University of Agricultural Sciences, Bangalore

Reference Material
on
Application of Scientific Data generated under REWARD Program for Planning and Implementation of Department of Agriculture Programs

September, 2024

Special Officer

WATERSHED MANAGEMENT
UAS BANGALORE

Promote science based approach in watershed management

Contents

Session plan:

#	Topic	Time (hrs)	Method	Resources required	Resource person
10.09.2024 (Tuesday)					
1	Registration and pre-test	09.00 10.30	Online	Participants' mobile phone	CoE team
2	An overview of REWARD program	10.30 11.30	Discussion	PPT on the topic Reference material	Prakash, N B Nagaraja, N
3	Land resource inventory (LRI) – Process and outputs for planning DoA activities	11.30 13.00	Discussion Exercise	PPT on the topic Reference material	Rajendra Hegde Dasog, G S
4	Hydrology assessments – Process and outputs for planning DoA activities	14.00 15.30	Discussion Exercise	PPT on the topic Reference material	Satish Kumar, U Premanand, B D Lakshminarayana, S V
5	LRI portal for accessing information for planning DoA activities	15.30 17.00	Discussion Exercise	Net connectivity Interactive board	Sagar, R Virupaksha, H S
11.09.2024 (Wednesday)					
6	Designing size of farm ponds based on runoff estimation	09.30 11.00	Discussion Exercise	PPT on the topic Reference material	Satish Kumar, U Premanand, B D Lakshminarayana, S V
7	LRI based crops selection and nutrient management	11.00 12.30	Discussion Exercise	PPT on the topic Reference material	Ramamurthy, V Thimmegowda, M N Sagar, R
8	Application of LRI data for planning and implementation of DoA programs	12.30 13.30	Discussion Exercise	PPT on the topic Reference material	Nagaraja, N Dasog, G S
9	Convergence of programs of DoA with REWARD program	14.30 16.00	Discussion Exercise	PPT on the topic Reference material	Nagaraja, N Dasog, G S
10	Training feedback and evaluation	16.00 17.00	Online	Participants' mobile phone	CoE team

CoE-WM Staff:

CoE-WM Research team: Drs: Divyashree, K. S., Lakshminarayana, S. V., Lingaraj Huggi, Premalatha, K., Pruthviraj, N., Rochana S. Roshan, Sagar, R., Soundarya, H. L., Virupaksha, H. S.

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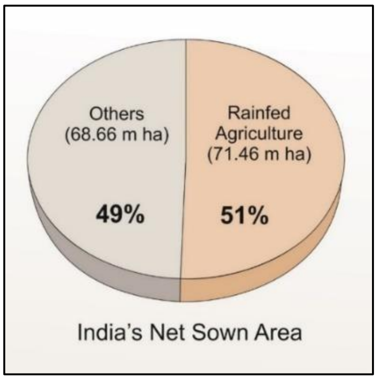
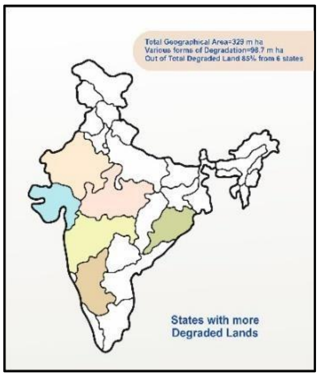
Dr. Thimmegowda, M. N., Professor & Head, Agrometeorology, GKVK, Bangalore

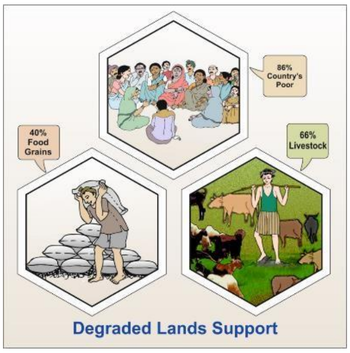
1. An Overview of REWARD program

A. Watershed development and its importance

1. India ranks first globally in area and value of production from rainfed agriculture. It occupies about 51 per cent of country's net sown area of 140.13m ha. Out of the total geographic area of 329 m. ha, more than 30 per cent is affected by various forms of land degradation and out of this, rainfed areas account for more than 85 per cent of degraded lands in the country, mostly occurring in Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha and Rajasthan.

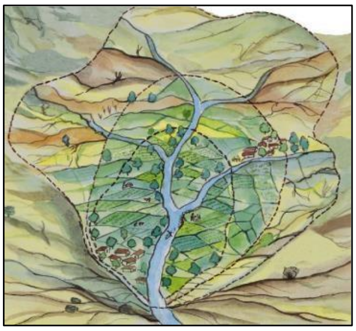




2. 

The degraded land is the home to 86% of the country's poor, produce 40% of the food grains, and support 66% of the livestock population. Among the various forms of degradation, soil erosion is the major cause for the declining factor of productivity followed by salinity and alkalinity. The situation is getting aggravated year after year and as per the estimate, the area critically affected by soil erosion alone has doubled in 30 years from 1977 to 2007 in the country. The solution is integrated watershed management development.

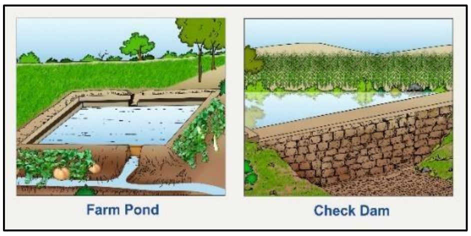
3. A watershed, is as an area in which all water flowing into it goes to a common outlet. All lands on earth are part of one watershed or the other. Watershed Development (WSD) is the preservation, renewal, and wise use of all natural resources, particularly those related to the land, the water, the vegetation, and the animals, as well as human development within the watershed.

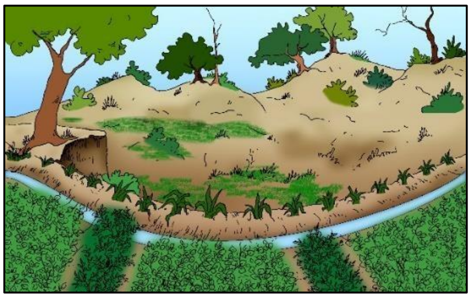


4. 

Watershed Development in India has been a part of the national approach to improve agricultural production and alleviate poverty in rainfed regions since 1970s. Watershed development programs aim to restore degraded watersheds in rainfed regions to increase their capacity to capture and store rainwater, reduce soil erosion, and improve soil nutrient and carbon content so that they can produce greater agricultural yields and other benefits.

5. The objective of watershed development is maximizing the productivity and income per unit area, per unit time and per unit of water thereby improving the socio-economic status of the farmers. The objective of watershed development can be achieved through implementation of a series of systematic approaches, (a) preserving as much water as possible at the place it falls to avoid gully formation and putting checks at suitable intervals to control soil erosion, (b) harvesting and storing excess runoff by draining out excess water with a safe velocity and diverting it to farm ponds, check dams and nala bunds, (c) promotion of alternate land use system to improve vegetation by intensifying horticulture, agro forestry, silvi-pasture etc., (d) improving crop production systems by effective crop and nutrient management, increased cropping intensity, and land equivalent ratio through intercropping and sequence cropping and (e) development of livelihood support systems by promoting appropriate bio mass based income generating activities for the vulnerable sections of the community.





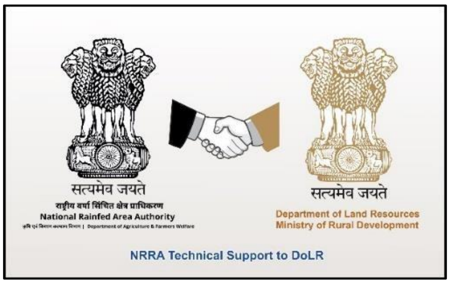
Alternate Land Use System

Increased Cropping Intensity

Bio-mass Based Income Generating Activities

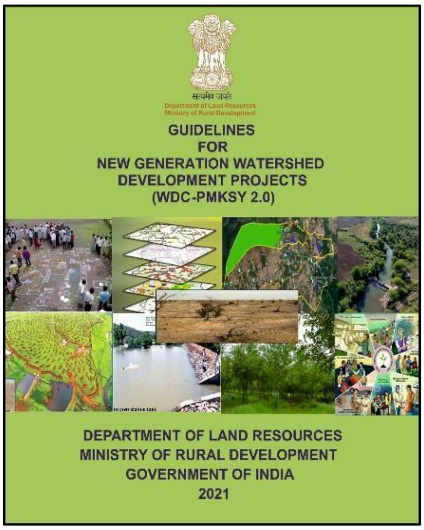
6.

