CHAPTER 10

Generation of Farm Specific Land Resources Database for Effective Implementation of Watershed Development Programs — A Case Study of Magadi Model Watershed in Karnataka

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The Government of India spends nearly Rs one lakh crore every year on various land based rural and agricultural development programs. However, various post project evaluation reports suggest that 50-75 percent of farm land areas suffer from various kinds of degradation, which indicates that there is some kind of mis-match between the actual requirement and what is actually implemented in the field in the form of various land-based rural development programs. Such situations can be avoided if detailed, site specific land resources database are generated in each and every project area. Such an inventory provides us the information to identify inherent potentials and constraints and suitability for various land uses. This scientific database is a prerequisite for implementing, monitoring, reviewing and evaluating all the land developmental programs. This can be obtained only by conducting cadastral level detailed surveys wherein we characterize and group soils into different soil series and delineate homogenous areas based on soil-site characteristics into management units or phases. Preparation of such a detailed land resources inventory is a very time consuming, highly skillful and costly exercise. The present

pilot study was aimed to provide such a database for all the 14 villages (1650 ha) in two micro-watersheds, namely Bairappapalya and Kadirenapalya, in Magadi *Taluk*, Ramanagara district of Karnataka during February 2011 (KSRSAC, 2005).

Materials and Methods

High intensity survey (at 1:8000 scale) was carried in the study area (Tirumale sub-watershed) lying between 77°12' 30" and 77°17'30" East longitudes and 12°55' 0"and 13°02'30" North latitudes with an area of 1650 hectares. Study was carried out for characterizing all the site (*viz.* slope of the land, erosion, drainage, occurrence of rock fragments etc.) and soil characteristics (*viz.* depth, texture, colour, structure, consistency, coarse fragments, porosity, soil reaction etc.), followed by grouping of similar areas based on soil-site characteristics into homogenous (management) units and showing their extent and distribution on the village cadastral map (Natarajan and Dipak Sarkar, 2009).

Base maps used: Study was carried out by using a cadastral map as a base. The cadastral map shows field boundaries with their survey numbers, location of tanks, streams and other permanent features of the area. Remote sensing data products from Google earth at the same scale were used in conjunction with the cadastral maps to identify the landforms and other surface features. Imageries helped in the identification and delineation of boundaries between hills, uplands and lowlands, water bodies, forest and vegetated areas, roads, habitations and other cultural features of the area. Apart from these, toposheets of the area at 1:50,000 scales were used for initial traversing, identification of geology and landform, drainage features, present land use and for the selection of transects at block level.

Field investigations: Based on the initial traversing, five representative transects were selected for study. In the selected transect, profiles were located at closely spaced intervals to take care of any change in the land features like break in slope, erosion, gravel, stones etc. In the selected sites, profiles (vertical cut showing the soil layers from the surface to the rock) were opened up to 200 cm or to the depth limited by rock or hard substratum and studied in detail for all their morphological and physical characteristics and recorded in standard proforma.

Based on the soil-site characteristics, the soils were 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, color, amount and nature of gravel present, nature of substratum and horizon sequence were the major identifying characteristics of soil series occurring in the area. Based on the above characteristics four soil series were identified in the area.

Seventy-five composite soil samples representing different land forms were collected for soil fertility analysis. Profile soil samples were collected from master profiles for chemical characterization. Thirty two farmers were interviewed on various constraints and potentials of the watershed for profitable faming, soil and water conservation and diversification of farming. Then the area under each series was further divided into phases and their boundaries delineated on the cadastral map based on the variations observed in the texture of the surface soil, slope, erosion, presence of gravels, stoniness, etc. A phase is a subdivision of a soil series based mostly on surface features that affect its use and management (Soil survey division staff, 2000).

The delineated mapping units are shown on the map in the form of symbols. , A combination of letters, both in upper and lower case, and numerals were used to arrive at the phases. During the survey, a total of 40 profiles and about 100 spot observations, in the form of mini pits and road cuts, terrace cuts and well cuts were studied.

The soil map for the study area was finalized in the field itself after thorough checking of soil and site characteristics and their correlation. Maps were prepared without any generalization and loss of information, and presented in the report and maps in the form of atlas for use by the field staff of the watershed development department. The soil map shows the individual field boundaries, their survey numbers and various soil units occurring in the sub-watershed (Fig. 2).

