Site-specific land resource inventory for scientific planning of Sujala watersheds in Karnataka

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Land resource inventory for site-specific planning and development of watersheds on scientific basis under Sujala-III project sponsored by the Watershed Development Department of Karnataka and funded by the World Bank is being implemented in 11 districts covering 9.66 lakh ha across 2531 microwatersheds benefiting 7.02 lakh households in the state. The analysis and interpretation of the spatial and non-spatial database generated so far in 1600 microwatersheds covering 5 lakh ha has revealed that most of the watersheds suffer from major problems. In many watersheds, soil erosion and alkalinity affected even up to 75% of the watershed area, thus reducing the production potential and crop choices. The soils are either moderately or highly suited for growing most of the agricultural and horticultural crops. By interfacing land resource data with RS, 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.

Keywords: Digital library, land resource inventory, land resources portal, land resource database analysis and interpretaion, Sujala-III project.

SITE-SPECIFIC land resource inventory (LRI) for farm level planning of watersheds 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. 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. The result is manifested in the form of soil erosion, salinity/alkalinity, forest loss and vegetation, and finally decrease in agricultural production in the watersheds. A study of Cauvery command area indicated that nearly 59% of the command area was degraded (>10,000 ha) leading to an economic loss of Rs 995 crores per year[1]. 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. The challenges posed by the continuing degradation and declining factor productivity of the resource base are very site-specific. They 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. 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. It is with this objective that the Watershed Development Department of the Government of Karnataka has initiated Sujala-III project funded by the World Bank for the planning and development of watersheds on scientific basis in 11 selected districts of Karnataka covering 12.5 lakh ha, across 2531 microwatersheds, benefiting about 7.00 lakh households by adopting the modern methods of RS and GIS for generating land resource information at the farm level.

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

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RS in terms of spatial, temporal, spectral and radiometric resolutions. Multispectral and hyperspectral sensors generate vast amount of data in a cost-effective manner at higher spatial and spectral resolutions. They provide repetitive and synoptic coverage of any part of the earth. 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.

Sujala-III project

Sujala-III project is formulated to address 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, provide datasets and inputs needed for planning and implement and monitor all land-based developmental programmes in the state. The project is executed in a consortia mode with the main objective of generating site-specific land resource database on soil and other resources at watershed level through LRI using state-of-the-art RS and GIS techniques with adequate ground truth. Digital Library is developed by pooling all spatial and non spatial data to establish a Land Resources Portal for effective information dissemination. This helps to develop a robust and dynamic decision support system (DSS) for improved programme integration at watershed and higher levels and to develop tools, packages and thematic outputs through R&D for use in LRI, integrated hydrological assessment, technology transfer and for strengthening research management in the state.

The Sujala-III project is implemented by the Watershed Development Department (WDD) of Karnataka from 2013–14 for 6 years in 11 districts (Table 1 and Figure 1) initially and will later be extended to other districts in the state. It is implemented by the consortia of partners through five different components of the project. They are: (i) support for improved programme integration in rainfed areas; (ii) research, development and innovation; (iii) institutional strengthening, training and capacity building and upgrading the existing training centres in project areas; (iv) strengthening horticulture in rainfed areas and (v) project management and coordination.

Table 1. Microwatersheds and taluks covered under LRI

Project district	MWS covered	Taluks to be covered
Bidar	38	Humnabad, Aurad
Chamarajanagar	63	Chamarajanagar
Davanagere	44	Channagiri
Gadag	77	Gadag
Gulbarga	92	Gulbarga
Koppal	37	Koppal
Yadgir	41	Yadgir
Tumkur	148	Tumkur
Chikkamagalur	42	Tarikere
Bijapur	73	Bijapur
Raichur	43	Lingsugur

The LRI atlases for all these watersheds are already available on Sujala website of the Department. The LRI activity finally covers 2531 MWS in these taluks.

