basin are varied in texture and fertility status. Soils are high in organic matter and acidic by reaction. Amelioration of soil acidity and external inputs of essential nutrients are necessary for successful crop production. The status of available nutrition provides the basis for soil and crop-specific mineral nutrition recommendations in all land uses in order to maintain soil nutrient balance and also enhance crop production and productivity.

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