Results and Discussion

Landform analysis : Granites and gneiss, belonging to Archaean period, are the major rock types and dykes occurring in few places as intrusive in the country rock. The granite and gneiss show great variations in their texture, color, mineral assemblage and degree of weathering. These variations are reflected in the soil types identified in the area. Rocky hills and rock outcrops cover almost 30 percent of

the area. The hills and ridges are mostly covered by rock outcrops. In patches, between the rock outcrops and boulders, good growth of mango, jackfruit, *Ficus* etc are observed in the entire watershed area. The summits are always covered with rock outcrops along with cultivated plots and such areas cover around 20 percent of the total area.

The elevation of the area ranges from 818 to 897 m above mean sea level (MSL). Entire area consists of moderately sloping to undulating lands with slope percentage ranging from 3-10. The direction of the slope is complex and is in all directions. Based on the general slope, the area can be broadly divided into rocky hills and ridges, summits, cultivated plots in between rocky lands, sloping uplands and valleys. A network of canals was built about 50 years ago to use water for irrigation from a village *Harthi* tank. For that purpose, most of the areas along the stream courses were leveled and terraced wherever necessary, and paddy was grown as the main crop besides ragi for many years in these plots. But due to shortage of water during last 15-20 years, no water flows in these canals and paddy is cultivated only in patches where drainage conditions do not allow any other crop to be raised. Few new tanks have been constructed and old ones, strengthened by Watershed Development Department. All the tanks are seasonal and rainfall dependant. Most of the tanks receive water from limited catchment area, and are therefore never completely filled up every year. Further, un-controlled erosion from marginal lands and uplands, result in the heavy siltation and reduction in water storage capacity of the tanks. Almost all the tank beds are covered by weeds.

Gently to moderately sloping lands cover around 40 per cent of the watershed area. These areas are under cultivation for a long time and terracing by the farmers is a common practice in all the villages of the watershed. However, most of the terraces are not in good condition due to poor maintenance. Improper execution of the terraces in many places has resulted in the loss of fertile top soils in about 20 percent of the area, which either have shallow soils or the weathered parent materials are exposed at the surface. Typical lowlands and valleys occupy about 10 per cent of the watershed area.

Climatic details : The climate of the study area is semi-arid or hot tropical monsoonal type (Fig. 1). The average maximum and minimum temperatures are 33°C and 14°C, respectively. The average annual rainfall is 996 mm, mostly received between June and September from

the south-west monsoon. The north-east monsoon also brings rain for a short period during November to December. The lowest rainfall of 575 mm was received in 1990 and the highest of 1913 mm, during 1975. Total potential evapo-transpiration (PET) is 1499 mm, which exceeds precipitation by 503mm.

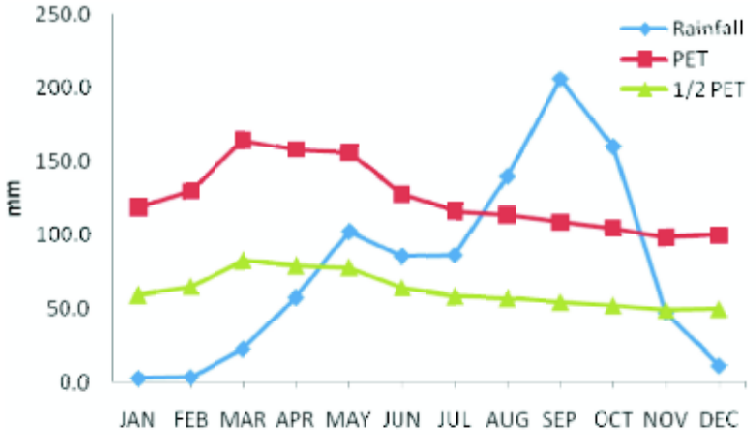

Fig.1 : Water balance diagram for Tirumale sub-watershed

The growing period, which indicates the availability of water for plant growth, is about four to five months in a year. It starts from the beginning of July and continues up to the end of December. Due to this, short to medium duration crops (like ragi, pigeon pea, french bean, fodder sorghum, etc.) can be grown successfully in the watershed area, whereas cultivation of long duration crops need supplemental or assured irrigation facilities. The deep rooted castor and pigeon pea are important long duration crops cultivated in this area, normally grown as an intercrop to exploit the residual moisture present in the lower horizons of the soil. During the last decade or so considerable area has been planted with mango and *Ficus*, particularly in the marginal lands.

Socio-economic constraints Large scale migration of younger generation has resulted in severe scarcity of labour for farm activities. As per the feedback received during the study, farming is no more attractive for large majority (> 60%) of population.