Consortia partners

The partners participating in the implementation of Sujala-III project are: (1) ICAR–National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP), Bengaluru (Lead Institute for the project for LRI); (2) Indian Institute of Science (IISc), Bengaluru – lead institute for hydrology; (3) International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad; (4) University of Agricultural Sciences (UAS), Bengaluru; (5) UAS, Dharwad; (6) UAS, Raichur; (7) University of Horticultural Sciences (UHS), Bagalkot; (8) University of Agriculture and Horticultural Sciences (UAHS), Shivamogga; (9) Karnataka Veterinary, Animal and Fishery Sciences University (KVAFSU), Bidar; (10) Karnataka State Remote Sensing Applications Centre (KSRSAC), Bengaluru; (11) Karnataka State Natural Disaster Management Center (KSNDMC), Bengaluru; (12) ICAR-ATARI- Bengaluru for dissemination of information; (13) ICAR-Indian Institute of Soil and Water Conservation

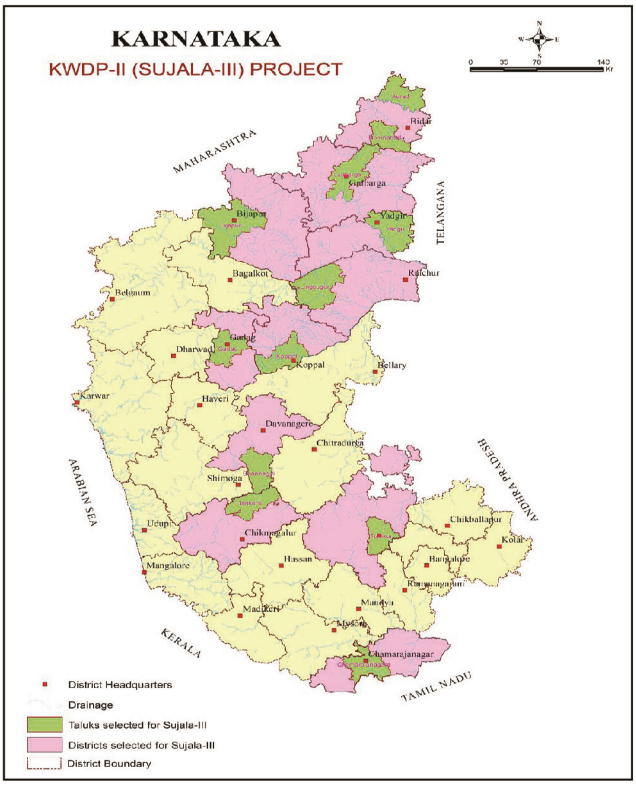


Figure 1. Location of project districts and taluks.

(IISWC), Regional Centre, Ballari for monitoring and evaluation.

Establishment of digital library

All spatial and non-spatial datasets generated at watershed/village level under LRI are first converted into digital form, then integrated in a GIS framework and housed in the Digital Library to be established in each of the five universities to cover the entire state (Figure 2) and later made available to the various line departments and developmental agencies on a real time basis through Land Resources Portal. This data handling system, its storage, retrieval, analysis and display capability and easy accessibility will be a valuable tool to planners, administrators, researchers, extension workers for making land use decisions and for providing proactive advice to the farmers on real time basis.

Information dissemination through land resources portal

The land resources portal helps in the dissemination of information to the line departments, administrators, researchers and NGOs and will also provide the required up-link facilities to the farm families required for day-to-day information needs that will help manage their resources at the farm level (Figure 3). This will be a one stop portal, which is expected to provide not only the required information to all the stakeholders, but also enable the users to benefit from the interactive and dynamic mode of operation. Apart from this, all types of queries during or before the execution of any land-based project can be put on the web-based DSS and needed solutions can be obtained by the developmental agencies as well as farmers in the state on a real time basis. State-of-the-art digital library and its link-up with all user agencies at different levels through the commissioning of the portal, supported by a dynamic DSS is expected to change the entire process of planning. Most cases at present follow a top down approach rather than of grassroots. This will bring in a paradigm shift by facilitating a two-way planning process in addressing the site-specific problems faced by farmers.

Various activities of LRI under Sujala-III project

The ICAR-NBSS&LUP is the lead institute for conducting LRI for some of the watersheds identified under the Sujala-III project. It is also assisting the LRI work done by the consortia partners (UAS Bangalore, Dharwad, Raichur; UAHS Shimogga and UHS Bagalkot) under the technical guidance and supervision of NBSS&LUP. The various activities in the project are training in LRI to research associates, senior research fellows and project assistants and awareness and familiarization programmes to the officers of WDD, Universities and other stake holders through training and workshops on the LRI data that would help in scientific planning and development of watersheds in Karnataka. Apart from this, several field reviews (World Bank Team, NBSS and WDD) involving soil correlation and classification are being conducted to bring in uniformity, consistency and quality of LRI data by the consortia partners. The NBSS&LUP together with the other consortia partners has completed about 1600 microwatersheds covering five lakh ha.

