International Journal of Environment and Climate Change

11(6): 64-81, 2021; Article no.IJECC.71453
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Land Resource Inventory (LRI) for Sustainable Watershed Development-A Case Study of Bisarahalli-1 Microwatershed of Semiarid Region of Koppal District, Karnataka, India

K. V. Niranjana[1], M. B. Mahendra Kumar[1*], Rajendra Hegde[1], K. V. Seema[1], B. A. Dhanorkar[1], S. Srinivas[1] and R. Srinivasan[1]

[1]ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre Hebbal, Bangalore-560 024, Karnataka, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2021/v11i630423
Editor(s):
(1) Dr. Wen-Cheng Liu, National United University, China.
Reviewers:
(1) Seyed mohammadmehdi nassabeh, Islamic Azad university, Iran.
(2) Solomon Dargie Chekole, Bahir Dar University, Ethiopia.
(3) Liang-ze-nan Wang, Hohai University, China.
Complete Peer review History: https://www.sdiarticle4.com/review-history/71453

Original Research Article

Received 24 May 2021
Accepted 29 July 2021
Published 03 August 2021

ABSTRACT

A land resource inventory (LRI) of Bisarahalli-1 microwatershed was located in the central part of northern Karnataka in semiarid region of Koppal taluk and district. A case study was taken under Sujala III project sponsored by the Watershed Development Department of Karnataka and funded by the World Bank. The analysis and interpretation of the spatial and non-spatial database generated has revealed that most of the areas suffer from major problems. In most of the areas, very gently sloping and alkalinity affected even up to 80% of the microwatershed area followed by gravelly and low available water capacity, thus reducing the production potential and crop choices. The soils are either moderately or marginally suited for growing most of the agricultural and horticultural crops. By interfacing land resource data with Remote Sensing, GIS and GPS, different management scenarios were analysed to arrive at the best management alternatives (optimum land use plans) that would be most suitable. This data handling system will be useful for making land use decisions and providing proactive advice to farmers on a real time basis protecting the health of natural resources.

**Corresponding author: E-mail: soil.mahendra@gmail.com, mahi7255@rediffmail.com;*

Keywords: Land resource inventory; spatial and nonspatial database; remote sensing; GIS and GPS.

1. INTRODUCTION

Site specific Land Resource Inventory (LRI) for farm level planning of watershed has gained importance in recent times because of improper utilization of natural resources and improper conservation measures that have led to the deterioration of watersheds in the country [1]. Watershed is considered as an ideal unit for the management of soil and land resources in achieving sustainable development. Watershed deterioration is a common phenomenon in most parts of the world. The major factors causing watershed deterioration are deforestation, improper land use, erosion, climate change and other anthropogenic activities [2]. The evident in the form of soil erosion, salinity/alkali, forest loss and vegetation and finally decreases in agricultural production in the watersheds. Therefore, it is necessary to develop a sustainable land management system for the watersheds that does not cause or at least prevent further degradation of such valuable resources [2]. The challenges posed by the continuing degradation and declining factor productivity of the resource base are very site specific and can be tackled only by addressing the concerned issues at the farm or watershed level by evolving rational, site specific and viable land use options suitable for each and every land holding at the village or watershed level [2,3]. The required data for farm level planning can be obtained by carrying out LRI that describes and characterizes the nature of land resources, their constraints, inherent potential and suitability for various land-based rural enterprises, crops and other uses for preparing location-specific action plans [2]. It is with this objective that the Watershed Development Department of Karnataka has initiated Sujala-III Project funded by the World Bank for the planning and development of watersheds on scientific basis in eleven selected districts of Karnataka covering an area of 14.06 lakh ha across 2534 microwatersheds benefitting about 9 lakh households by adopting the modern methods of Remote Sensing (RS) and GIS for generating land resource information at farm level [2,3].

Remote sensing (RS) and GIS technologies have emerged as powerful tools for generating reliable spatial information on various natural resources. Application of RS technology for characterizing and mapping of soils is increasing rapidly due to great strides made in space-borne RS in terms of spatial, temporal, spectral and radiometric resolutions. The advent of GIS and GPS has added a new dimension to resources survey and information integration. By interfacing RS with GIS and GPS, different management scenarios can be processed allowing the resource manager to analyse various management alternatives and come out with the best and most suitable alternative [2]. Hence, the study was carried out with the objectives to collect site specific data base, to provide farm specific crop choices, to evolve location specific soil and water conservation measures and to provide datasets and inputs needed for planning, implementing and monitoring of all land based developmental programmes to develop tools, packages and thematic outputs.

2. MATERIALS AND METHODS

The Bisarahalli-1 microwatershed is located in the central part of northern Karnataka of Koppal Taluk and District. It lies between $15^{0}15'$ to $15^{0}16'$ north latitudes and $76^{0}3'$ to $76^{0}5'$ east longitudes and covers an area of 571 ha. Physiographically, based on geology the area has been identified as granite gneiss and alluvial landscapes. The climate is semiarid tract and is categorized as drought prone with total annual rainfall of 662 mm.

2.1 Methodology for LRI Generation

Land Resource Inventory for site specific planning and development of watersheds is carried out by using digitised cadastral map and False Colour Composites (FCC) of Cartosat-1 and LISS-IV merged satellite data (Fig. 1) [4]. The methodology followed for carrying out LRI was as per the guidelines given in Soil Survey Manual [5,6,7]. The FCCs were visually interpreted using image interpretation elements (colour tone, texture, pattern, association, etc.) along with all the collateral data available for the area. The delineated physiographic boundaries were transferred on to a cadastral map overlaid on satellite imagery and used as base map for mapping soils. Intensive traversing of each physiographic unit like hills, uplands and low lands was carried out. Based on the soil variability observed on the surface, transects were selected across the slope covering all the physiographic units identified in the Micro-watershed [4]. In the selected transect, soil profiles were located at closely spaced intervals to take care of any change in the land features like break in slope, erosion, gravel, stones, saline/alkali etc. In the selected sites, soil profiles (vertical cut showing the soil layers from surface to the rock/water) were dug up to 200 cm or to the depth limited by rock or hard substratum. The profiles were studied and described in detail for all their morphological and physical characteristics. The soil and site characteristics were recorded for all the profile sites on a standard proforma as per the guidelines given in the USDA soil survey manual [5,8]. Apart from the transect study, soil profiles were also studied at random, almost like in a grid pattern outside the transect areas to validate the soil map unit boundaries. Based on soil characteristics, the soils were classified up to series level and grouped into different soil series [5,7,8]. Soil series is the most homogeneous unit having similar horizons and properties, and behaves similarly for a given level of management. Soil depth, texture, colour, kind of soil horizon and its sequence, gravel, stones, calcareousness, nature of substratum etc. were used as differentiating characteristics for identifying soil series. The differentiating characteristics used for identifying soil series in the watersheds are given in Table 1.

The soils were mapped as phases of soil series (Fig. 2). The area under each soil series was further separated into soil phases (management units) by traversing each and every land parcel in all directions in the watersheds and their boundaries were delineated on the cadastral map based on the variations observed in the texture of the surface soil, presence of gravel/stones, slope, erosion etc. A soil phase is a subdivision of soil series based mostly on surface soil features that affect its use and management. The soil mapping units are shown on the map in the form of symbols. The soil map shows the spatial distribution and the area extent of different soil mapping units (soil phases) identified under each soil series. All the land parcels/survey numbers included in one soil phase will have similar soil and site characteristics that require same management and respond similarly for a given level of management. Soil samples were collected from representative master profiles for each soil series for laboratory characterisation of physical and chemical properties [9]. Surface soil samples collected from farmers fields at 320 m (one sample for every 10 ha area) grid interval were analysed [10] in the laboratory for fertility status (macro and micronutrients).The data is used for soil health card generation by the department.