Land use : The net area sown (rainfed) in the sub-watershed is about 50 percent of the total area, while three percent of the area is under horticulture and forestry (*Eucalyptus* spp.). Fallow and

community lands occupy about 14 and 2.30 percent area, respectively. About 30 per cent of the area are rocky hills or rock out crops and is government owned. Large population of goats, sheep and cattle grazing extensively in village common lands and rocky hills has caused widespread soil degradation, and loss of vegetation and their natural regeneration capacity. As a consequence, the natural vegetation is sparse, comprising few tree species, shrubs and herbs.

The major crops grown are *ragi*, pigeonpea, frenchbean, castor, mango, areacanut and coconut. Vegetables and banana plantations are present in patches where borewell irrigation facility is available.

Soils : Soils of the sub-watershed are moderately shallow to deep (50-150 cm). The colour is dark red to dark reddish brown. The texture is dominantly sandy clay. The slope is generally 1-10 per cent. These soils are developed from granites and gneiss. The major series differentiating parameters are depth, color, texture and horizon sequence (Table 1). Taking into consideration the soil and site characteristics, 20 management units are identified (Table 2 and Figure 2).

Table 1 : Series identification characteristics of Tirumale sub-watershed

Series	Depth (cm)	Color (moist)	Texture	Gravel (%)	Horizon sequence	Classification
Hebbalpalya (Hpl)	50-75	2.5YR3/4, 3/6 5 YR4/4, 4/6, 5/6 7.5YR 4/4	sc-scl	10-20	Ap-Bt-Cr	Fine Typic Haplustalfs/
Byadarahalli (Brh)	50-75	2.5YR ¾, 3/6	sc-scl	10-25	Ap-Bt-Cr	Fine-Rhodic Paleustalfs
Belagumba (Bgb)	75-100	2.5YR ¾, 3/6	sc	0-20	Ap-Bt-Cr	Fine-Rhodic Paleustalfs
Kallentepalya (Klp)	100-150	2.5YR ¾, 3/6	c, sc	0-25	Ap-Bt-Cr	Fine Rhodic Paleustalfs