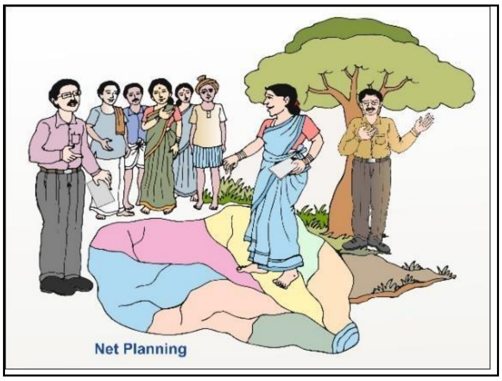
In 1970's Soil and water conservation was taken up with a focus on engineering structures mainly for protecting dams. In 1983, the Operation Research Projects (ORPs) were established in 47 watersheds spread over 16 states covering an area of 35739 ha under the technical guidance of Indian Council of Agricultural Research. The ORPs aimed at arresting the deterioration of environment and building up permanent assets in the form of water, sustainable vegetation and improved productivity of cropped land. During 1990's emphasis was given on participatory watershed development where the community was involved in planning, implementation and management.



In 2006 National Rainfed Area Authority (NRAA) by the Planning Commission was established to provide technical support to Department of Land Resources (DoLR), GoI, and issued common guidelines for all watershed development programmes for the development of rainfed farming in India.

7. The Guidelines for new Generation Watershed Development Projects (WDC-PMKSY 2.0) issued by DoLR in 2021, emphasizes shifts in approaches from mechanical to agricultural engineering structures, effective use of rain water by relying more on water productivity, crop systems diversification for risk management, promotion of water use efficient crops, integrated farming systems for adaptation and mitigation of adverse impacts of climate variability, establishing FPOs to promote agri-business and nurturing of community groups. The DoLR Guidelines issued during 2021, under WDC-PMKSY 2.0, also emphasizes the use of GIS and RS technologies for scientific planning and monitoring the performance of watershed development projects.



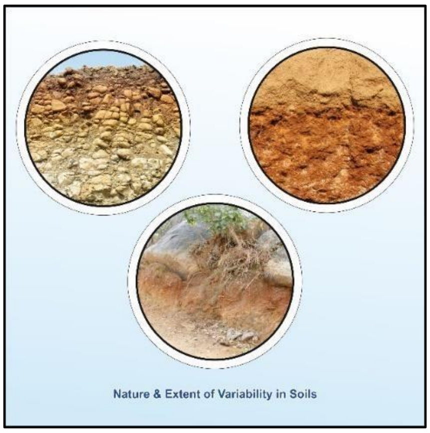
8. 

Net Planning

The common approach followed in watershed planning in earlier watershed development programmes was, net-planning which is an eyesight-based planning for each survey number. The designs of drainage line structure were standardized ones and do not take into account the run-off available at the site. Indiscriminately, water harvesting structures were built.

B. Emergence of Sujala-3 project

9. It is a recognized fact that the factors and processes affecting degradation, productivity and sustainability are very site and location specific. For any meaningful intervention needed for the restoration and management of degradation, necessitates site-specific land resource information which is not available at present for major part of the country. As the land resources are not uniform, generation of location speci fic information pertaining to the nature and extent of variability in soil, water availability, topography and land use is a prerequisite for successful planning and implementation of development programs by agriculture, horticulture, watershed, forestry, irrigation, and other programs in any area. Non availability or lack of such site-specific land resource information is responsible for the failure of many development programmes implemented in the past by Development Departments in the Country.

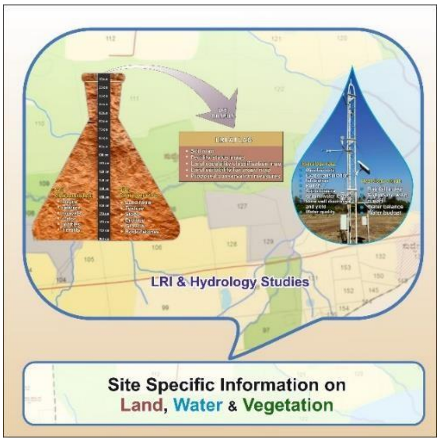


Nature & Extent of Variability in Soils

10. Realizing the importance of site-specific soil and other information for taking up targeted interventions, the World Bank supported Karnataka watershed Development Project-KWDP II, popularly known as Sujala-3 project, implemented from 2013 to 2019 in about 14 lakh ha spread over in 11 Districts of Karnataka. Sujala-3 has clearly demonstrated the importance of cadastral level database, thematic maps and digital tools in planning, implementation, and monitoring of various interventions at the field level. This approach has significantly reduced the watershed develop ment cycle to four years. The advanced approaches in Sujala-3 have helped to take up site-specific soil and water conservation interventions, selection of crops as per their suitability, nutrient management as per the fertility status and crop requirement, construction of water harvesting structures as per the available excess runoff from the area, allocation of water to different sectors as per the balance and water budgeting as per the present and future demands.

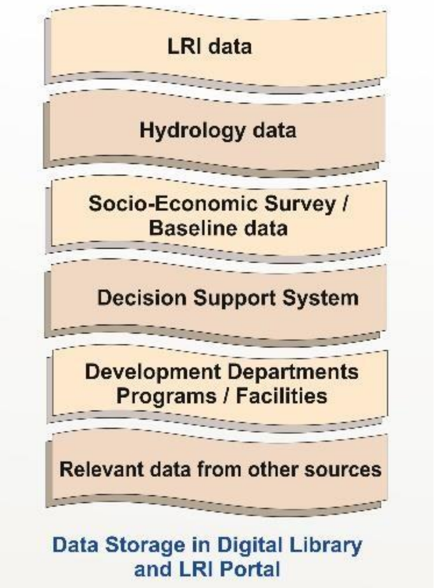
Sujala-3 Watershed Districts

11. The uniqueness Sujala-3 project was adoption of more advanced scientific approaches for capturing the data on status of land, water, and other resources at cadastral level through land resource inventory (LRI) and hydrological assessments for preparation of scientific Detailed Project Reports (DPR) for watershed development. Sujala-3 has clearly demonstrated the importance of cadastral level database, thematic maps and digital tools in planning, implementation, and monitoring of various interventions at the field level. This approach has significantly reduced the watershed development cycle to four years.

12. 

The advanced approaches in Sujala-3 have helped to take up site-specific soil and water conservation interventions, selection of crops as per their suitability, nutrient management as per the fertility status and crop requirement, construction of water harvesting structures as per the available excess runoff from the area, allocation of water to different sectors as per the balance and water budgeting as per the present and future demands.

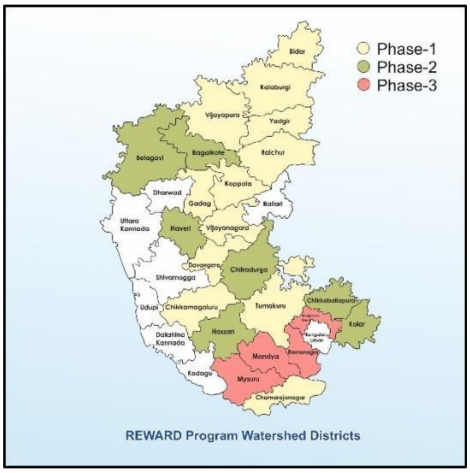
13. To carryout LRI and hydrological studies under Sujala-3 project, 15 scientific consortium partners were involved. Development of Decision Support System (DSS), to improve watershed planning, by integrating the data base generated with decision criteria, models and algorithms is one of the noteworthy outcomes of the project. A web-based portal was created for easy access to data sets for multiple purposes in targeted watersheds



C. Emergence of REWARD program

14. Appreciating the impact of Sujala-3, the Government of Karnataka has extended it to cover the whole rainfed area of the state with Land resource inventory (LRI) technology. Appreciating the impact of LRI and hydrological assessments in scientific planning for watershed development under Sujala-3 project, the Government of Karnataka, is extending it to cover the whole rainfed area of the State under the REWARD program, with the support from the World Bank from 2022.