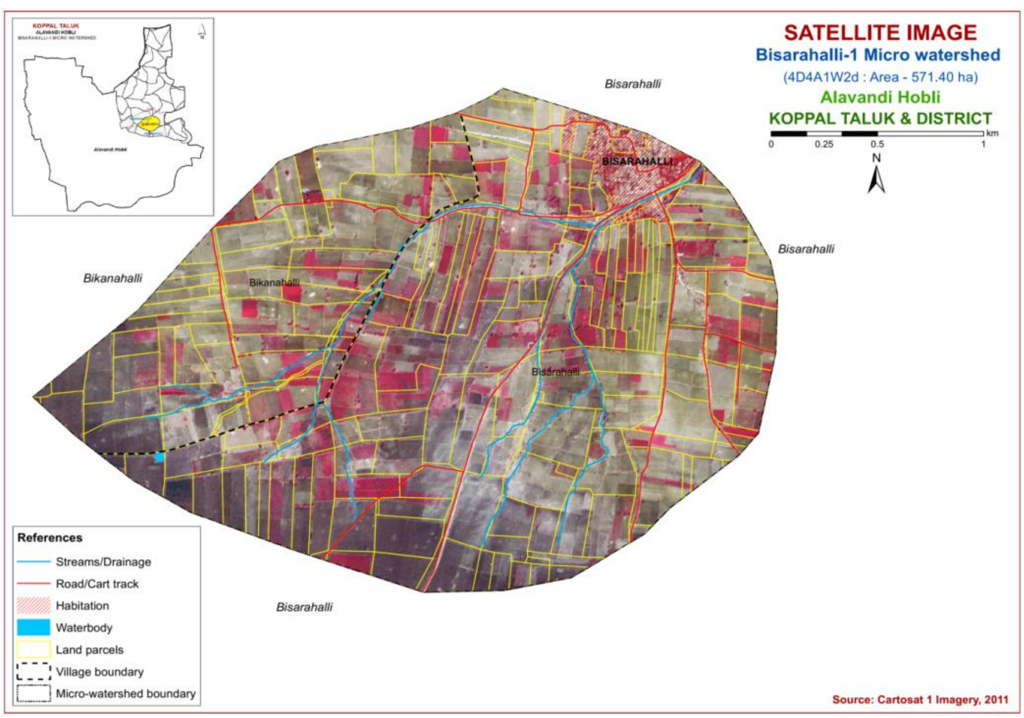

Fig. 1. Cadastral map overlaid on IRS PAN+LISS IV merged imagery

Table 1. Differentiating characteristics used for identifying soil series (characteristics are of series control section)

Sl. No	Soil Series	Depth (cm)	Colour	Texture	Gravel (%)	Horizon sequence	Calcareo-usness
Soils of Granite Gneiss Landscape							
1	Chikkasavanur (CSR)	25-50	7.5YR3/2,3/3,3/4	scl	<15	Ap-Bw-Cr	-
2	Kethanapura (KTP)	50-75	2.5YR3/4, 3/6	gscl	15-35	Ap-Bt-Cr	-
3	Mukhadahalli (MKH)	50-75	5YR3/3,3/4,4/3, 5/4,6/6 2.5YR3/4	gsc	>35	Ap-Bt-Cr	-
4	Hatti (HTI)	50-75	5YR3/3,3/4	gsc	15-35	Ap-Bt-Cr	-
5	Gollarahatti (GHT)	75-100	2.5YR3/4,4/6	gscl	15-35	Ap-Bt-Cr	-
6	Bisarahalli (BSR)	75-100	5YR3/3,3/4	gsc	15-35	Ap-Bt-Cr	-
7	Bidanagere (BDG)	75-100	5YR3/3,3/4,4/3, 5/4,6/6 2.5YR3/4	gsc	>35	Ap-Bt-Cr	-
8	Kumchahalli (KMH)	100-150	2.5YR3/4, 3/6	scl-sc	<15	Ap-Bt-Cr	-
9	Balapur (BPR)	100-150	2.5YR2.5/4,3/4	gsc-gc	15-35	Ap-Bt-Cr	-
10	Niduvalalu (NDL)	>150	7.5YR3/2,3/3,3/4	gsc	15-35	Ap-Bt-Cr	-
Soils of Alluvial landscape							
11	Muttal (MTL)	25-50	10YR3/2,3/3,4/2 7.5YR3/2,3/3,6/4	gc	15-35	Ap-Bw-Ck	e-ev
12	Ravanaki (RNK)	50-75	7.5YR3/2,3/3,5/2,5/3 10YR3/1,3/2,4/2,5/1,6/1	sc-c	-	Ap-Bw-Cr	e-ev
13	Dambarahalli (DRL)	75-100	10YR2/1,3/1,4/3	c	-	Ap-Bw-Ck	e-es
14	Gatareddihal (GRH)	100-150	10YR2/1,3/1 2.5Y4/3,5/4	c		Ap-Bw-BC-C	e

Note: The textural classes are scl- sandy clay loam, gscl-gravelly sandy clay loam, sc-sandy clay, gsc-gravelly sandy clay, c-clay, gc-gravelly clay

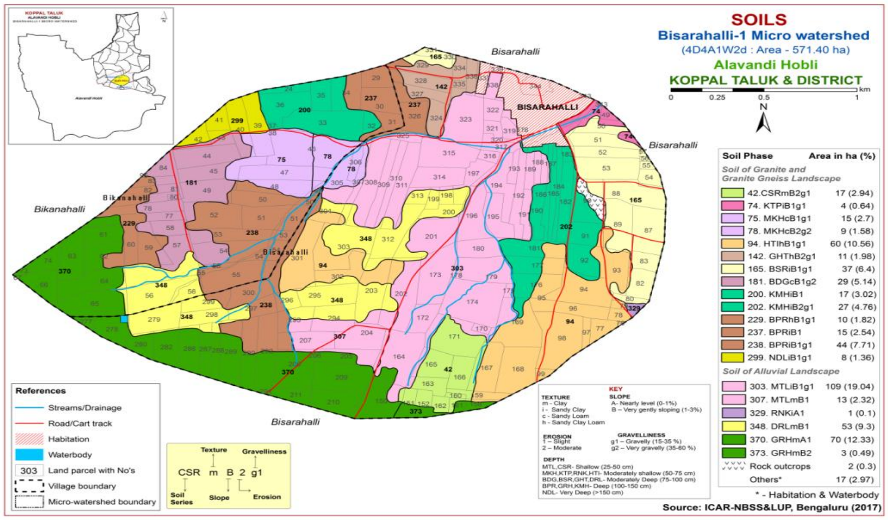

Fig. 2. Soil phase map

2.2 Interpretation of LRI Database

LRI provides the required database and maps needed for addressing the complex issues at the micro level and more specifically to provide farm-specific crop choices, evolve location-specific soil and water conservation measures, package of practices and to provide inputs needed for planning, implementing and monitoring of all land-based developmental programmes. For this, the detailed spatial and non-spatial site-specific databases required on various parameters that influence the use of land are generated through LRI and other socio-economic surveys for each microwatershed. Though the database is comprehensive, it cannot be readily used by planners or farmers or any other land user unless the scientific database is transformed as information that can be easily understood by different stakeholders. This has been achieved by interfacing RS, GIS, GPS with LRI databases and generating several interpretative and thematic maps like land capability, soil depth, surface soil texture, gravelliness, available water capacity, slope, erosion, soil pH, soil fertility status for organic carbon, major (P & K), secondary (S) and micronutrients (Fe, Zn and B). Land suitability for major agricultural and horticultural crops grown was assessed by following FAO framework for land evaluation [11,12,13]. Soil and water conservation treatments required were assessed and treatment plans [13] were prepared for microwatershed identifying the sites to be treated and also the type of conservation structures required. Land resource atlases depicting interpretative maps for microwatershed were prepared. These maps show the spatial distribution of both problem and potential areas with suggested interventions.