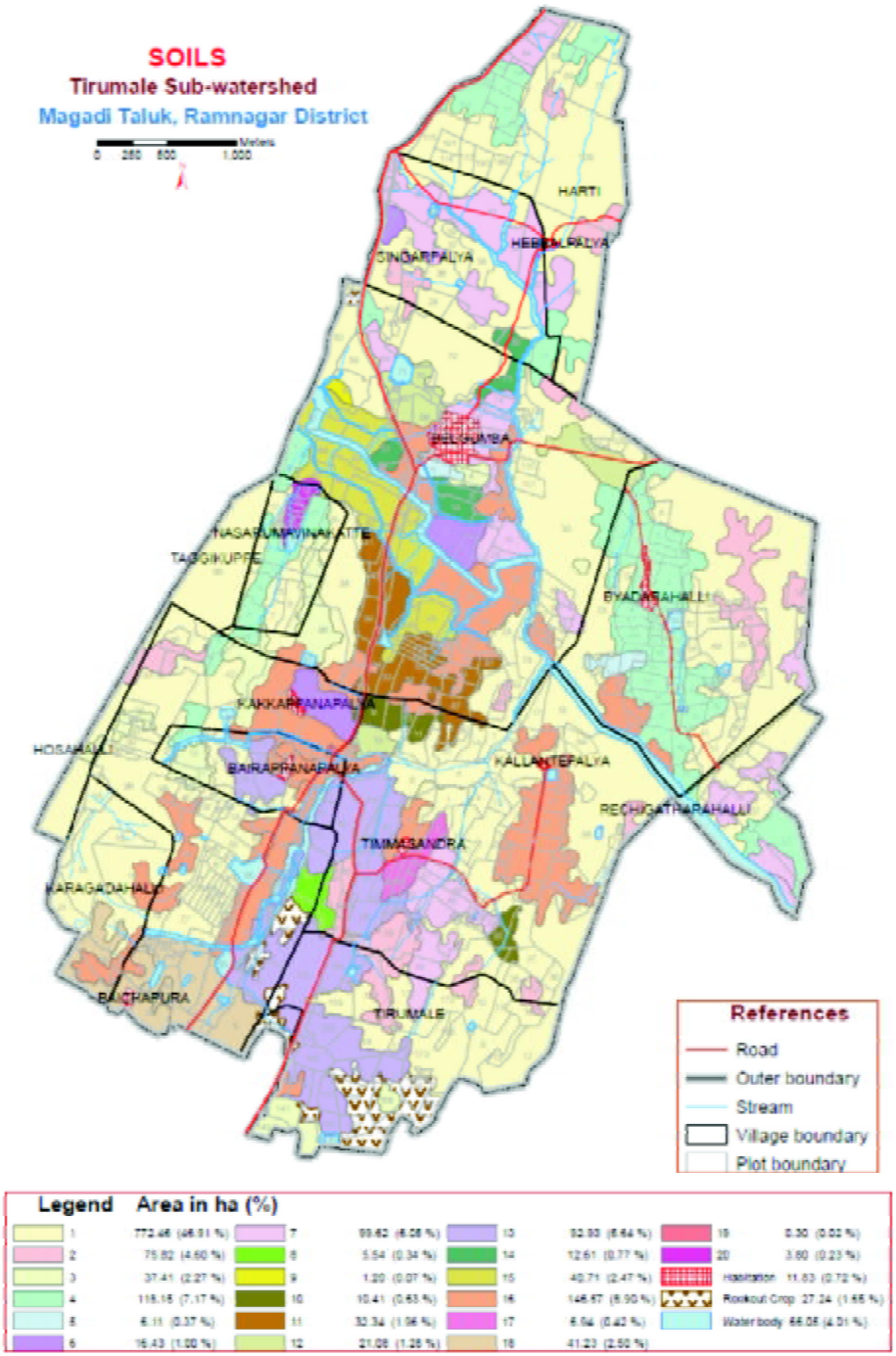

Fig. 2 : Soils of Tirumale sub-watershed.

Table 2 : Soil legend – Tirumale sub watershed

Map unit	Description	Area (ha)	Area (%)
1	Mostly of rock outcrops with patches of shallow gravelly loam soil on highly denuded hills/ridges with the spread of boulders and sparse scrub vegetation	772.46	46.91
2	Shallow, gravelly sandy loam surface and gravelly red clay sub soils with 15 to 20 per cent gravels on side/foot slopes with moderate erosion associated with 25 to 30 per cent rock outcrops.	75.82	4.60
3	Deep, loamy sand surface and red clay sub soils on gently sloping summits and uplands, gravelly in few horizons moderately eroded with patches of shallow red clay soils.	37.41	2.27
4	Moderately deep, loamy sand surface and gravelly red clay sub soils with 15 to 20 per cent gravels on very gently to gently sloping summits and uplands moderately eroded with some patches of moderately shallow red clay soils.	118.15	7.17
5	Moderately shallow, loamy sand surface and gravelly red clay sub soils with 15 to 20 per cent gravels on very gently to gently sloping summits and uplands moderately eroded with some patches of moderately shallow red clay soils.	6.11	0.37
6	Moderately shallow, loamy sand surface and red clay sub surface soils on very gently to gently sloping summits and uplands moderately eroded with some patches of moderately deep gravelly red clay soils.	16.43	1.00
7	Moderately deep, loamy sand surface and gravelly red clay sub soils with 15 to 20 per cent gravels on very gently to gently sloping uplands moderately eroded with some patches of moderately shallow red clay soils.	99.62	6.05
8	Moderately shallow, loamy sand surface and red clay sub soils on gently sloping uplands moderately eroded with some patches of moderately deep gravelly red clay soils.	5.54	0.34
9	Moderately shallow, sandy loam surface and gravelly red clay sub soils with 15 to 20 per cent gravels on gently sloping uplands moderately eroded with some patches of moderately shallow red clay soils.	1.20	0.07

10	Moderately shallow, sandy loam surface and gravelly red clay sub soils with 15 to 20 per cent gravels on very gently to gently sloping uplands moderately eroded with some patches of moderately shallow red clay soils.	10.41	0.63
11	Moderately deep, loamy sand surface and gravelly red clay sub soils with 15 to 20 per cent gravels on gently sloping uplands moderately eroded with some patches of moderately shallow red clay soils.	32.34	1.96
12	Moderately shallow, loamy sand surface and gravelly red clay sub soils with 15 to 20 per cent gravels on gently sloping uplands severely eroded with some patches of moderately shallow red clay soils.	21.08	1.28
13	Deep, sandy loam surface and red clay sub soils on gently sloping uplands, gravelly in few horizons moderately eroded with patches of moderately shallow gravelly red clay soils.	92.93	5.64
14	Moderately deep, sandy loam surface and gravelly red clay sub soils with 15 to 20 per cent gravels on very gently sloping uplands moderately eroded with some patches of moderately shallow red clay soils.	12.61	0.77
15	Moderately shallow, sandy clay loam surface and red clay sub soils on gently sloping uplands moderately eroded with some patches of moderately deep gravelly red clay soils.	40.71	2.47
16	Deep, loamy sand surface and red clay sub soils on very gently sloping uplands, gravelly in few horizons moderately eroded with patches of moderately shallow gravelly red clay soils.	146.57	8.90
17	Deep, loamy sand surface and red clay sub soils on gently sloping uplands, gravelly in few horizons moderately eroded with patches of moderately shallow gravelly red clay soils.	6.94	0.42
18	Deep, sandy loam surface and red clay sub soils on moderately sloping uplands, gravelly in few horizons moderately eroded with patches of moderately shallow gravelly red clay soils.	41.23	2.50
19	Deep, cracking clay surface and sub soils on nearly level lowlands with slight erosion.	0.30	0.02
20	Deep, clay surface and sub soils on nearly level lowlands with slight erosion.	3.80	0.23