15. The REWARD program's Development Objective is to strengthen capacities of National and State institutions to adopt improved watershed management for increasing farmers' resilience and support value chains in selected watersheds of participating States. The REWARD program in Karnataka, covers 21 Districts with a budget of Rs 600 crores. The duration of the program is for five years.



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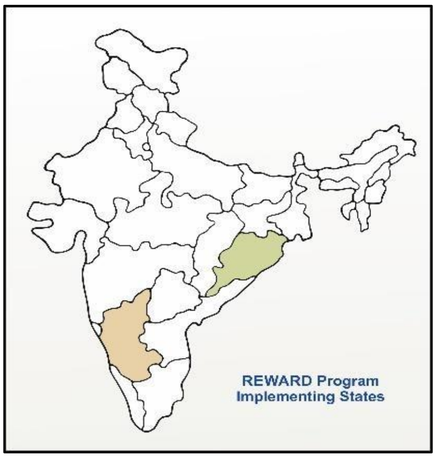
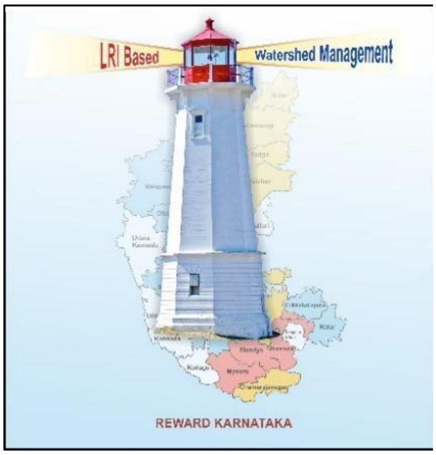
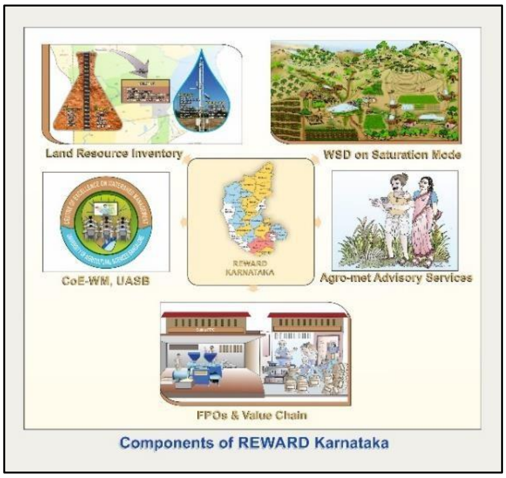




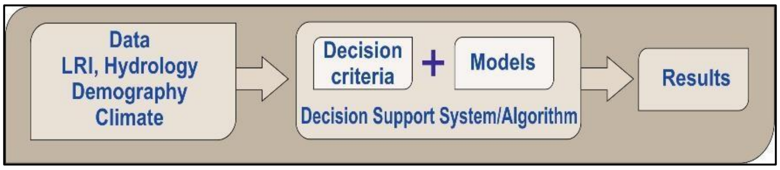
The REWARD-Rejuvenating Watersheds for Agricultural Resilience through Innovative Development program, will create a path for adoption of LRI (including hydrology) based scientific watershed management by all the States through WDC –PMKSY. Karnataka is identified as a light house partner to provide technical guidance for other States. The Odisha State has already started implementing REWARD program from 2022 with the support from the World Bank. To achieve agricultural resilience, the science-based approaches are being adopted in assessing the status of natural resources and improving them through comprehensive approaches in the watershed management program, to improve soil organic carbon, improvement in soil pH, improvement in soil moisture retention and improvement in length of growing period.

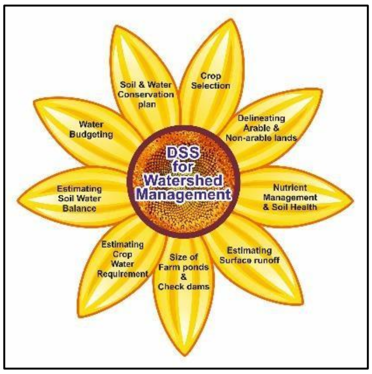
17. The major Components of REWARD program are (a) Land resource inventory (LRI) in 19 lakh ha of rainfed watershed areas spread over in 21 districts, (b) watershed development on Saturation mode covering an area of one lakh ha in 20 sub watersheds based on LRI & Hydrology recommendations, (c) FPO and Value chain development through 25 FPOs, (d) providing improved agro-met advisory services to farmers, (e) anchoring Centre of Excellence on Science based Watershed Management at UAS Bangalore.



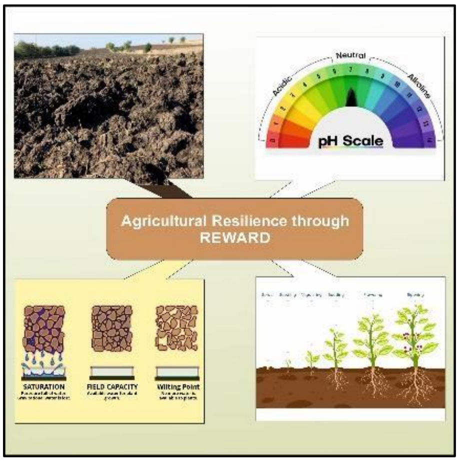
Components of REWARD Karnataka

18. Salient features of REWARD are (a) generation of cadastral level land resource information using RS, GIS and other advanced scientific tools and technologies, (b) development of criteria, models, algorithms and guidelines, (c) understanding hydrological dynamics vis–a-vis hydro-geology & climatic variability and develop tools to measure them (d) developing protocol fo r demystifying the science to community through consultation process and thus reducing watershed development cycle, (e) evidence based monitoring and impact evaluation of the project interventions, (f) consortium approach in achieving objectives - Scientific research institutes associate as project stakeholders, (g) establishing CoE on WM plays a critical role in building capacity of all the States on LRI and operationalization of future generation PMKSY- WDC programs in the country.





19. To achieve agricultural resilience, the science-based approaches are being adopted in assessing the status of natural resources and improving them through comprehensive approaches in the watershed management program, to improve soil organic carbon, improvement in soil pH, improvement in soil moisture retention and improvement in length of growing period.



20. The REWARD program's Development Objective is to strengthen capacities of National and State institutions to adopt improved watershed management for increasing farmers' resilience and support value chains in selected watersheds of participating States.

21. The committees for smooth implementation of the REWARD program
    a. National Level Steering Committee (NLSC): Headed by Secretary, DoLR, Senior Officers from: DoLR, NRAA & relevant national departments and research organizations; and State Watershed Departments of Karnataka and Odisha

       Responsibilities of NLSC: (a) To improve convergence between agriculture, watershed, water resources, rural development and other related ministries and (b) provide high level oversight and guidance for the implementation of the Program

    b. National Level Technical Committee (NLTC): The committee will be constituted by DoLR.