3. RESULTS AND DISCUSSION

3.1 Soils of Granite Gneiss Landscape

The soils from granite gneiss landscape are medium deep to very deep with well drained, dark reddish brown to dark red in colour, texture varied from gravelly clay loam to gravelly sandy clay and occurring on nearly level to very gently sloping uplands under cultivation. Dinesh et al. (2017) [14] reported that, the variation in the soil colour was due to function of textural makeup, topographic position, mineralogy, chemical composition and moisture regimes of the soil. In this landscape, 10 soil series were identified and mapped.

3.2 Soils of Alluvial Landscape

Soils of alluvial landscape are shallow to deep, moderately well drained, dark brown to very dark grayish brown calcareous clay texture and occurring on nearly level to very gently sloping plains under cultivation. In this landscape, 4 soil series are identified and mapped.

The soil map shows the geographic distribution of 21 mapping units (Fig. 2) representing 14 soil series occurring in the microwatershed (Table 1). Each mapping unit (soil phase) delineated on the map has similar soil and site characteristics. In other words, all the farms or survey numbers included in one phase will have similar management needs and have to be treated accordingly. The 21 soil phases identified and mapped in the microwatershed were regrouped into 9 Land Management Units (LMU's) based on soil properties (soil depth, texture, gravelliness and land form), land use and agro ecological units for the purpose of preparing a proposed crop plan for sustained development of the microwatershed (Table 4). The database (soil phases) generated under LRI was utilized for identifying Land Management Units (LMU's) based on the management needs [15]. One or more than one soil site characteristic having influence on the management have been chosen for identification and delineation of LMUs. For Bisarahalli-1 microwatershed, five soil and site characteristics, namely soil depth, texture, slope, erosion and gravel content have been considered for defining LMUs. The land management units are expected to behave similarly for a given level of management.

The most important soil and site characteristics that affect the land use and conservation needs of an area are land capability, soil depth, soil texture, coarse fragments, available water capacity, slope, soil erosion, soil reaction etc [2]. These are interpreted from the data base generated through land resource inventory and several thematic maps are generated. These would help in identifying the areas suitable for growing crops. Soil and water conservation measures and structures needed thus helping to maintain good soil health for sustained crop production. The various thematic maps generated are described below.

3.3 Land Capability Classification

The 21 soil map units identified in the Bisarahalli-1 microwatershed are grouped under 2 land capability classes (soil characteristics, external land features and environmental factors) and 5 land capability subclasses (dominant limitations within the given capability class) (Fig. 3). An area of about 97 per cent in the microwatershed is suitable for agriculture and 3 per cent is not suitable for agriculture. Similar results were also found by Mahender Reddy et al. [16] and Rajendra Hegde et al. [17].

3.4 Soil Depth

About 40 per cent area is covered by shallow (25-50 cm) to moderately shallow (50-75 cm) soils, whereas moderately deep (75-100 cm) and deep to very deep (100-150cm and > 150 cm) soils occupied in an area of 57 per cent (Fig. 4). Kumar and Naidu [18] reported that, the shallowness of soils is due to more erosion and slow weathering process.

3.5 Soil Surface Texture

An area of 24 per cent has soils that are loamy at the surface and clay soils occupy in an area of about 73 per cent (Fig. 5). Vedadri and Naidu [19] reported that, the heavier textures of the soils are due to less erosion, less slope and good managements by the farmers.

3.6 Soil Gravelliness

About 7 per cent has soils that are very gravelly (35-60%), 60 per cent has gravelly (15-35%) and non-gravelly (<15%) soils cover in an area of about 30 per cent (Fig. 6). This is mainly due to differential weathering of rocks.

3.7 Available Water Capacity

An area of about 12 per cent has soils that are very low (<50 mm/m), 54 per cent low (51-100 mm/m), 17 per cent medium (101-150 mm/m) and 13 per cent very high (>200 mm/m) in available water capacity (Fig. 7).This variation is due to soil depth, texture and gravelliness. Similar results were reported by Rajendra Hegde et al. [2].

3.8 Soil Slope

Major area of about 84 per cent falls under very gently sloping (1-3% slope) lands whereas nearly level (0-1%) lands occupy in an area of 12 per cent (Fig. 8). Similar results were also found by Rajendra Hegde et al. [2].This is mainly due to physiography of the land (land form, texture, relief factor etc.

3.9 Soil Erosion

Soils that are moderately eroded (e2 class) cover in an area of about 12 per cent whereas slightly eroded (e1 class) soils cover a major area of about 85 per cent (Fig. 9). Major area is accounted for slight erosion due to gently sloping land with clay texture, vegetation and well managed bunds.

3.10 Soil Fertility

Soil fertility data generated has been assessed and individual maps for all the nutrients for the microwatershed have been prepared by using the Kriging method under GIS (Fig. 10, 11, 12, 13, 14, 15, 16 & 17). The details are given below:

The soil analysis of the Bisarahalli-1 microwatershed for soil reaction (pH) showed that major area of about 41 per cent has moderately alkaline (pH 7.8-8.4) followed by 26 per cent strongly alkaline (pH 8.4-9.0), 20 per cent slightly alkaline (pH 7.3-7.8), 8 per cent very strongly alkaline (pH >9.0) and 2 per cent has neutral (6.5-7.3) in reaction. The soil alkalinity is due to presence of calcium carbonate and increase in exchangeable bases brought by runoff water in these soils and also due to higher temperature results in accumulation of salts in the surface layers. Similar results were reported by Rajendra Hegde et al. (2018) [2] and Ram *et.al*. (2010) [20]. Most of the soil organic carbon content of the microwatershed has medium (0.5-0.75%) with area of 57 per cent followed by 36 per cent low (<0.5) and 3 per cent high (>0.75%).This is due to depletion of soil organic carbon due to continuous removal by crops [21]. Most of the soils were low (<23 kg/ha) in available phosphorus content with an area of 50 per cent followed by 45 per cent medium (23-57 kg/ha*)* and 1 per cent high (>57 kg/ha). Low status may be due to the precipitation of added phosphorous as iron and aluminium phosphate of low solubility. This might be due to the granitic parent material and presence of small amounts of phosphate bearing minerals. The findings are in agreement with the results reported by Gupta (1965) [22] and Mahendra Kumar et al. (2015) [23]. Majority of the soils were medium (145-337 kg/ha) in available potassium content in an area of 54 per cent followed by 37 per cent is high (>337 kg/ha) and 6 per cent low (<145 kg/ha). This is due to potassium bearing minerals and rocks of the study area [24]. Maximum area of about 71 per cent is medium (10-20 ppm) in available sulphur and 26 per cent high (>20 ppm) in available sulphur. This is due to less addition of sulphur to soils and more removal by plants which is in confirmation with the findings of Balangoudar (1989) [25].

Among the micronutrients available iron content was sufficient (>4.5 ppm) in 50 per cent and deficient (<4.5 ppm) in an area of 47 per cent. Available zinc content was deficient (<0.6 ppm) in most of the area of 76 per cent and sufficient (>0.6ppm) in 21 per cent. The deficiency of iron and zinc is due to calcareousness of the soils and higher pH values. Available boron content was low (<0.5 ppm) in majority of the area of 79 per cent and medium (<0.5-1.0 ppm) in 18 per cent. Similar results were reported by Gurumurthy et al. [26].

3.11 Land Suitability for Major Crops

The soil and land resource units (soil phases) of Bisarahalli-1 Microwatershed were assessed for their suitability for growing food, fodder, fibre and other horticulture crops by following the procedure as outlined in FAO (1976 and 1983) [11,12]. The crop requirements were matched with the soil and land characteristics to arrive at the crop suitability. Using the above criteria, the soil map units were evaluated and land suitability maps for major annual (Sorghum) and perennial (Pomegranate) crops were generated.