Data collected and generated from the detailed land resources survey of the sub-watershed provides comprehensive information land resources of the area. Effective utilization of the database depends on the extraction of relevant and required data by the concerned users to meet their specific needs. To help various land users and planners to make use of the database effectively, various user friendly interpretations were carried out for the study area.

Identification of prime farm lands : Prime farmland is one which has the best combination of physical and chemical characteristics for producing food, fodder, fiber, oilseeds, plantation and other crops). Prime farmland has the required soil quality, growing season, and moisture supply to produce high yields of crops in a sustainable way when treated and managed according to the acceptable farming methods (e.g. water management). In general, prime farmlands have an adequate and dependable water supply from precipitation or irrigation, a favorable temperature and length of growing period, acceptable acidity or prime farmlands are not excessively erodible or saturated with water for a long period of time, and they either do not flood frequently or are protected from flooding. In the watershed area, the lands falling within the capability class I, II and III can be easily categorized as prime farm lands as they contribute significantly to the food and economic security of the area. In the present study nearly 40 per cent lands (II and III) are prime farm lands and remaining 60 per cent land is available for other uses including industry and recreation, etc. This provides one of the important basis for undertaking all kinds of soil and water conservation measures.

Land capability classes : As per the classification, the phases mapped in the watershed were grouped into three capability classes. As per the assessment, class III lands occupy about 25 per cent of the area. In the uplands, the class III lands have soil depth and erosion as major limitations. Moderately good agricultural lands (Class II) with the limitations of erosion and other soil related issues occupied 17.5 percent area mostly in the valleys all along the streams.

Slope : Moderately sloping lands D ((5-10%) occupied the major parts of the watershed area (54%). Cultivable area available is minimum under this class since rock out crops and denuded hills and hill slopes are the major land forms noticed under this class. Very gently sloping lands (1-3%), occurring mostly all along the streams occupied the next largest area (23%). Another major slope class noticed is gently sloping lands (3-5%), which occur in 16 percent area near the streams.

Soil depth : Within the cultivated fields, deep soils (100-150 cm) occur in major parts (20% area) particularly along streams and gently sloping lands. Moderately deep (75-100 cm) soils occur in about 16 percent area and this formed the next major group. Such soils are noticed mostly in the gently sloping uplands. Shallow and very shallow lands are noticed in about 10 percent area either very near to water canal/streams or hill tops. Near the streams these soils are noticed due to severe cutting and filling for leveling and making terraces to facilitate paddy cultivation.

Surface soil texture : Loamy sand and sandy loams are the dominant surface soil textural groups found in the watershed. Together they occupy 43 percent of watershed area. These soils mostly occur on gently sloping uplands and lowlands.

Soil erosion : Moderate erosion is the dominant erosion class observed in nearly 39 percent of the watershed area and was noticed in all types of land forms. Sheet erosion is a serious problem in the very gently to gently sloping uplands while rill erosion is observed in some areas. Neglect of rills has led to the development of gullies, mostly seen in the lower part of the uplands. Soil erosion that has taken place due to unscientific cutting and filling of soils is one of the major constraints for crop production in this area. It affects soil management in a significant way and has been used to divide the series into different phases.

Available water capacity : Deep soils all along the streams in the valleys, occupying nearly 20 per of the watershed area show medium available water capacity. Lands with lower available water capacity, in about27 percent of the study area were noticed in uplands and gently sloping lands.

Soil organic carbon status : Only 3 percent of the area had a low organic carbon content. Other areas had high organic matter content mainly due to crop rotation practices followed in the region.