       Responsibilities of NLTC: (a) review and standardize scientific protocols; (b) develop national technical standards; (c) strengthen the national web-based portal; and (d) provide high level support to the National Level Steering Committee

    c. National Program Management Unit: Chaired by the Joint Secretary of DoLR, Program Director supported by an additional Program Director, watershed management expert, hydrologist/water resource expert, institution and capacity building expert, monitoring and evaluation expert, financial management expert, and procurement expert

    d. Karnataka State Level Nodal Agency: Chaired by the Commissioner & Program Director of Karnataka's Watershed Development Department, and include senior officers of the rank of Joint Director, Deputy Directors and consultants, for covering subjects related to soil and water conservation (including land resource inventory), agronomy, horticulture, forestry, animal husbandry, hydrology, social development, capacity building, RS/GIS, value chains (FPOs), procurement, monitoring and evaluation, and others

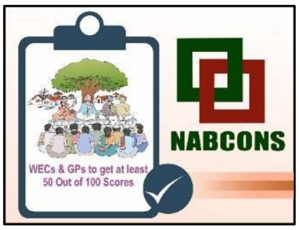
    e. District and Block Level (PIA): Officers of Karnataka's DoA will supervise the implementation of the Program Implementing Agency's Respective Part of the Program at the District and Block levels

f. WCs and GPs: Program Implementing Agency shall support WC and GPs to actively participate in the implementation of Program, including operation and maintenance, reporting.

22. The REWARD program in Karnataka, covers 21 Districts with a budget outlay of Rs 600 Crores. Out of the total budget, the World Bank share is 70% and GoKs share is 30%. The duration of the program is for five years. The major Components of REWARD program are (a) Land resource inventory (LRI) in 19 lakh ha of rainfed watershed areas spread over in 21 districts, (b) watershed development on Saturation mode covering an area of one lakh ha in 20 sub watersheds based on LRI & Hydrology recommendations, (c) FPO and Value chain development through 25 FPOs, (d) providing improved agro-met advisory services to farmers, (e) anchoring Centre of Excellence on Science based Watershed Management at UAS Bangalore.

23. The World Bank financing for the REWARD program is “P for R” (Program for Results) mode and disbursement of funds by the World Bank is based on achievements of the results (a) strengthened institutions and supportive policy for watershed development and (b) scientific watershed development and enhanced livelihoods. A set of Disbursement Linked Indicators (DLI) are identified for the components of REWARD program. The NABCONS (NABARD Consultancy Services) has been entrusted for verification of the indicators at different phases of the project cycle.

24. Disbursement of funds based on achievements of the results. For this purpose, Disbursement Linked Indicators are set for important components. The NABCONS (NABARD Consultancy Services) has been entrusted for verification of the indicators.



According to the first indicator, the WCs & GPs demonstrate satisfactory watershed management as measured through a performance rating system-30% WCs and GPs get more than 50% score on the indicators at three stages of project cycle- preparatory, works and operation and maintenance.

According to the second indicator, the land area in 200 MWS should be treated as per the scientific recommendations (LRI and Hydrology). It is also called watershed development on saturation mode.

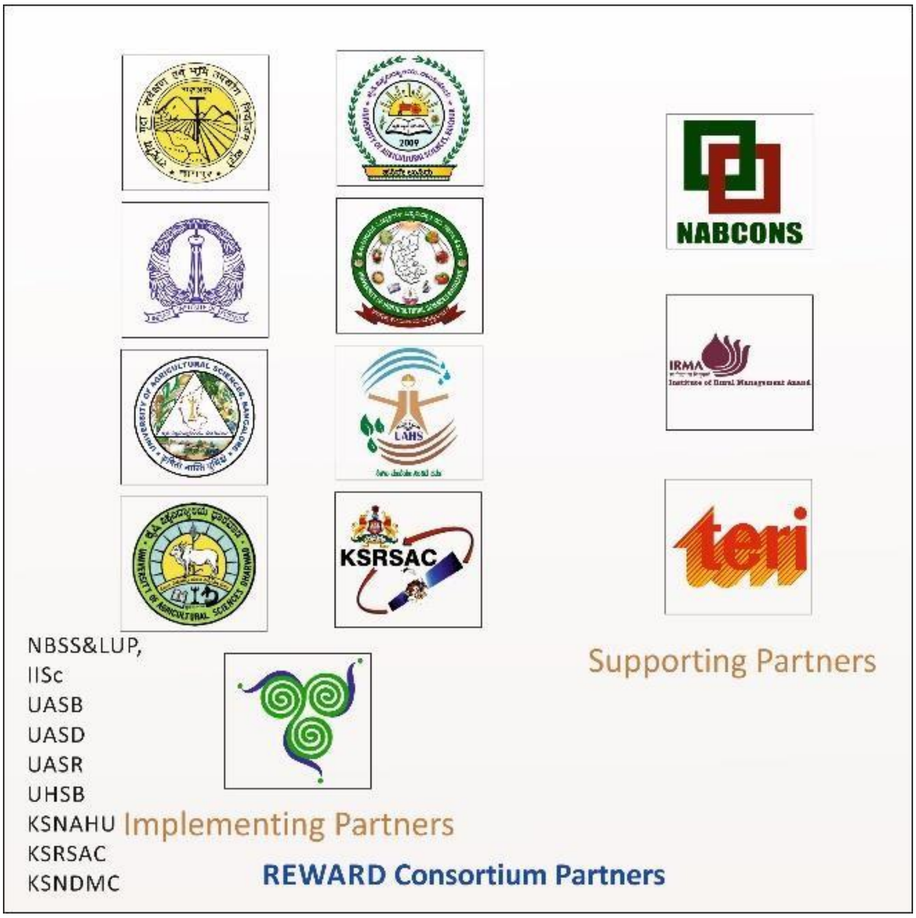
According to the third indicator, 27000 farmers to adopt and practice resilient agriculture technologies.

According to fourth indicator, there should be 25 per cent increase in business turnover relative to baseline among existing FPOs and additional 15 FPOs should be started.

According to fifth indicator, certified training to 1125 professionals on improved watershed management by the Centre on Excellence on Watershed Management.

25. The REWARD program is distinctly different from other watershed development programs initiated in the country. Its distinctness is attributed to seven in built salient features of the program namely, (a) generation of cadastral level land resource information using RS, GIS and other advanced scientific tools and technologies, (b) development of criteria, models, algorithms and guidelines, (c) understanding hydrological dynamics vis–a-vis hydro-geology & climatic variability and develop tools to measure them (d) developing protocol for demystifying the science to community through consultation process and thus reducing watershed development cycle, (e) evidence based monitoring and impact evaluation of the project interventions, (f) consortium approach in achieving objectives - Scientific research institutes associate as project stakeholders, (g) establishing CoE on WM plays a critical role in building capacity of all the States on LRI and operationalization of future generation PMKSY-WDC programs in the country.

26. The REWARD program creates an opportunity for establishment of a consortium of scientific partners'/user agencies with defined roles & responsibilities, which will form a template to take forward science-based watershed development approach. Two types of consortium partners are involved namely implementing partners and supporting partners. Implementing Partners include (a) National Bureau of Soil Survey & Land Use Planning (ICAR-NBSS&LUP)-lead institute for LRI, (b) Indian Institute of Science (IISc), Bengaluru- lead institute for hydrology, (c) Five State Agricultural Universities (UAS-B/D/R/UHS-B/ KSNA&HU-S)- for LRI and hydrology, (d) Karnataka State Remote Sensing and Application Centre (KSRSAC)-providing m aps and satellite imageries, (e) Karnataka State Natural Disaster Monitoring Centre (KSNDMC)- for metrological data.



The Supporting partner institutes under REWARD program are (a) NABARD Consultancy Services (NABCONS)- as an Independent Verification Agency (IVA) for verifying disbursement linked indicators (DLI) achievement and reporting to the World Bank, (b) Centre of Excellence for Watershed Management, UAS Bangalore for upscaling LRI, (c) Institute of Rural Management, Anand (IRMA) as a consulting Research Agency (CRA) for impact evaluation, and (d) The Energy and Resources Institute (TERI) as a Process Monitoring Agency (PMA) for process monitoring.