3.12 Land Suitability for Sorghum (*Sorghum bicolor)*

The crop requirements for growing sorghum (Table 2) were matched with the soil-site characteristics (Table1) and a land suitability map for growing sorghum was generated (Fig. 18). Highly suitable (Class S1) lands occupies a very small area of about 20 ha (4%) and maximum area of about 287 ha (50%) was moderately suitable (Class S2) due to minor limitations of rooting depth, gravelliness, nutrient availability and calcareousness. Marginally suitable lands (Class S3) occupy an area of about 246 ha (43%) with moderate limitations of gravelliness, rooting depth and calcareousness. Similar results were reported by Geetha et al. [27].

3.13 Land Suitability for Pomegranate (*Punica granatum*)

For growing pomegranate (Table 3), the crop requirements were matched with the soil-site characteristics (Table 1) and a land suitability map for growing pomegranate was generated (Fig. 19). An area of about 44 ha (8%) in the microwatershed was highly suitable (Class S1) for growing pomegranate and moderately suitable (Class S2) lands occupy in an area of about 182 ha (32%). They have minor limitations of gravelliness, rooting depth and texture. Marginally suitable (Class S3) lands occupy major area of about 187 ha (33%) with moderate limitations of gravelliness, rooting depth and calcareousness. An area of about 139 ha (24%) is not suitable (Class N) for growing pomegranate due to severe limitations of calcareousness and rooting depth. Similar findings were reported by Rajendra Hegde et al. [28].