Land suitability evaluation : Crop and soil suitability evaluation was carried out for all the major group of crops like *ragi*, redgram, castor, arecanut, coconut, banana, mango, etc (Naidu *et al*., 2006). A land suitability map for mango is presented in Figure 4.

Soil fertility evaluation : Fertility evaluation was carried out for all the major nutrients and few important micro-nutrients for the surface soil samples. Available nitrogen status is low in the entire study area. Available phosphorus content is high in 37 percent area and medium

in nearly 57 percent area . Available potassium is low in 52 percent of the area and medium, in 41 percent area. Available iron, manganese, copper and zinc are adequately available in all the cultivated fields except for zinc, which is low in few fields in Hebbalapalya and Harthi villages. Boron plays a critical role in cell division and cell differentiation and its deficiency leads to stunted growth in plants and reproductive parts in plants. Surface soils of entire study area are low in boron (Fig 3). Available sulphur was deficient in 38 percent of the study area, while in 20 percent of area, its content is higher than the sufficiency level.

Major constraints in the watershed

1. Considerable area is covered with rock out crops and marginal lands are widespread And degraded due to erosion and over grazing. These lands are not terraced systematically, but they are surrounded by rocks in most places. Overgrazing particularly by sheep and goats in these areas prevents natural regeneration of vegetation, thus exposing the soils to further degradation. In the long run, this becomes the cause for poor performance of these animals, which in turn adversely affectsthe income of farmers. Regeneration of forestry and horticultural crops becomes very difficult unless stall feeding is adopted for these animals.
2. Area receives on average rainfall of about 996 mm. Hence, in most of the areas one rainfed crop mixed with two or more crops are raised. During the years of deficit rainfall farmers, experience economic stress unless they have diversified enterprises to tide over the situations.
3. Ground water level has gone down below 200 meters and efforts for rain water harvesting and ground water recharging are not at all noticed. Awareness about this problem is also insignificant.
4. Farmers express that “water is the main limiting factor” in achieving higher productivity/diversification of enterprises. They tell that if water supply arrangements are made, they can create another green revolution”. However, there is complete lack of awareness about the economic use of water as well as harvesting of rainwater. Digging of deep borewells is very rampant (although a large number of bore wells have failed) & awareness on adoption of water efficient irrigation technologies and tools like micro-irrigation have not yet been adopted in the study area.