2. Land Resources Inventory - Meaning and Importance

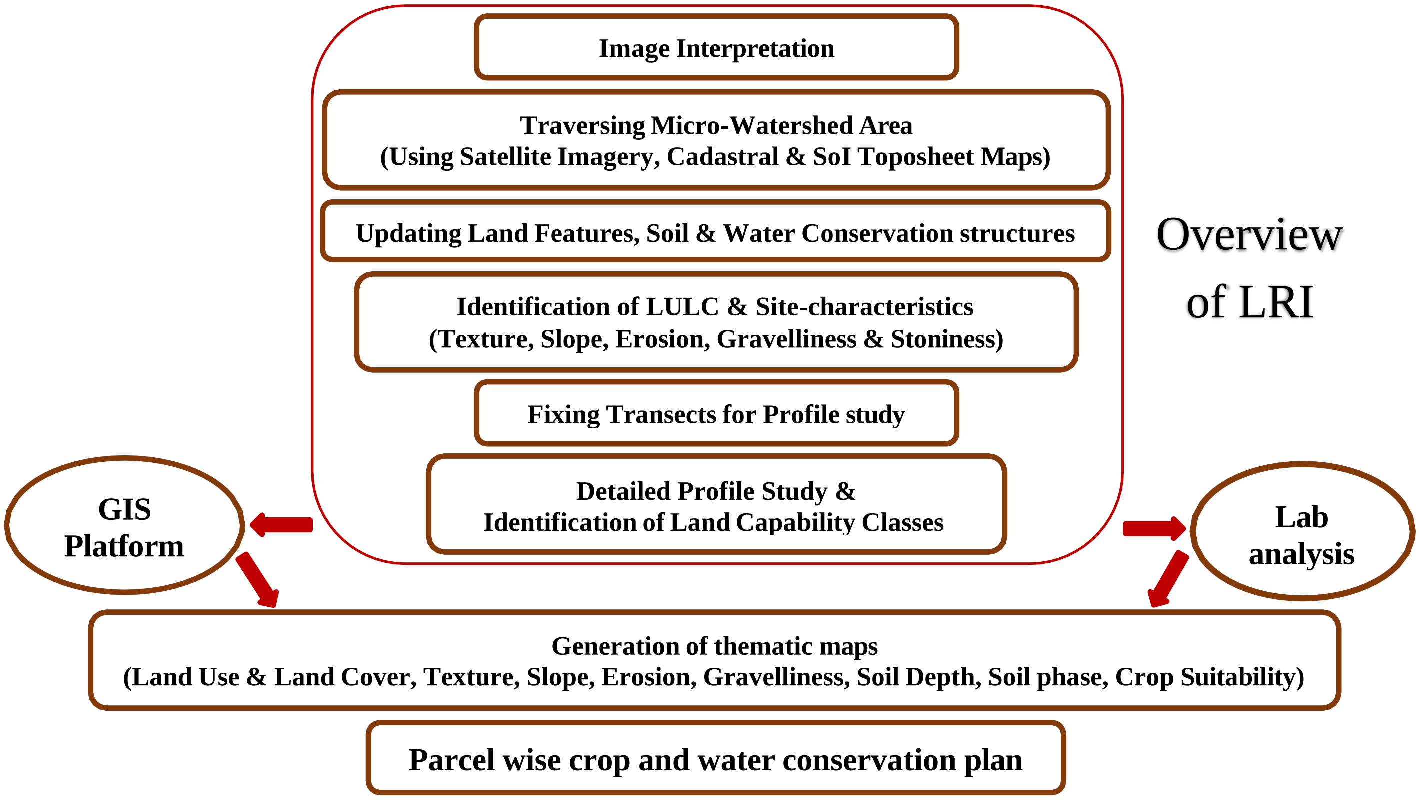
The Land Resource Inventory (LRI) is an assessment of the status and changing condition of soil, water and related resources at the field level. The LRI database is generated on a geo-referenced cadastral map, superimposed on satellite imagery. The land parcels are grouped into management units based on similarity in soil and site characteristics.

Significance of LRI

- Identification of land resources
- Provides scientific database for adopting suitable soil and water conservation measures
- Helps in developing site specific agricultural technologies
- Helps in increasing productivity
- Helps in enhancing farmers income and increasing the socio-economic status of the farmer

Maps inputs needed for LRI

- Village cadastral maps at a particular scale
- Satellite imagery like Cartosat/Quick Bird images at a convenient scale
- Seamless image for micro watersheds and sub watersheds
- Overlay of seamless cadastral maps on micro watershed, sub watersheds
- Survey of India Topographical sheets of 1: 50,000 or larger if available
- Geology map of the Taluk/District sheets on 1:50,000 scale or larger
- Overlay of 1:50,000 scale geology map on 1: 50,000 scale imagery
- Geomorphology map, wherever available
- Land use/Land cover map
- Drainage and water bodies map

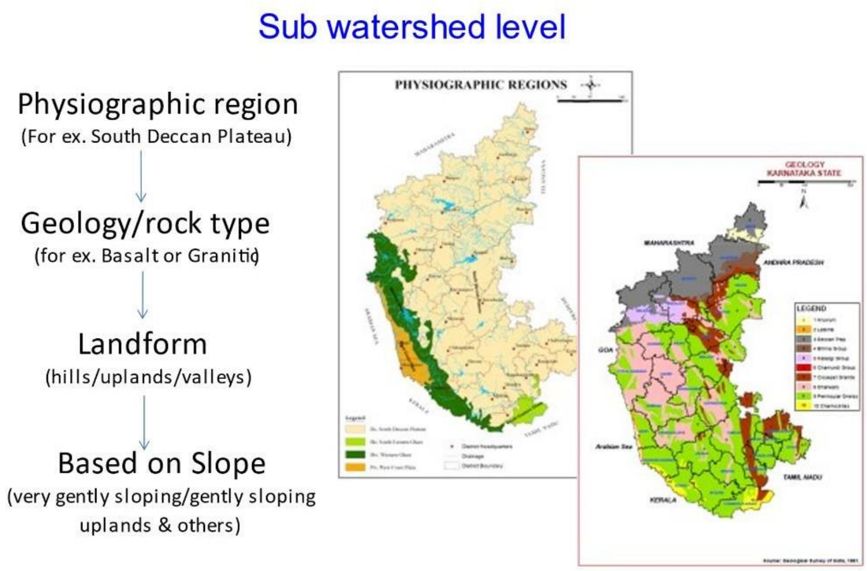


LRI approach - data generation process

Pre-field activities: Image interpretation for various physiographic units and identification of transect for profile studies

This is the most important pre-field activity, carried out to identify and delineate different physiographic regions, rock types, landscapes, landforms and their subdivisions at different levels-from district, taluk, watershed and village before the start of the field work in the survey area. At the time of interpretation itself transects representing the variations observed on the imagery to be selected and marked on the base map.

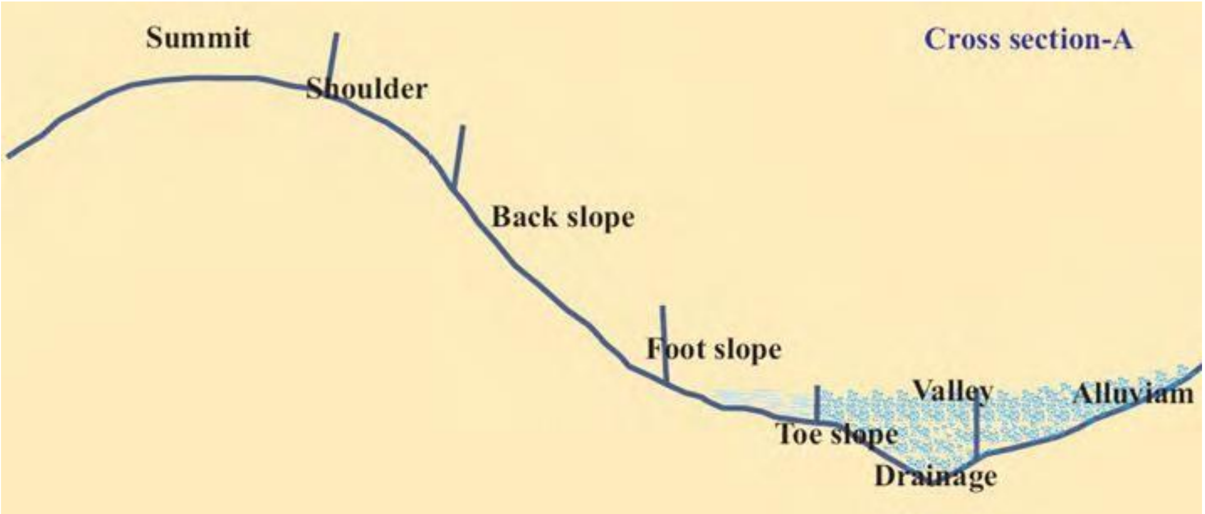
Interpretation at Sub watershed level:
At SWS level, interpretation is done to identify major physiographic regions/units, geology or rock types, different landforms occurring within the geological formations and landform units based on land use, slope, image characteristics and other converging evidence.