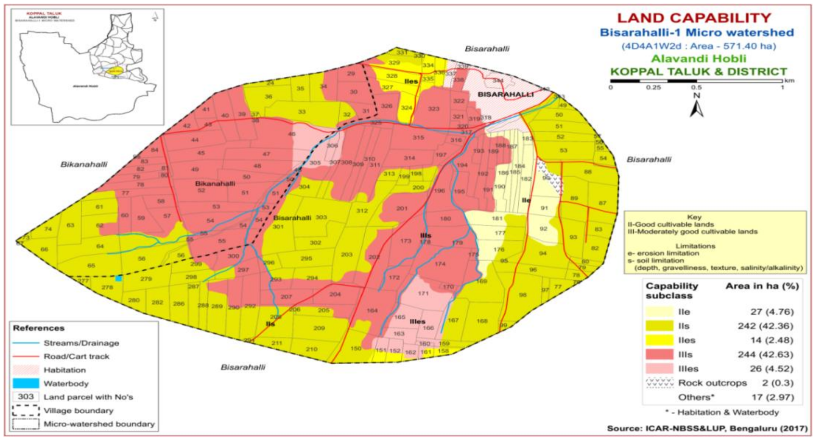

Fig. 3. Land capability map

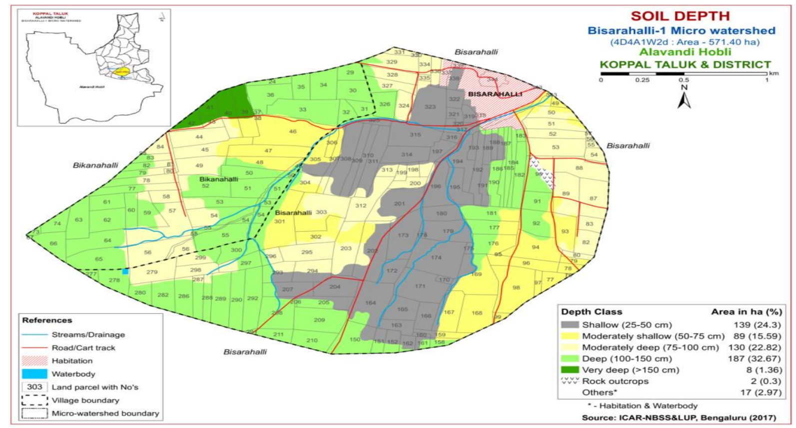

Fig. 4. Soil depth map

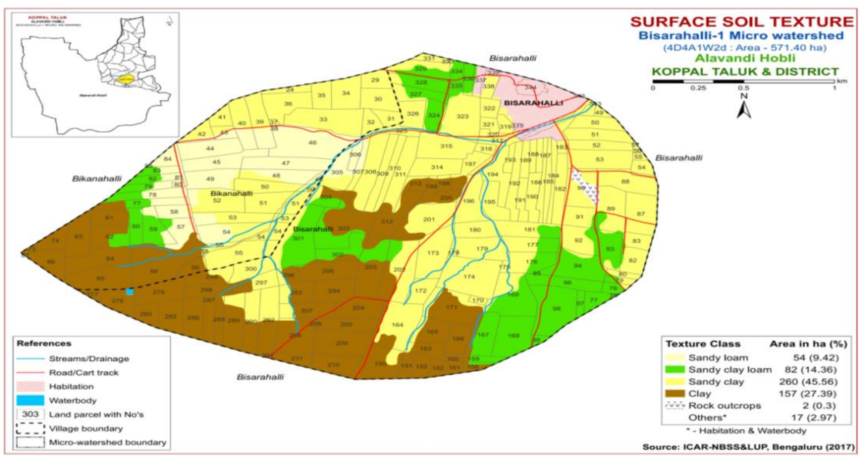

Fig. 5. Surface soil texture map

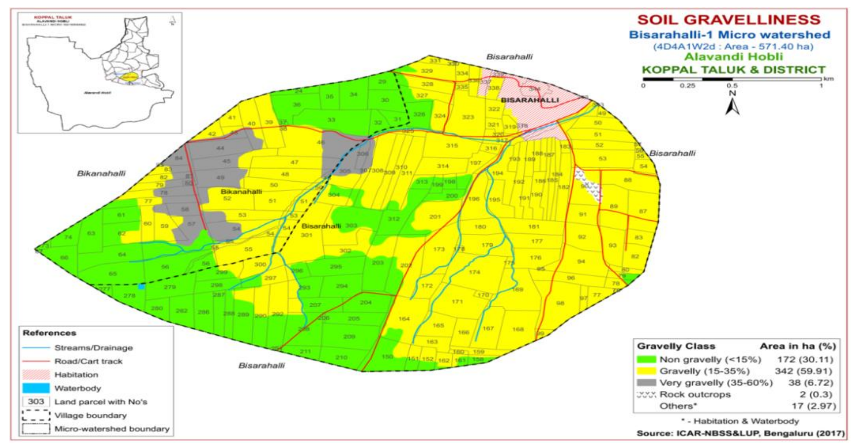

Fig. 6. Soil gravelliness map

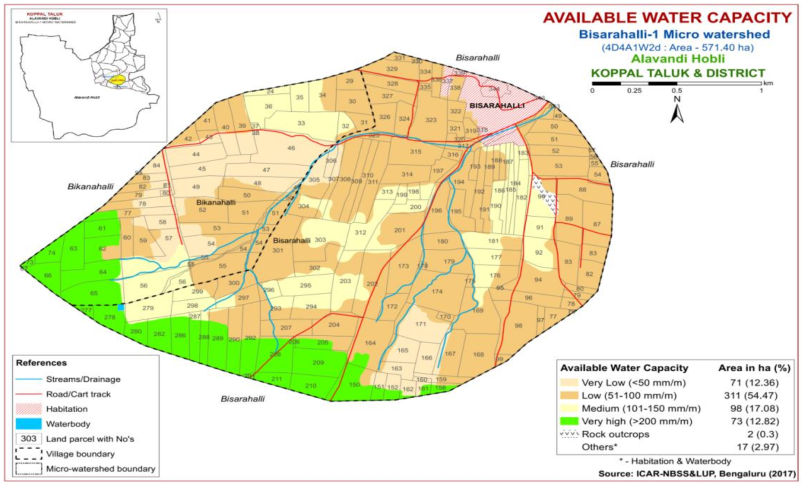

Fig. 7.Available water capacity map

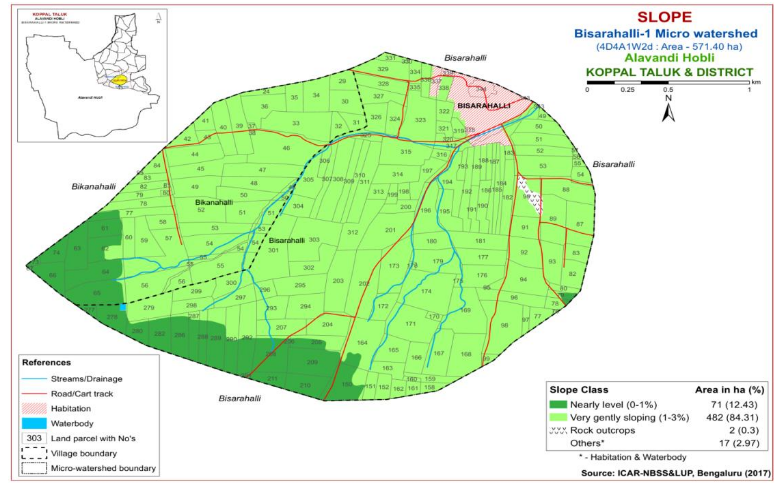

Fig. 8. Soil slope map

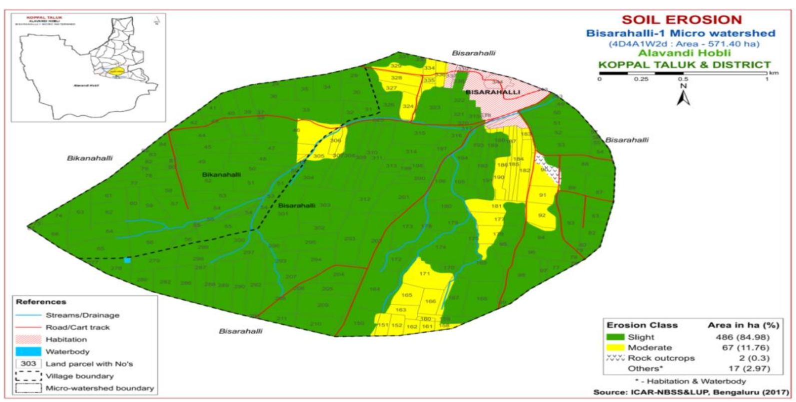

Fig. 9. Soil erosion map

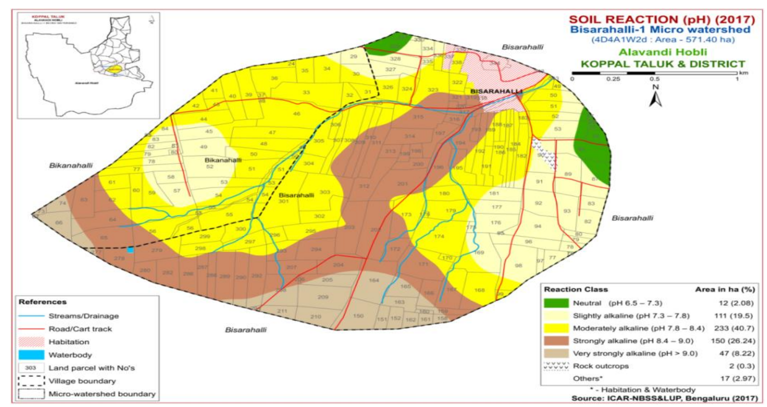

Fig. 10. Soil reaction (pH) map

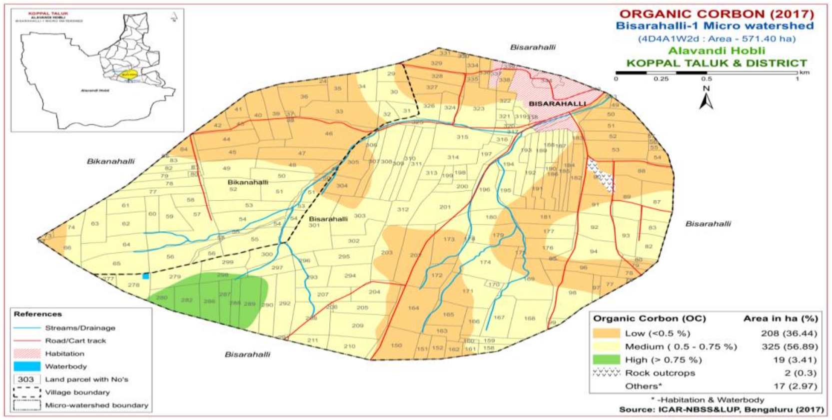

Fig. 11. Soil organic carbon map

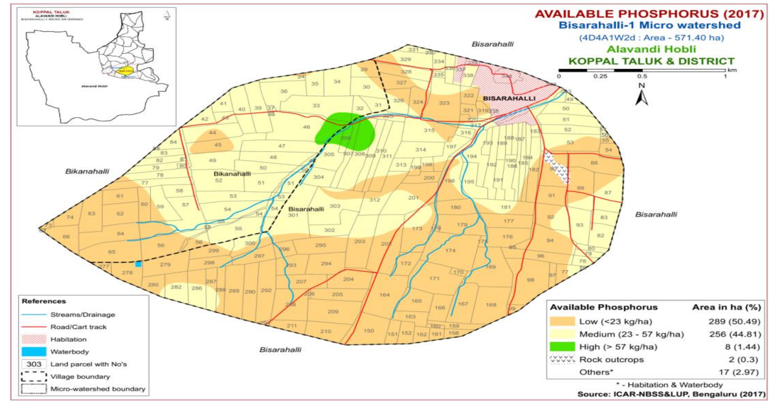

Fig. 12. Soil available phosphorous map

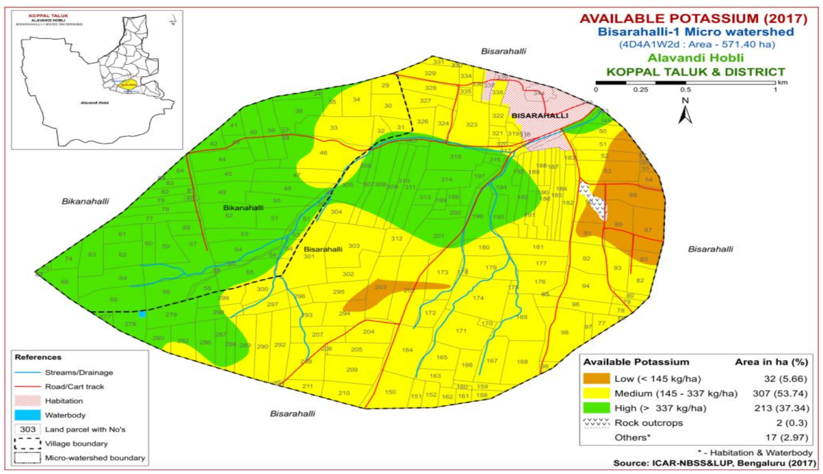

Fig. 13. Soil available potassium map

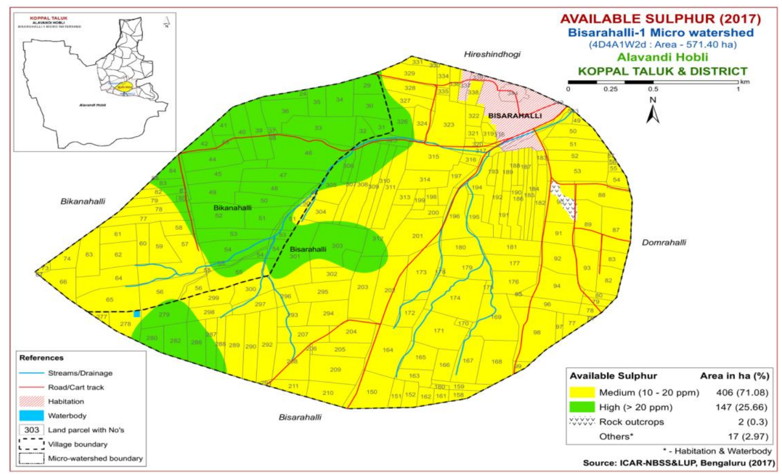

Fig. 14. Soil available sulphur map

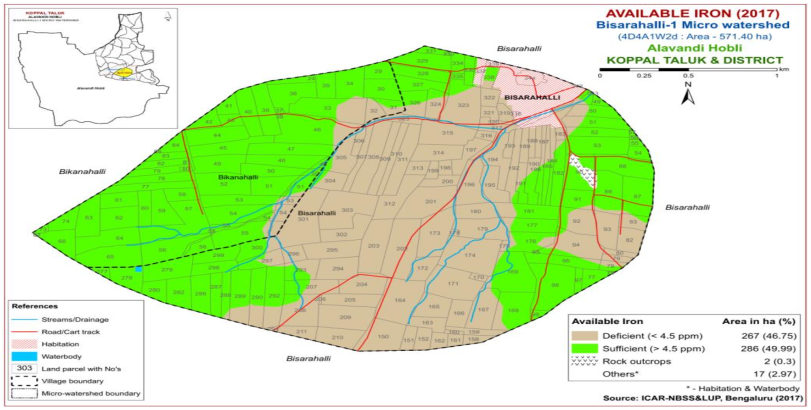

Fig. 15. Soil available iron map

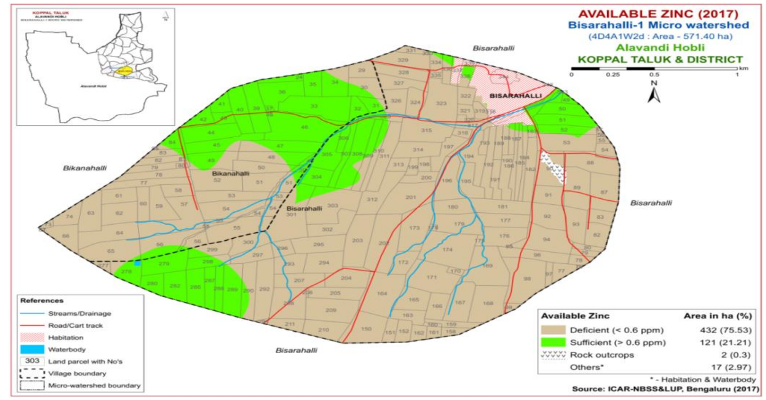

Fig. 16. Soil available zinc map

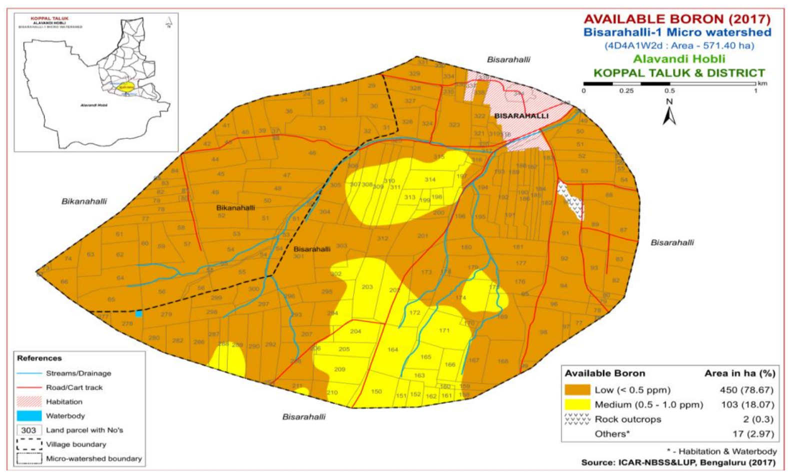

Fig. 17. Soil available boron map

Table 2. Crop suitability criteria for Sorghum

Crop requirement		Rating			