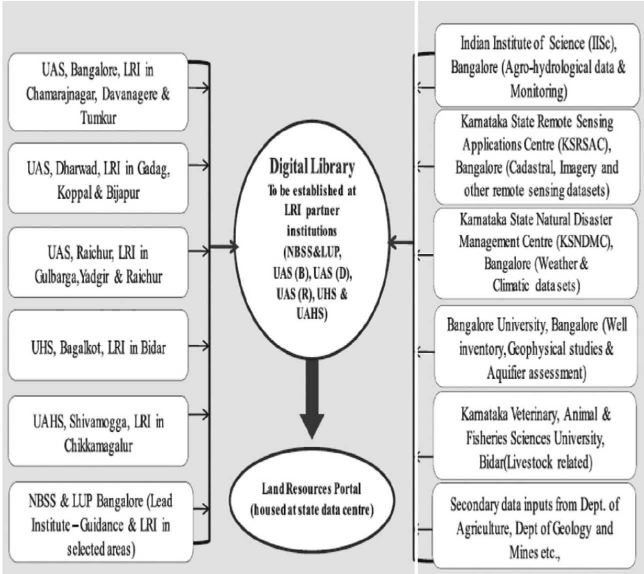


Figure 2. Digital library.

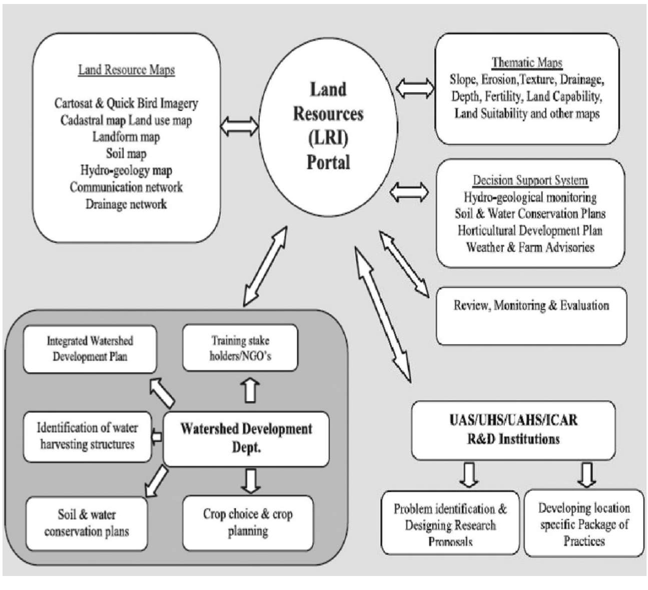


Figure 3. Land resources portal.

Methodology for LRI generation

LRI for site-specific planning and development of watersheds is being carried out by using digitized cadastral map (Figure 4) and false colour composites (FCC) of Cartosat-1 and LISS-IV merged satellite data (Figure 5). The methodology followed for carrying out LRI was as per the guidelines given in Soil Survey Manual[2–4]. The FCCs were visually interpreted using image interpretation elements like 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 watershed[5]. In the selected transect (Figure 6), 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, salinity/alkalnity, 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[2,6]. 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[5] and grouped into different soil series. 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 2. The soils were mapped as phases of soil series. 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. 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 (Figure 7) 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

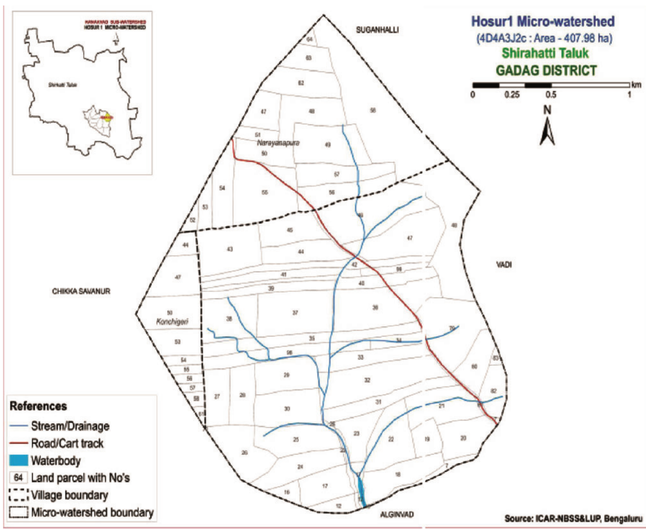


Figure 4. Scanned and digitized cadastral map.