Then within the physiographic region/unit, any variation in geology/rock formations is identified and separated on the imagery and within each geological area landforms like hills, mounds and ridges, inselbergs, uplands, valleys, lowlands, *etc*. are delineated based on contour intervals as observed from the contour map/toposheet and image characteristics. This will result in the generation of physiography-landform map with the legend at the SWS level. During the interpretation itself few transects representing major landforms selected and marked on the imagery.

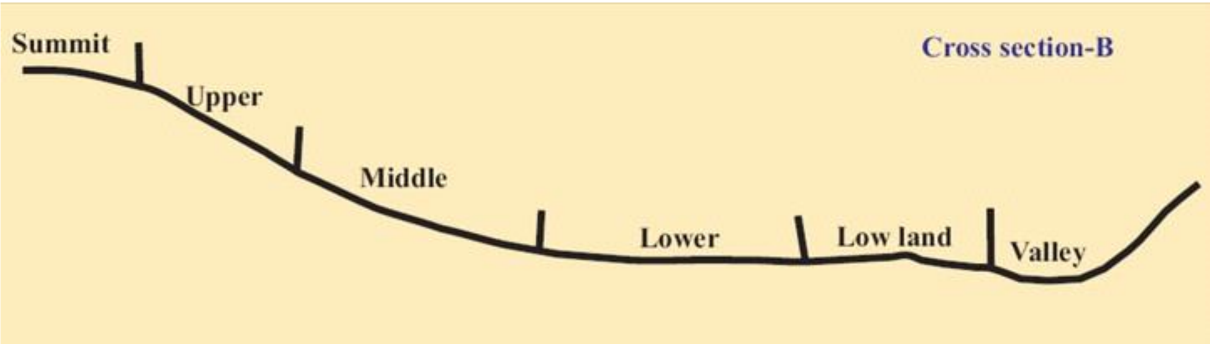
Interpretation at MWS level:
At MWS level, the landform units identified at SWS level is further subdivided based on change in slope, land use and other surface features as evidenced through the image characteristics and other converging evidence of the area.

For example, the hills identified at sub-watershed level and not subdivided due to the scale limitation can be further subdivided into summits, escarpments, side slopes (upper, middle, and lower side slopes) and foot slopes at the MWS level based on their extent and slope. Similarly, the uplands can be subdivided into rolling, undulating, gently sloping, very gently sloping and nearly level lands based on their extent and slope at the MWS level.



Different slope elements as seen in hills landform in a micro watershed

In the next level, the landform units can be further subdivided based on variations like erosion, presence of gravel/stones/boulders, rock outcrops, drainage, salinity *etc*., as evidenced further through the image characteristics and other converging evidence of the area.



Different slope elements as seen in uplands landform in a micro watershed

For example, within the undulating or gently sloping area of the upland if there are any variations observed in the tonal characteristics of the imagery and such variations are mappable, then such areas are to be delineated on the imagery. The variations at this level could be due to the severity of erosion in some areas of the unit or the presence of gravel or stones *etc*. Many times, the reasons for these variations could not be ascertained clearly on the imagery at this level and in such situations, the delineated unit can be checked in the field later and corrected accordingly.

In lowland areas, slope will not be a critical factor, instead soil texture, colour, drainage, flooding, salinity and sodicity *etc*., will be critical for management. If there is any significant change in one of these properties as seen on the imagery, then it needs to be identified and delineated based on the tonal characteristics.

Image Interpretation Legend for Physiography

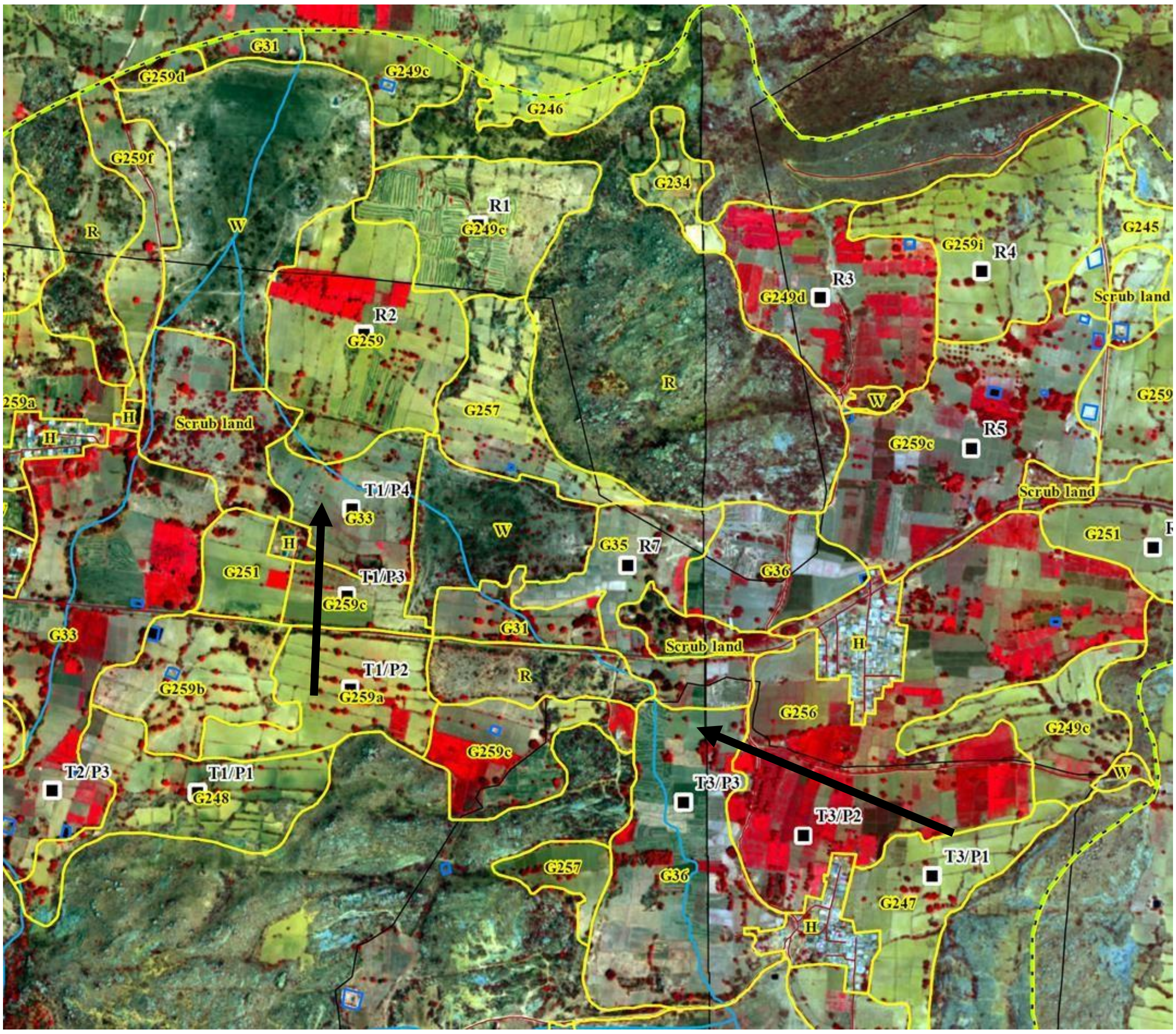
- **D Deccan Plateau**
- **DS South Deccan Plateau**
- **G Granite and Granite Gneiss Landscape**
  - **G1 Hills/Ridges/ Mounds**
    - G11 Summits
    - G12 Hill/Side Slopes
      - G121 Side slopes with dark grey tones
    - G13 Isolated hillocks
  - **G2 Uplands**
    - G21 Summits/ Nearly Level Lands
    - G22 Very gently sloping uplands
      - G22l Very gently sloping uplands, yellowish green
      - G222 Very gently sloping uplands, medium green and pink
      - G223 Very gently sloping uplands, pink and green (scrub land)
      - G224 Very gently sloping uplands, medium greenish grey
      - G225 Very gently sloping uplands, yellowish white (eroded)
      - G236 Very gently sloping uplands, dark green
      - G237 Very gently sloping uplands, medium pink (coconut garden)
    - G23 Gently sloping uplands
      - G231 Gently sloping uplands, yellowish green (eroded)
      - G232 Gently sloping uplands, yellowish white (severely eroded)
    - G24 Undulating uplands
  - **G3 Valleys**
    - G31 Interhill Valley
    - G32 Valley /Lowlands
- **A Alluvial landscape**
  - A1 Nearly level Uplands
  - A2 Very gently sloping lands