Soil –site characteristics	**unit**	**Highly suitable (S1)**	**Moderately suitable (S2)**	**Marginally suitable (S3)**	**Not suitable (N)**
Slope	%	2-3	3-8	8-15	>15
LGP	Days	120-150	120-90	<90	
Soil drainage	Class	Well to mod.Well drained	imperfect	Poorly/excessively	Very poorly
Surface soil texture	Class	c, cl, sicl, sc	l, sil, sic	sl, ls	S, fragmental skeletal
Soil depth	Cm	100-75	50-75	30-50	<30
Gravel content	% vol.	5-15	15-30	30-60	>60
Soil reaction	pH	6.0-8.0	5.5-5.9 8.1-8.5	<5.5 8.6-9.0	>9.0
Salinity (EC)	dSm^{-1}	2-4	4-8	8-10	>10
Sodicity (ESP)	%	5-8	8-10	10-15	>15

Table 3. Crop suitability criteria for Pomegranate

Crop requirement		Rating			
Soil –site characteristics	**unit**	**Highly suitable (S1)**	**Moderately Suitable (S2)**	**Marginally suitable (S3)**	**Not suitable (N)**
Slope	%	<3	3-5	5-10	-
Temperature in growing season	^0C	30-34	35-38 25-29	39-40 15-24	-
LPG	Days	>150	120-150	90-120	<90
Soil drainage	Class	Well drained	imperfectly drained	-	-
Surface soil texture	Class	Sl, scl, l, cl	C, sic, sicl	Cl, s, ls	S, fragmental
Soil depth	Cm	>100	75-100	50-75	<50
Gravel content	% vol.	nil	15-35	35-60	>60
Soil reaction	pH	5.5-7.5	7.6-8.5	8.6-9.0	-
Salinity (EC)	dSm^{-1}	-	<9	>9	<50
Sodicity (ESP)	%	-	-	-	-