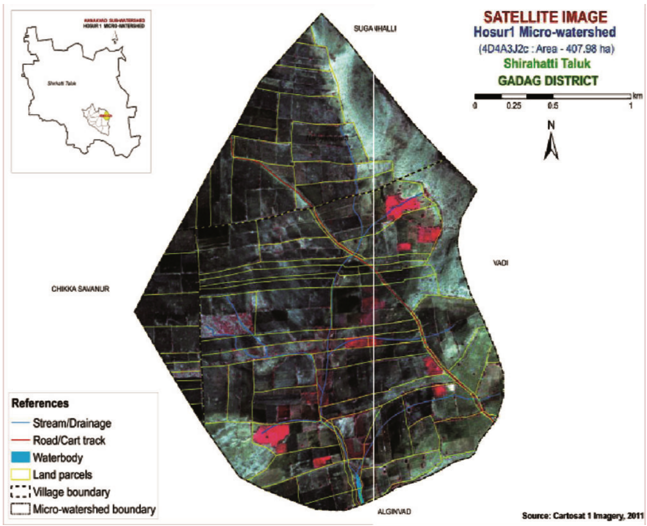


Figure 5. Cadastral map overlaid on IRS PAN + LISS IV merged imagery.

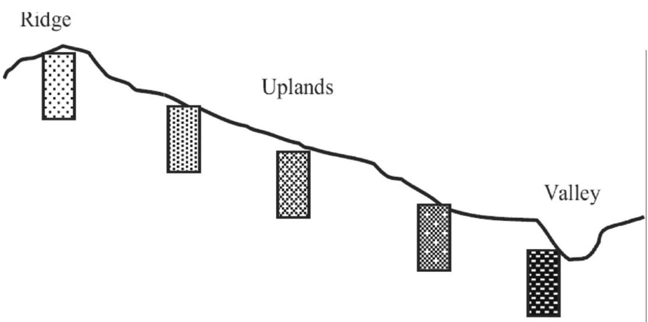


Figure 6. Location of soil profiles in a transect.

Table 2. Differentiating characteristics used for identifying soil series

Soil series	Depth (cm)	Series control section: Colour	Texture	Gravel (%)	Kind of horizon and its sequence	Calcareousness/ others
Soils of granite gneiss landscape						
Devihal (DVH)	<25	2.5YR 2.5/4 5YR 3/4, 4/6	cl	<15	Ap–Cr	–
Harve (HRV)	25–50	2.5YR 3/6 5YR 4/4	scl	>35	Ap–Bt–Cr	–
Soils of basalt landscape						
Atharga (ARG)	<25	10YR 2/2, 3/3, 3/4, 4/3, 4/4	sc–c	15–35	Ap–Crk	e–es
Karjol (KRJ)	>150	10YR 2/1, 3/1, 3/2, 3/3, 3/4, 4/1, 4/2, 4/3	cl–c	<15	Ap–Bss	es–ev