Available Boron

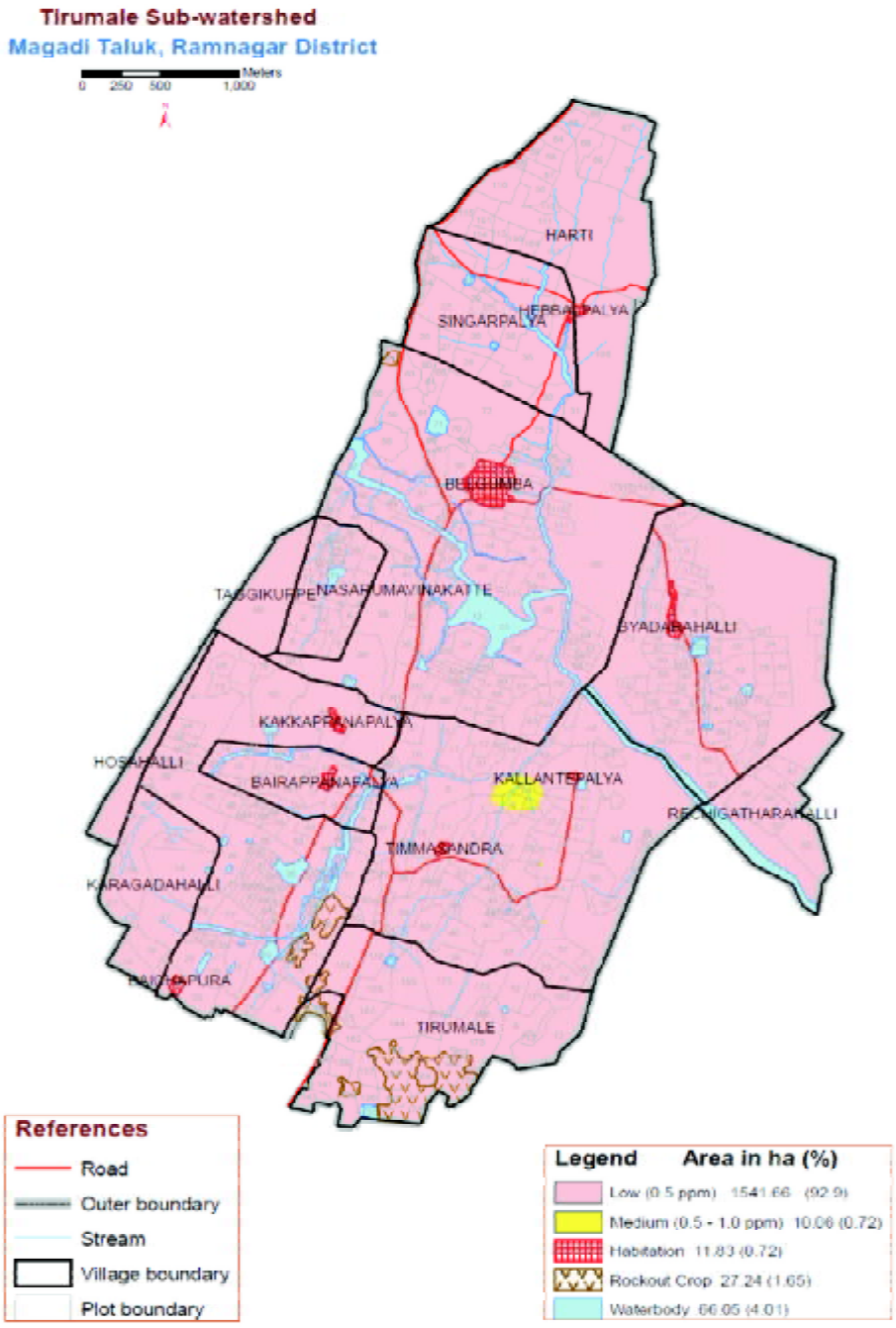

Fig. 3 : Available boron status in the watershed

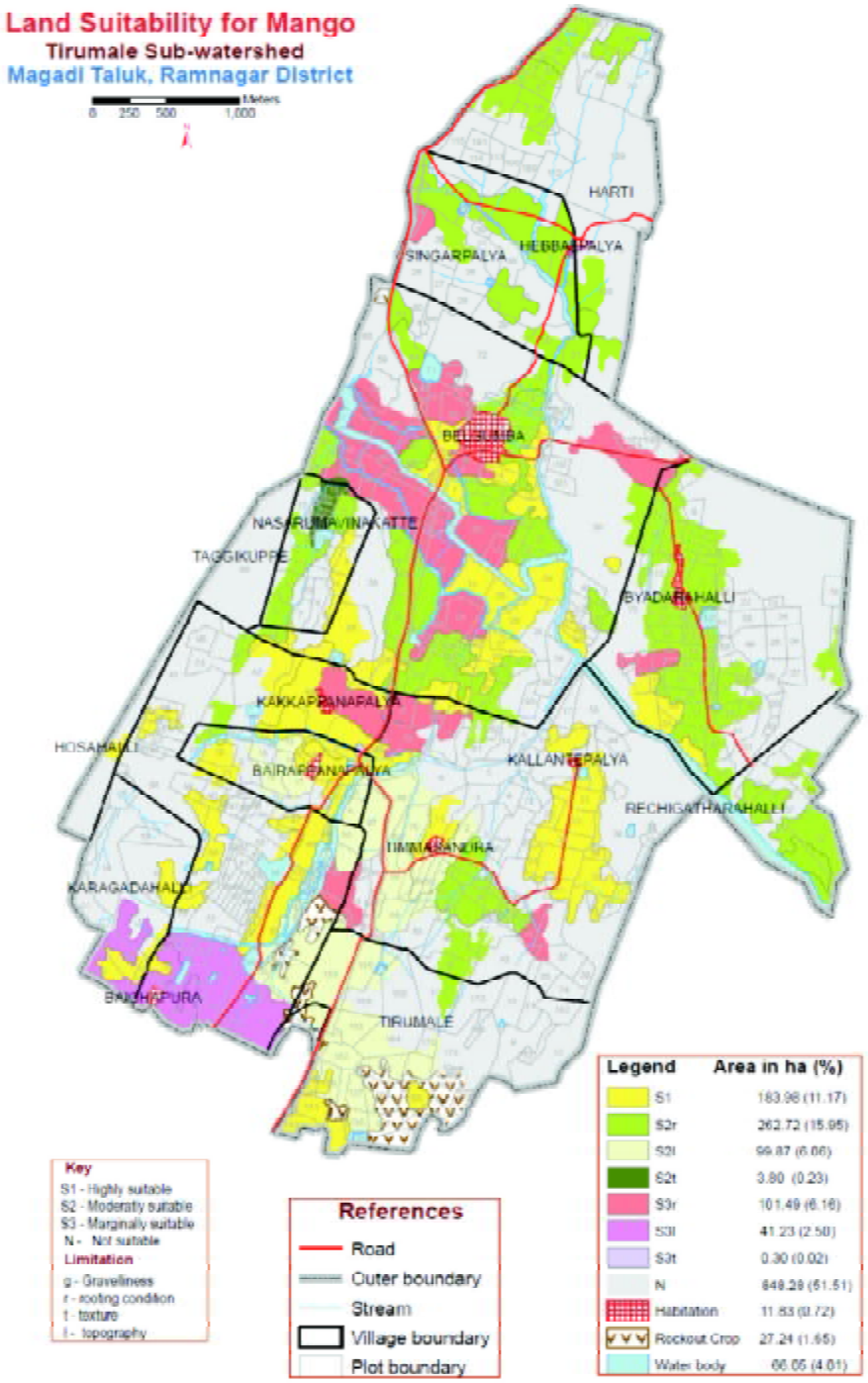

Fig. 4 : Soil-site suitability for mango in the watershed.

5. While terracing the cultivated areas, large quantity of top soils are lost and in some areas weathered parent materials are exposed.
6. Labour scarcity has become a serious limiting factor in adopting essential package of practices in the region. Due to shortage of labour, farmers are employing heavy machinery like JCB for opening the pits to plant perennial, deep rooted crops like arecanut and banana etc., which exposes the weathered parent material. Thus, young saplings suffer during initial growth period leading to overall poor performance of the crops.
7. Green energy technologies like "bio-gas" is totally missing, although the cattle population is high in all the villages.

Potentials and opportunities observed in the area

1. Most of the cultivated fields are already terraced. There is only a need for strengthening the weak and damaged structures to minimize soil erosion.
2. Rainfed cropping systems consisting of *ragi*, pigeon pea castor, field bean are very ideal for maintaining soil health and utilizing soil resources from different depths of soil profile.
3. In most areas top soil layer consists of lighter texture (sandy loam and sandy clay loam) which allows easy infiltration of water into the soil profile. The sub-surface layers are of heavy texture which store /hold good quantity of soil moisture thus allowing good performance of rainfed crops.
4. Deep soils occur even below rocky surfaces in certain places allowing the good performance of tree crops like mango, jack fruits etc.
5. The soils of watershed are free from soil alkalinity, acidity, drainage or erosion problems. Hence, there is absolutely no need for costly ameliorative measures.
6. Large number of termite hills and failed borewells noticed in the region, and above average rainfall during 5 out of 10 years can be utilized for rain water harvesting and ground water recharging.