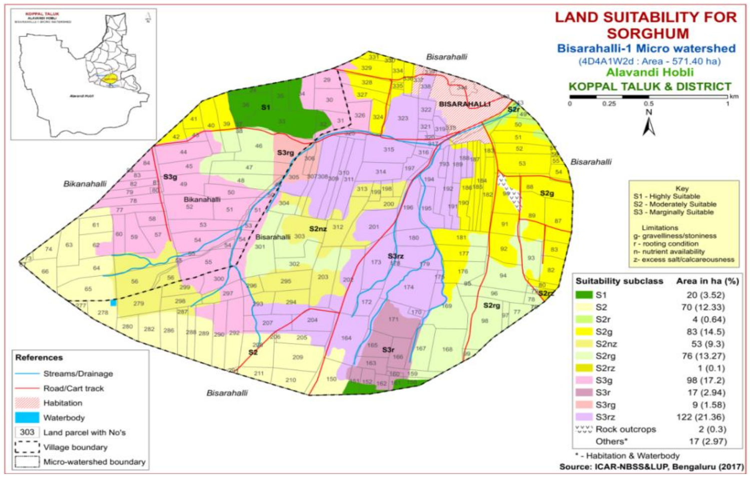

Fig. 18. Land suitability for sorghum

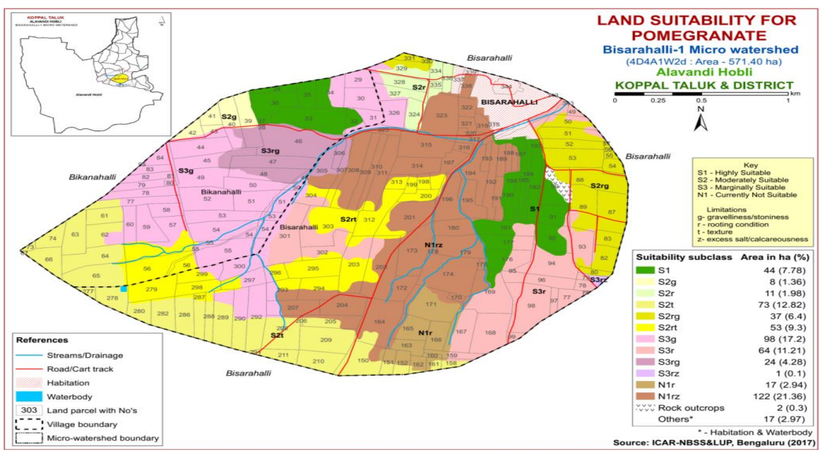

Fig.19. Land suitability for pomegranate

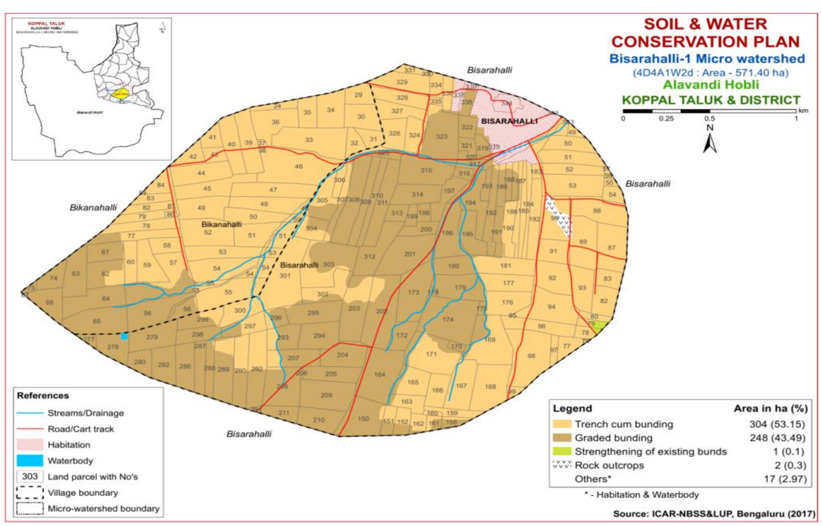

Fig. 20. Soil and water conservation plan map

Table 4. Proposed crop plan for bisarahalli-1 microwatershed

LMU	Mapping Units	Survey Number	Field Crops/ Forestry	Horticulture Crops	Suitable Interventions
1	GRHmA1 GRHmB2 (Deep to very deep, black clay soils)	**Bikanahalli:**61,62,63,64,65,66,67,73,74 **Bisarahalli:**150,158,161,206,208,209,210,211,277,278,280,282,286,287,288,289,290,291	Sunflower, Sorghum, Cotton, Bengal gram, Safflower, Linseed, Bajra	**Fruit crops:** Amla, Custard apple, Jamun, Lime, Musambi, Tamarind, Pomegranate **Vegetables:** Drumstick, Chilli, Coriander **Flowers:** Marigold, Chrysanthemum	Application of FYM, Biofertilizers and micronutrients, drip irrigation, mulching, suitable soil and water conservation practices
2	NDLiB1g1 BPRhB1g1 BPRiB1 BPRiB1g1 (Deep to very deep, red gravelly clay soils)	**Bikanahalli:**29,30,31,34,39,40,41,42,50,51,52,53,54,55,59,60,79,82,83,95 **Bisarahalli:**292,297,300,326	Groundnut, Redgram, Bajra, Horsegram	**Fruit crops:** Amla, Cashew,Custard apple **Vegetables:** Drumstick, Coriander	Drip irrigation, mulching, suitable soil and waterconservation practices (Crescent Bunding with Catch Pit etc)
3	DRLmB1 (Moderately deep, calcareous black clay soils)	**Bikanahalli:** 56,57 **Bisarahalli:**198,199,200,203,279,293,294,295,296,298,299,303,312,313	Sunflower , Sorghum, Bajra, Bengal gram	**Fruit crops:** Amla,Custard apple, Lime, Pomegranate, Musambi **Vegetables:** Drumstick, Coriander **Flowers:** Marigold, Chrysanthemum	Application of FYM, Biofertilizers and micronutrients, drip irrigation, Mulching, suitable soil and water conservation practises
4	KMHiB1 KMHiB2g1 BSRiB1g1 GHThB2g1 (Moderately deep to deep, red sandy clay to sandy clay loam soils)	**Bikanahalli:**24,32,33,35,36,37 **Bisarahalli:**50,51,52,53,54,55,56,57,80,82,83,87,88,89,90,91,92,176,177,181,182,183,184,185,186,190,324,327,328,329,330,331,334,335,336,	Maize, Sorghum, Bajra, Groundnut, Redgram	**Fruit crops:** Guava, Jackfruit, Jamun, Mango, Tamarind**,** Amla,Custard apple, Lime, Pomegranate, Musambi **Vegetables:** Drumstick, Tomato, Chilli, Coriander **Flowers:** Marigold, Jasmine, Chrysanthemum,	Drip irrigation, mulching, suitable soil and waterconservation practises (Crescent Bunding with Catch Pit etc)
5	BDGcB1g2 (Moderately deep, gravelly sandy clay to sandy clay loam soils)	**Bikanahalli:**43,44,45,49,58,77,78,80,81,84	Groundnut, Redgram, Bajra, Horsegram	**Fruit crops:** Amla, Cashew,Custard apple **Vegetables:** Drumstick, Coriander	Drip irrigation, mulching, suitable soil and water conservation practises

LMU	Mapping Units	Survey Number	Field Crops/ Forestry	Horticulture Crops	Suitable Interventions
					(Crescent Bunding with Catch Pit etc)
6	RNKiA1 (Moderately shallow, calcareous black gravelly sandy clay to clay soils)	**Bisarahalli:** 78,79,80	Bengal gram, Sorghum, Coriander	**Fruit crops:**Amla, Custard apple **Flowers:**Marigold,Chrysanthemum, Jasmine	Application of FYM, Biofertilizers and micronutrients, drip irrigation, mulching, suitable soil and water conservation practises
7	HTIhB1g1 KTPiB1g1 MKHcB1g1 MKHcB2g2 (Moderately shallow, red gravelly sandy clay to sandy clay loam soils)	**Bisarahalli:** 38,46,47,48 **Bisarahalli:**49,76,77,78,79,93,94,95,96,97,98,99,159,167,168,169,301,302,304,305,306,307,343	Maize, Sorghum, Groundnut, Bajra	**Fruit crops:** Amla,Custard apple **Vegetables:** Tomato, Chilli, Coriander **Flowers:**Marigold,Chrysanthemum, Jasmine	Drip irrigation, mulching, suitable soil and water conservation practises (Crescent Bunding with Catch Pit etc)
8	MTLiB1g1 MTLmB1 (Shallow, calcareous Black gravelly sandy clay to clay soils)	**Bisarahalli:**164,170,172,173,174,175,178,179,180,187,188,189,191,192,193,194,195,196,197,201,202,204,205,207,308,309,310,311,314,315,316,317,319,320,321,322,323,325,338	Bengal gram, Horsegram	**Agri-Silvi-Pasture:** Hybrid Napier, *Styloxantheshamata, Styloxanthesscabra*	Use of medium duration varieties, sowing across the slope, drip irrigation and mulching is recommended
9	CSRmB2g1 (Shallow, red loamy soils)	**Bisarahalli:**151,152,160,162,163,165,166,171	-	**Agri-Silvi-Pasture:** Hybrid Napier, *Styloxantheshamata, Styloxanthesscabra*	Use of medium duration varieties, sowing across the slope, drip irrigation and mulching is recommended

3.14 Soil and Water Conservation Plan

For preparing soil and water conservation plan for Bisarahalli-1 microwatershed, the appropriate conservation structures best suited for each of the land parcel/ survey number are selected based on the slope per cent, severity of erosion, amount of rainfall, land use and soil type [29]. The different kinds of conservation structures recommended are Graded/Strengthening of bunds, Trench cum Bunds (TCB), Trench cum Bunds / Strengthening and Crescent Bunds.

A map (Fig. 20) showing soil and water conservation plan with different kinds of structures recommended has been prepared which shows the spatial distribution and extent of area. Maximum area of about 304 ha (53%) requires trench cum bunding and about 248 ha (43%) area needs graded bunding. The conservation plan prepared may be presented to all the stakeholders including farmers and after including their suggestions, the conservation plan for the microwatershed may be finalised in a participatory approach [30].