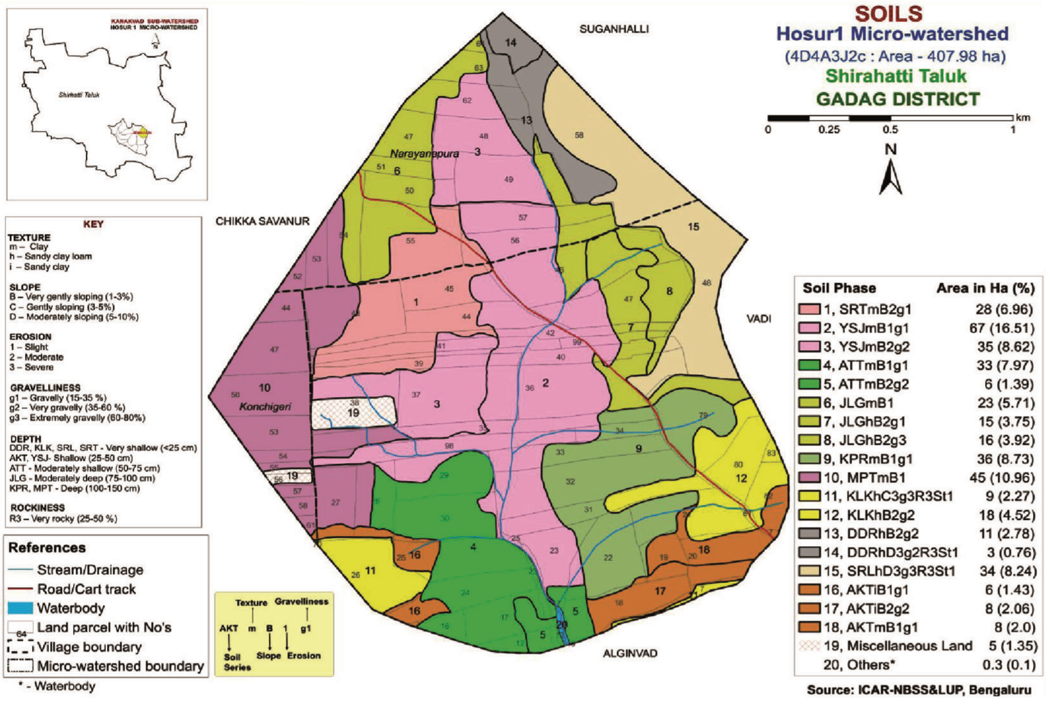


Figure 7. Soils (phases of soil series).

representative master profiles for each soil series for laboratory characterization of physical and chemical properties by following the methods outlined in the laboratory manual[7]. Surface soil samples collected from farmers fields at 250 m grid interval were analysed in the laboratory[8] for fertility status (macro and micronutrients). The data is used for soil health card generation by the department.

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 in the state particularly the flagship programmes like Pradhan Mantri Krishi Sinchayee Yojana, Krishi Bhagya, Soil-Health Cards, etc. 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 watershed. 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