Identification of transect for profile studies:

After the interpretation of maps for physiographic units, transects can be fixed tentatively based on variations observed in the map. Transects can be marked on different landform units falling adjacent and along the slope.

Criteria for transect identification:

- ✓ Should represent large area and lengthy slope
- ✓ Should be along the slope
- ✓ Preferably in odd numbers
- ✓ Should not cross river, drainages and water bodies
- ✓ Each profile point in a transect should represent different landform units



Transects and randoms marked for profile study

Field activities: Traversing and validation of interpreted map

a) At Sub watershed level:

The physiography-landform map is to be checked for the accuracy of the delineation and their description in the field by taking up rapid traverse of the sub watershed area and corrected wherever necessary. During the traverse available road/well cuts, excavations, and profiles in few transects are examined, and variations observed in soil-site characteristics recorded. Based on the information collected a tentative map with legend of the SWS is prepared along with identifying characteristics for the major soils observed. This preliminary legend forms the basis for detailed field investigations at MWS level.

Differentiating Characteristics for identifying Soils at SWS level

Sl. No.	Soil Series	Depth (cm)	Colour	Texture	Gravel (%)	Horizon	Others
Soils of Granite gneiss Landscape							
1	Devihal (Dvh)	<25	2.5YR2.5/4 5YR3/4 ,4/6	cl	<15	Ap-Cr	
2	Harve (Hrv)	25-50	2.5YR3/6 5YR4/4	cl	>35	Ap-Bt-Cr	

b) At Micro watershed level:

The delineated units are checked and corrected and extent of habitations, permanent features, rock outcrops, gullies and ravines, quarried areas, fishponds, check dams *etc*., are marked on the map which eliminates areas that are not to be surveyed.

Study of site characteristics (phases):

During the traverse any variations observed in slope, erosion, texture, presence of stones, boulders, rock outcrops, drainage, salinity *etc*., are recorded on the map (preferably cadastral map) and in the proforma (if required). Then profiles are opened in the selected transects and their morphological and physical characteristics will be recorded.

Based on field observations and profile study, the initial legend prepared earlier at the SWS level is updated at the MWS level. After finalizing the soil series and updating the map legend, the soils series identified can be linked to the delineations along with site characteristics recorded earlier. This process results in the conversion of the interpreted map into a soil map for the MWS area. The delineated mapping units are shown on the map in the form of symbols.

For example, in the map unit **GHTcB2**

GHT - indicates the name of the soil series
c - indicates the texture of the surface soil
B - indicates the slope of the land
2 - indicates the degree of erosion

Any other feature observed in the field (like salinity, gravel *etc*.) can be shown by using appropriate symbols on the map. It is not possible to depict all the variations observed in the field on the map itself. The legend accompanying the map provides detailed description of the properties (like depth, texture, gravel, slope, salinity *etc*.) and their variations for each mapping unit.

Codification of soil samples (in master profiles):
Soil samples are collected from a representative pedon for each series for laboratory analysis. For labelling, the codification given below may be followed

For example - **Gg-Sht-Rtr-T1-P1 -P1/1, P1/2, P1/3, P1/n**

Gg - indicates the name of the district, Gadag

Sht - indicates the name of the taluk, Shirahatti

Rtr - indicates the name of the village, Ranatur

T1 - Transect No.1 in Ranatur village

P1 - profile No.1 in transect No.1 in Ranatur village

P1/1 (0-11 cm) - soil sample No.1 from Profile No.1

P1/2 (11-33 cm) - soil sample No. 2 from profile No.1

or

R1 Random profile No.1 from Ranatur village

R1/1 (0-18 cm) - soil sample No.1 from Random profile No. R1

R1/2 (18-42 cm) - soil sample No. 2 from Random profile No. R1

Grid soil sampling:
Composite soil samples are to be collected from grids drawn on the cadastral map at every 320 m interval (10.24 ha) for rainfed/dry land areas and 160 m interval (2.56 ha) for irrigated/command areas respectively. On an average, about 50 to70 soil samples are collected for an area of about 500 ha. The codification indicated below may be followed on the sample bag.

For example - **Kp/Gn/Kav/F1**

Kp - indicates the name of the district, Koppal District

Gn - indicates the name of the taluk, Gangavati Taluk

Kav - indicates the name of the village, Kavalur village

F1 - indicates the surface soil sampled at Grid Point No.1

Well Inventory:
The number of wells, both open and bore wells, tube wells with their exact locations to be collected along with water samples in the project area

Socio- economic data:
Socio-economic data on demography, land holdings, land use, cropping pattern, source of irrigation, cattle population *etc*., are to be collected from Census reports, village records and

Directorate of Statistics either during or even prior to the start of the LRI. If the available data is not complete or insufficient, then efforts can be made to collect the required additional data for the area.

Land use particulars (land use and land cover):

During the execution of the LRI, the land cover and land use particulars are to be collected. Apart from this, data on cropping pattern, inputs and level of management followed, yields obtained for different crops and other information pertaining to land use are to be collected wherever possible. For this, first broad land use areas like arable and non-arable lands, forest areas, community, and wastelands *etc*., are identified, and then within each land use area, like arable lands, major crops or combination of crops that are under cultivation are identified and marked for each survey number. Similarly, the tree species, shrubs and other vegetation types observed in non-arable, forest, community and wasteland areas are identified during the survey and land use map prepared for the watershed.

Identification of existing structures:

All the existing soil and water conservation and harvesting structures are to be identified and marked on the map

Profile study

Description of Site characteristics:
Soils are formed by the influence of various soil forming factors like climate, biota, topography, parent material and time. Since these factors are not uniform in any landscape, the soils formed will be different from place to place. To understand their variability and to map the distribution of soils, we need to have not only a detailed study and description of the soils but also the landform or site characteristics of the area. This chapter provides the guidelines needed for describing soil-site characteristics observed in the field. The information to be filled up in the standard formats suggested.

Series name - This box to be filled at the end of the soil profile study by comparing the pedon description with the series identification table provided for the survey area.

Map unit symbol - Indicate two or three letter symbols for the series, followed by the phase symbols

Soil classification - This box to be filled at the end of the soil profile study as per Soil Taxonomy

Observation number - Follow codification as described in previous section Codification of soil samples (in master profiles)

The list of districts with their symbols in the state, name of taluks and their symbols from each district and list of villages and their symbols in each taluk will be provided to the field parties before the start of LRI. This observation number will be unique for each site and to be followed both on the site description proforma as well as in the collection of soil samples for analysis from the site.

Toposheet, imagery, base map and cadastral sheet particulars are self-explanatory

Location - Indicate the exact location of the profile on the cadastral map within the survey number and describe the location of the profile with reference to some nearby fixed features. Precise GPS reading of the location is to be taken and entered in the box provided for latitude and longitude. The other locational details like plot number, village, hobli, taluk *etc*., are to be entered in their respective spaces.