3.15 Proposed Crop Plan for Bisarahalli-1 microwatershed

After assessing the land suitability for the major crops, the proposed crop plan has been prepared with database (soil phases) generated under LRI was utilized for identifying LMU's based on the management needs. One or more than one soil site characteristic having influence on the management have been chosen for identification and delineation of LMU's. The 9 identified LMU's by considering only the highly and moderately (Class S1 and S2) suitable lands for each of the crop. The resultant proposed crop plan is presented in Table 4 [29].

4. CONCLUSION

The LRI database in the form of maps, atlases and tables shows different types of soils, their spatial distribution and extent, classification, characteristics and use-potentials on an appropriate base map. It shows the problem and potential areas giving their spatial distribution and type of limitation. It also shows areas suitable and not suitable for agriculture, horticulture, pasture, forestry, recreation etc., and identifies areas that need soil and water conservation and reclamation measures. It gives information on areas suitable for growing major annual and perennial crops with limitations. It helps in identifying areas that are deficient or sufficient in major and micronutrients, thus facilitating preparation of soil health cards for each land parcel/survey number for the crops intended to be grown. Finally, the LRI database helps in preparing optimum land use plans for the microwatersheds that help not only in restoring the ecological balance but also in improving the production on a sustainable basis. The data handling system will be useful for making land use decisions and providing proactive advice to farmers on a real time basis protecting the health of natural resources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Rajendra Hegde, Natarajan A, Meena RS. Niranjana KV, Thayalan S, Singh SK. Status of soil degradation in an irrigated command area in Chikkaharasinakere Hobli, Mandya district, Karanataka. Current Science. 2015;108(8):1501–1511.
2. Rajendra Hegde, Niranjana KV, Srinivas S, Danorkar BA, Singh SK. Site-specific land resource inventory for scientific planning of Sujala watersheds in Karnataka. Current Science. 2018;115(4):644-652.
3. Patil PL, Kuligod VB, Gundlur SS, Jahnavi K, Nagaral IN, Shikrashetti P, Geetanjali HM, Dasog GS. Soil fertility mapping in Dindur subwatershed of Karnataka for site specific recommendations. Journal of Indian Society of Soil Science. 2016;64:381-390.
4. Natarajan A, Dipak Sarkar. Field guide for soil survey, national bureau of soil survey and land use planning (ICAR), Nagpur, India; 2010.
5. Soil Survey Staff, Soil Survey Manual, Handbook No. 18, US Department of Agriculture, Washington DC, USA; 2012.
6. Soil Survey Staff, Natural Resources Conservation Service, National Soil Survey Handbook, Title 430–VI, US Department of Agriculture, Washington DC, USA; 1996.
7. IARI. Soil survey manual, all india soil and land use survey organization, IARI, New Delhi. 1971;121.
8. Soil Survey Staff, Keys to Soil Taxonomy, Tenth edition, US Department of Agriculture/NRCS, Washington DC, USA; 2006.

9. Sarma VAK, Krishnan P, Budihal SL. Laboratory manual, technical bulletin 23, NBSS &LUP, Nagpur; 1987.
10. Katyal JC, Rattan RK. Secondary and micronutrients; Research gap and future needs. Fertilizer News. 2003;48(4):9-20.
11. FAO. Frame work for land evaluation, Food and Agriculture Organization, Rome. 1976;72.
12. FAO, Guidelines for land evaluation for rainfed agriculture, Food and Agriculture Organization, Rome. 1983;237.
13. Naidu LGK, Ramamurthy V, Challa O, Hegde R, Krishnan P. Manual soil site suitability criteria for major crops, NBSS Publ. No. 129, NBSS&LUP, Nagpur. 2006;118.
14. Dinesh Bhat MA, Grewal KS. Characterization and classification of soils on different geomorphic units of northeastern Haryana, India. Agropedology. 2017;27(2):103–106.
15. Ramamurthy V, Nair KM, Ramesh Kumar SC, Srinivas S, Naidu LGK, Dipak Sarkar. Land management unit approach: Step towards precision farming, XIX National symposium on "Resource Management Application towards Livelihood Security". December 2nd to 4th, UAS, Bangalore. 2010;455.
16. Mahender Reddy D, Patode RS, Nagdeve MB, Satpute GU, Pande CB. Land use mapping of the Warkhed microwatershed with geo-spatial technology. Contemporary Research India. 2017;7(3):403-409.
17. Rajendra Hegde, Mahendra Kumar MB, Seema KV, Niranjana KV, Dhanorkar BA. Study of land use mapping of Devarahalli microwatershed with geospatial technology. Journal of Pharmacognosy and Phytochemistry. 2021;10(1):1556-1561.
18. Kumar YSS, Naidu MVS. Characteristics and classification of soils representing major landforms in Vadamalapetamandal of Chittoor district, Andhra Pradesh. Journal of Indian Society of Soil Science. 2012;60:63-67.
19. Vedadri U, Naidu MVS. Characterization, classification and evaluation of soils in semi-arid ecosystem of Chillakurmandal in SPSR Nellore district of Andhra Pradesh. Journal of Indian Society of Soil Science. 2018;66:9-19.
20. Ram RL, Sharma PK, Jha P, Das N, Ahmed N. Characterization and classification of Nagarjuna sagar catchement in Shorapur taluk of Gulbarga district in Karnataka. Agropedology. 2010;20:112-123.
21. Rao APVP, Naidu MVS, Ramavatharam N, Rao GR. Characterization, classification and evaluation of soils on different landforms in Ramachandrapurammandal and Chittoor district in Andhra Pradesh and sustainable land use planning. Journal of Indian Society of Soil Science. 2008;56(1):23-33.
22. Gupta AP. Studies on the distribution, fixation and availability of phosphate in soils of sugarcane growing tracts of Bihar and Uttar Pradesh. Agra University Journal of Research. 1965;14:191-194.
23. Mahendra Kumar MB, Subbarayappa CT, Ramamurthy V, Shreenivas BV, Vijay Kumar C. Characterization of surface soils in irrigated land management unit-1 (Command area) of Mysore District, Karnataka. Ecology Environment and Conservation. 2015;21(1):471-476.
24. Tawande SK, Patil JD, Zende GK. The forms and contents of sulphur in soils of Maharashtra state. Journal of Maharashtra Agricultural University. 1976;1(1):1-6.
25. Balanagoudar AB. Investigations on status and forms of sulphur in soils of North Karnataka. M.Sc (Agri.) Thesis, University of Agricultural Sciences, Dharwad (India); 1989.
26. Gurumurthy KT, Balaji Naik D, Ravikumar D, Ganapathi, Raghu AN, Raghavendra S, Thippeshappa GN, Sindhu HS, Anantakumar Patil. Evaluation of Soil fertility status of macronutrients and mapping in Beguru microwatershed of Tarikere taluk of Chikkmagaluru district, Karnataka, India. International Journal of Current Microbiology and Applied Sciences. 2019;9:223-229.
27. Geetha GP, Prabhudev Dhumgond, Shruti Y, Ramakrishna Parama VR, Sathish A. Study of Land Evaluation in Giddadapalya Microwatershed, Tumkur District. Journal of Pharmacognosy and Phytochemistry. 2017;6(5):2123-2130.
28. Rajendra Hegde, Mahendra Kumar MB, Niranjana KV, Seema KV, Dhanorkar BA. Land suitability evaluation in Yaadhalli-1 Microwatershed of Yadgir Taluk and District of Karnataka, India, using remote sensing and geographical information system (GIS) tools. International Journal of Chemical Studies. 2021;9(1): 2144-2153.

29. Technical Bulletin on Land Resource Inventory (LRI) under Karnataka Watershed Development Project-II (Sujala-III) Government of Karnataka, September; 2018.

30. Natarajan A, Rajendra Hegde, Raj JN, Shivananda Murthy HG. Implementation manual for sujala-III project, Watershed Development Department, Bengaluru, Karnataka; 2015.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/71453