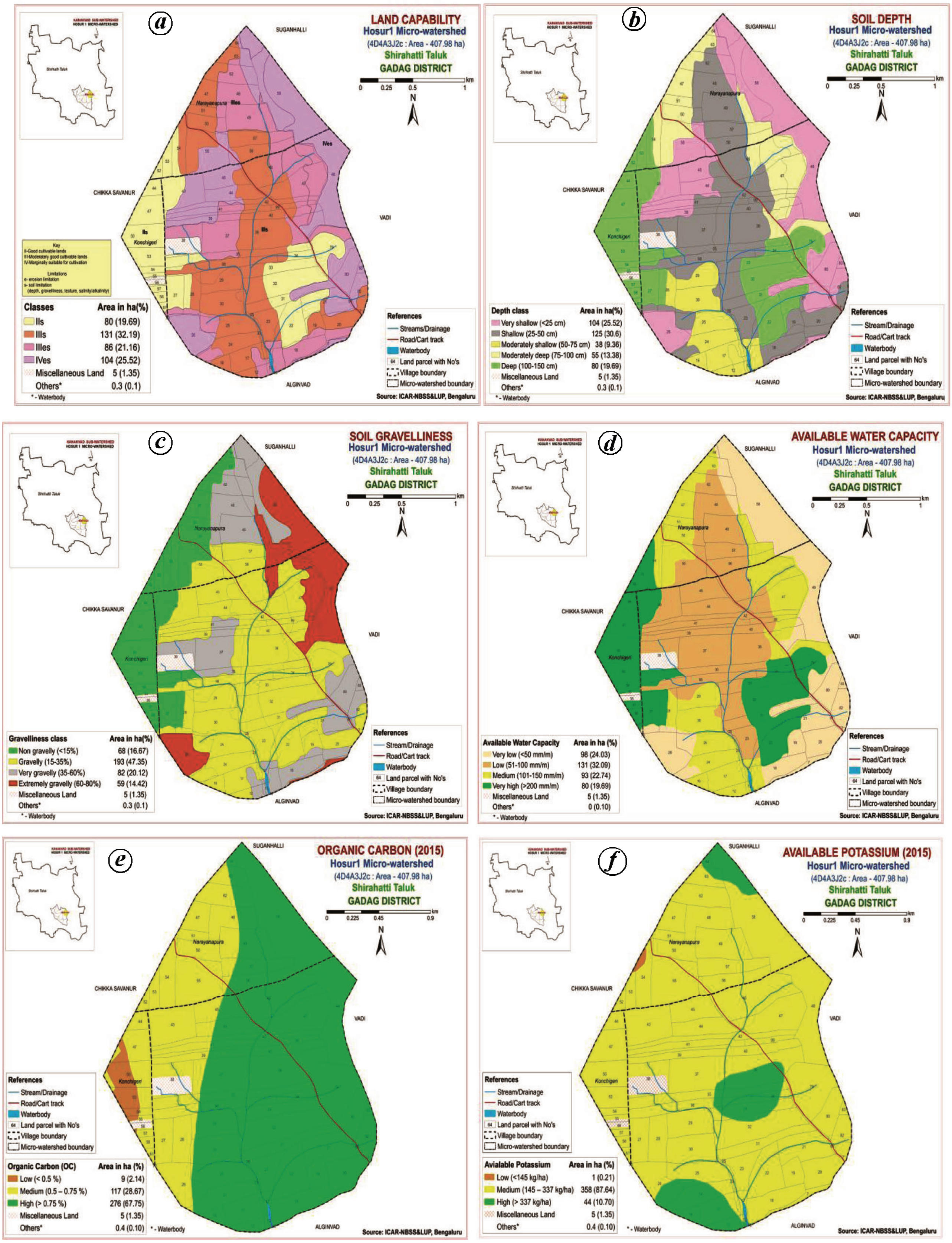
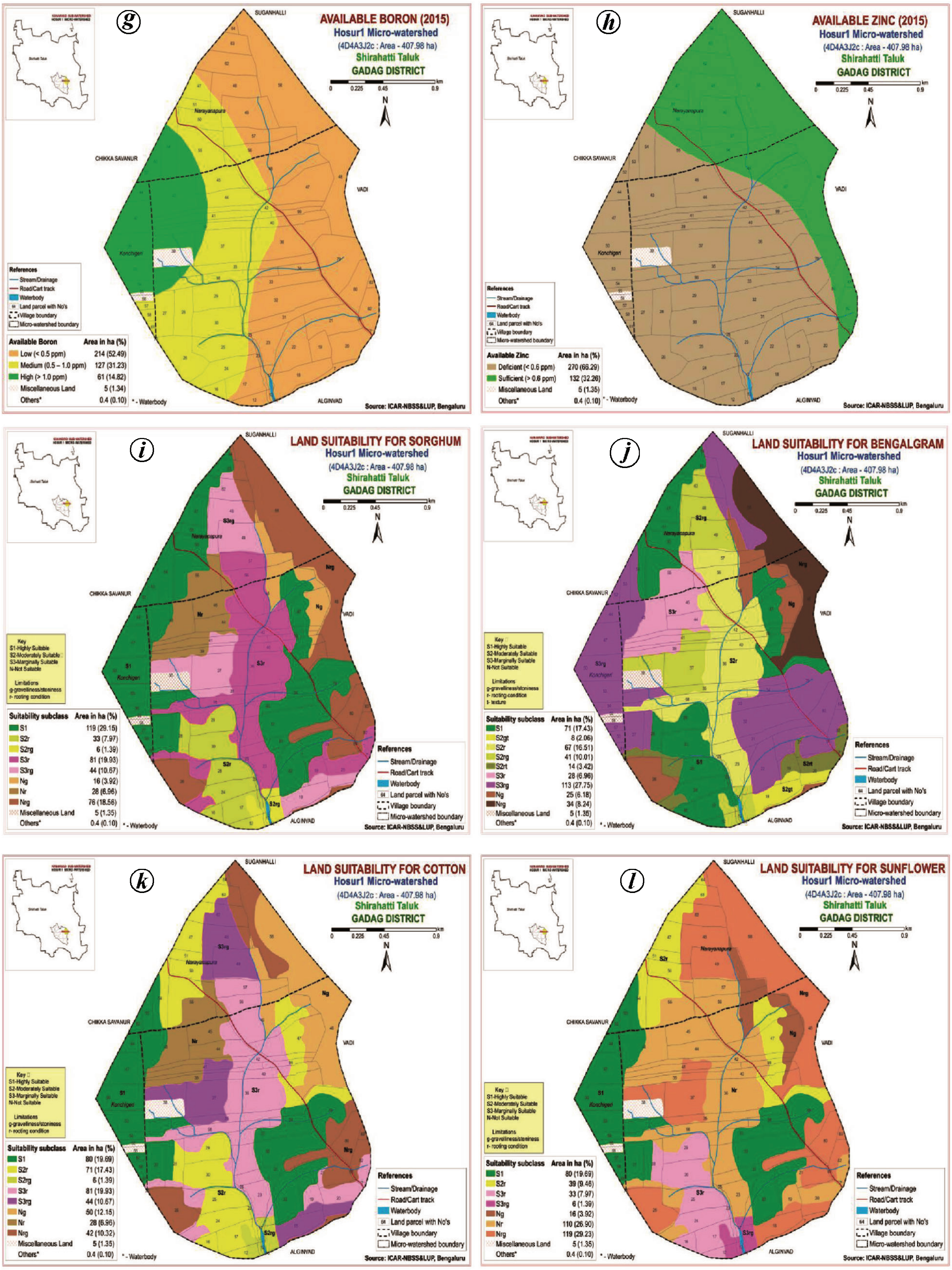