7. There is a good potential for the cultivation of high value fruit and vegetable crops, owing to the suitability of climate and closeness to Bangalore. Protective cultivation is another good option to make best use of the resources and the market.

8. Goat and sheep rearing is a most common enterprise and provides a good source of income. However stall feeding needs to be promoted to prevent the degradation soil and vegetation in village common lands.
9. Higher generation and consumption of energy is most essential for the economic progress. There is good scope for generation of low cost green energy "bio-gas" in these villages. Studies have conclusively proved that "bio-gas slurry" is can be used as a good quality manure for enhancing soil fertility.
10. Consistent efforts of the watershed team have finally created an interest among the farmers to go for proper soil testing, which is a positive sign.

Conclusions

The study conclusively proves that detailed land resources database is most useful and essential in preparing a comprehensive development plan for any watershed. This can be effectively used for implementing the site specific land based development plan based on a scientific foundation. Such a database provides the basis for monitoring, reviewing and post project evaluation. The programs can be modified in the future as per the requirement of the site for which readymade database is available. Thus, the resources can be conserved and improved, while public funds can be most effectively utilized during the project implementation.

References

Karnataka State Remote Sensing Applications Centre, 2005. *Watershed Atlas of Karnataka*. Report. KSRSAC, Bangalore-34. pp.137

Natarajan A and Dipak Sarkar, 2009. *Field guide for soil survey*. NBSS&LUP(ICAR), Nagpur-10.pp.73.

Naidu L G K, Ramamurthy V., Challa, O., Rajendra Hegde and Krishnan , P. 2006. *Manual of soil-site suitability criteria for major crops*. NBSS&LUP Publ. 129.pp.118.

Soil Survey Division Staff, 2000. *Soil Survey Manual*. United States Department of Agriculture Hand book No. 18. pp.437.

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