Figure 8. (*Contd*)



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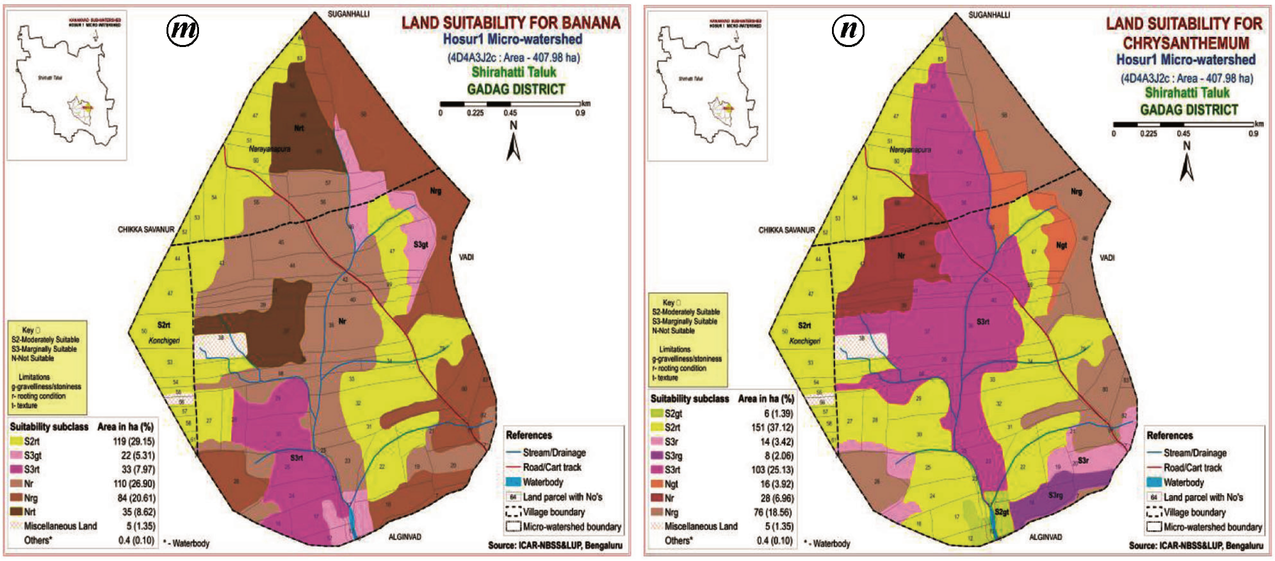

Figure 8. ***a***, Land capability; ***b***, Soil depth; ***c***, Soil gravelliness; ***d***, Available water capacity; ***e***, Soil organic carbon; ***f***, Available potassium; ***g***, Available boron; ***h***, Available zinc; ***i***, Land suitability for sorghum; ***j***, Land suitability for Bengal gram; ***k***, Land suitability for cotton; ***l***, Land suitability for sunflower; ***m***, Land suitability for banana and ***n***, Land suitability for chrysanthemum.

thematic maps like land capability, soil depth, surface soil texture, gravelliness/stoniness, available water capacity, slope, erosion, soil fertility status for major (N, P, K) and micronutrients (S, B, Fe, Mn, Cu and Zn) and soil pH and electrical conductivity. Land suitability for 27 major agricultural and horticultural crops grown in Karnataka were assessed by following FAO framework for land evaluation[9–11]. Soil and water conservation treatments required were assessed and treatment plans[11] were prepared for each microwatershed identifying the sites to be treated and also the type of conservation structures required. Land resource atlases depicting 42 interpretative maps for each microwatershed were prepared. These maps show the spatial distribution of both problem and potential areas with suggested interventions.

Significant findings from LRI of Sujala watersheds and suggested interventions

Major findings of LRI so far conducted in 1600 microwatersheds covering about 9.0 lakh ha have revealed that most watersheds have problems as well as potentials which need different interventions that ensure production on a sustained basis. Some of the interpretative maps generated depicting different thematic areas for one microwatershed are presented as an example from Figure 8 *a–n* that help in planning of watershed development on a scientific basis. This microwatershed is located in Shirahatti taluk, Gadag district in Karnataka and lies between 15°2′–15°4′ lat. and 75°39′–75°41′E long. The problems and potentials identified in general in all the microwatersheds surveyed under Sujala-III along with the suggested interventions are presented below.

Problem areas

- The soils in microwatersheds are generally gravelly (>15–60% gravel). Gravel in the surface hinders seed bed preparation and seedling emergence, is poor in soil moisture storage and nutrient availability, but is favourable for run-off harvesting. It plays a significant role in deciding the type of crop to be grown.
- The soils are dominantly clayey and loamy at the surface. These soils are prone to sheet erosion and poor in water infiltration and percolation. They have high potential for soil-water and nutrient retention and availability but have problems of drainage, infiltration, workability and other physical problems. Such soils can be improved by sand mulching. A wide range of climatically adapted crops (food and horticultural) can be grown.
- Majority of the soils are low in available water capacity (<100 mm/m of soil). Only short duration crops can be grown and the probability of crop failure is high. They are best suited for other alternative uses such as pasture, agro-forestry or agri-horti-slivipasture.
- About 50% of area in the microwatersheds is prone to sheet, rill and gully erosion. They need appropriate soil and water conservation and other land husbandry practices for restoring soil-health.
- The soils are alkaline (pH 7.3–9.0) in almost all the microwatersheds except in Tumkur district, where the soils are mostly acidic to neutral (pH 5.1–7.3). For alkaline soils, regular addition of organic manure, green manuring, green leaf manuring, crop residue incorporation, mulching, application of biofertilizers, application of 25% extra N and P (125% RD N&P),

application of gypsum once in three years and proper drainage will improve the soil-health condition. For acidic soils, application of lime based on the soil-test values will help neutralize the soil condition.

- Most of the soils are low (<23 kg/ha) in available phosphorus. Hence for all the crops, 25% additional P needs to be applied over and above the recommended dose.
- Generally the soils are low (<10 ppm) in available sulphur. Such areas need to be applied with magnesium sulphate or gypsum or factamphos (P) fertilizer (13% sulphur) for 2–3 years for the deficiency to be corrected.
- Majority of the soils are deficient (<4.5 ppm) in available iron. To manage iron deficiency, iron sulphate at 25 kg/ha needs to be applied for 2–3 years.
- Most of the soils are deficient (<0.6 ppm) in available zinc. Zinc sulphate at 25 kg/ha needs to be applied for correcting the Zn deficiency.
- Generally, the soils are low in (<0.5 ppm) available boron. For such areas, boron at 5 kg/ha needs to be applied for 2–3 years to correct the boron deficiency.
- Loss of forest and vegetative cover is one of the major causes of land degradation in most microwatersheds. As part of the greening programme, it is recommended to plant a variety of horticultural and other tree plants that are edible, economical and produce lot of biomass which helps restore the ecological balance in the watersheds. The lands that are suitable for greening programme are non-arable lands (land capability classes V, VI, VII and VIII) and also lands that are not suitable or marginally suitable for growing annual and perennial crops[12].

Potential areas

- The soils are deep to moderately deep (>75–100 cm depth) in red soil microwatersheds where all climatically adapted crops can be grown.
- Majority of the soils in the microwatersheds are high (>337 kg/ha) in available potassium and as such, may not require addition of potassium.
- Generally, the soils in most of the microwatersheds are sufficient in available manganese and copper.
- Most of the lands in the microwatersheds are suitable for agriculture with different types and degrees of limitations. If these limitations are attended to, the production can be enhanced.
- About 50% of area in the microwatersheds is either moderately suitable or highly suitable for growing sorghum, maize, finger millet (ragi), red gram, horse gram, bengal gram, sunflower, groundnut, cotton, soybean, chillies, onion, guava, sapota, pomegranate, musambi, lime, amla, custard apple, jamun, tamarind, marigold and chrysanthemum. Various constraints/limitations like length of crop growing period, soil depth, gravelliness, lighter/heavy soil texture, moisture availability, drainage, nutrient availability, erosion hazard, etc. limit the productivity. With suitable management interventions as recommended by the AICRP–Dryland Agriculture, productivity can be enhanced.

Conclusion

The LRI database in the form of maps, illustrations, atlases and tables shows different types of soils, their spatial distribution and extent, correlation, 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 specific 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 no. 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.

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