Physiographic region - Based on geology, relief and land use, the state is divided broadly into four physiographic regions *viz*., South Deccan Plateau, Western Ghats, Eastern Ghats and West Coast. Enter the appropriate physiographic region of area in the provided box.

Geology - The major geological formations are Granite Gneiss (GG), Granite (G), Charnockite (C), Basalt (B), Schist (S), Limestone (LS), Sandstone (SS), Laterite (L), Quartzsite (QZ) and Alluvium (A). Indicate the type of rock types observed in the area. Geology maps provided to the field parties can be used as a reference.

Parent material - The loose unconsolidated mineral material formed by weathering of rocks, from which the soils form is known as the parent material of the soil. The parent material is designated as C horizon in the soil profile and can be grouped into those formed in place through the disintegration and decomposition of rocks and those that have been transported from the place of their origin by various agents like water, wind and gravity *etc*.

Topography of the surrounding country - The surrounding area of the profile will normally have complex slopes and the terms used to describe the topography are indicated below. This contrasts with the simple slopes (soil slopes) used to describe the location of the profile in the pedon description form. This indicates the general variation in slope of the landform from its summit to its lowest one. Tick the one which is appropriate for the area after checking the slope with the counter map or with the help of Abney level or Clinometer.

Level	0-1 % slope 1-3 % slope
Nearly Level	3-8 % slope
Undulating	8-16 % slope
Rolling	16-30 % slope
Hilly	30-60 % slope
Steep	>60 % slope
Very steep	0-1 % slope 1-3 % slope

Landform - Based on geology, elevation, location and other features, the four major physiographic regions of the state are further subdivided broadly into nine landscape areas.

For example, the South Deccan Plateau region is subdivided broadly into Granite and granite gneiss landscape, basalt landscape, schistose landscape and lateritic landscape. Similarly, the Western Ghats region is divided into Northern and Southern Ghats, coastal plains into coastal uplands and marine plains. Since there is not much variation in the landscape features of the Eastern Ghats region, it is not subdivided further and retained as such as one landscape area. Enter the appropriate landscape name in the proforma.

Any physical, recognizable feature of a landscape, having a characteristic shape and mappable area at the scale of survey is to be recorded

Major landscape areas	*Landforms identified*
Basalt landscape	Plateau, Mesas, butte, summits, escarpments, side slopes, sloping uplands, plains, valleys
Granite and gneiss landscape	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, tors, inselbergs, foot slopes, sloping uplands, valleys
Schistose landscape	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, foot slopes, sloping uplands, valleys
Lateritic landscape	Hills, ridges, mounds, summits, side slopes, sloping uplands, valleys
Western Ghats-northern region	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, tors, inselbergs, foot slopes, sloping uplands, valleys

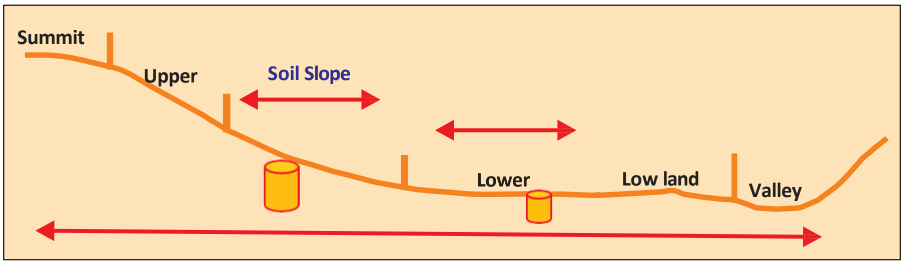
Western Ghats-southern region	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, tors, inselbergs, foot slopes, sloping uplands, valleys
Eastern Ghats landscape	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, tors, inselbergs, foot slopes, sloping uplands, valleys
Coastal uplands landscape	Mounds, ridges, summits, side slopes, foot slopes, uplands, lowlands, valleys
Coastal plains landscape	Beach, dunes, plains, salt pans, swamps, marshes, island

Micro-features - Any discrete, natural or artificial surface feature, occupying very small area on the land surface, which cannot be delineated at the scale of mapping are known as micro features. These small features individually cover less than 100 m^2 area and the height difference will be within few metres from the ground level. For example, small gullies or sand dunes if they occur in a very small extent in the survey area are described as micro features and if the same occupy large areas, then they are delineated and described as a mapping unit.

The other examples of micro features are ridge-and-furrow, erosion rills, ant hills, channel, depression, hillock, interdune, intermittent stream, minor scarp, mound, hummocks, dune, gilgai, cracks, pond, pool, ripple mark, shoreline, tank, contour terracing, levees and land slip features. Describe the nature and frequency of occurrence of such micro features in the survey area and the relationship of the profile site to such features in the proforma.

Profile position - In a hilly area the profile position can be indicated as summit, shoulder, backslope, footslope or toeslope as the case may be. In uplands, the profile position can be indicated as summits, upper, middle and lower part of the upland and lowlands or valleys.

Soil slope - Soil slope refers specifically to the slope of the land immediately surrounding the profile (*i.e.* within 100 m of the profile pit) or representative section of the landform from which the profile is described. Since soil slope is generally in one direction, it is considered as simple slope. Slope has gradient, complexity, length, form and aspect.



Slope gradient is the inclination of the surface of the soil from the horizontal. The difference in elevation between two points is expressed as a percentage of the distance between those points. If the difference in elevation is 1 meter over a horizontal distance of 100 meters, then slope gradient is 1 per cent.

The slope gradient is measured at the profile site by using Abney Level and ranging rods or Clinometer. The Abney Level readings, degrees of inclination or declination can be converted into slope percentages and slope classes. The equivalence between percentage gradient, degree of slope angle and class of slope to be used in the field are as follows:

Class of slope	Range of slope %	Abney Level reading
A	0-1	0 to 35 min
B	1-3	35 min to 1 degree 44 min
C	3-5	1 degree 44 min to 2 degrees 52 min
D	5-10	2 degrees 52 min to 5 degrees 43 min
E	10-15	5 degrees 43 min to 8 degrees 32 min
F	15-25	8 degrees 32 mins to 14 degrees 03 mins
G	25-33	14 degrees 03 mins to 18 degrees 16 mins
H	33-50	18 degrees 16 mins to 26 degrees 34 mins

Slope length - Indicates the distance up to which there is no break in the slope. For example, if the length of B slope is 100 m, then this indicates that the distance between the starting point of the slope and the point where it breaks is about 100 m. Record the gradient and length in the proforma.

Erosion - The detachment and movement of soil materials from one place to another is known as soil erosion. Sheet, rill and gully erosion is common in the state.

a) Sheet erosion is responsible for almost uniform removal of soil from an area without leaving any significant marks at the surface.

b) Rill erosion is the removal of soil through many small incipient channels or rills.

c) Gully erosion is the consequence of water that cuts down into the soil along the line of flow.

Erosion classes - The erosion classes are estimated in the field based on the proportion of upper horizons/layers that have been removed. Since these horizons may range widely in their thickness, estimating the absolute amount of erosion in the field is not possible. The erosion classes indicated below are applicable for both water and wind erosion.

Erosion Class	*Estimated % loss of the surface soil (A horizon)*
1	Up to 25%
2	25 to 75%
3	75 to 100%
4	>75 % and total removal of surface or even subsoil

Class 1 (slight erosion) - This consists of soils that have lost some, but on the average less than 25 per cent of the surface soil (A horizon). Evidence for class 1 erosion includes

1. a few rills
2. an accumulation of sediment at the base of slopes or in depressions
3. scattered small areas where the plough layer contains material from below
4. evidence of the formation of widely spaced deep rills.

Class 2 (moderate erosion) - This class consists of soils that have lost, on the average, 25 to 75 per cent of the surface soil (A horizon). In cultivated areas, the surface layer consists of a mixture of the original A and/or horizons and material from below. Some areas may have intricate patterns, ranging from uneroded small areas to severely eroded small areas.

Class 3 (severe erosion) - This class consists of soils that have lost, on the average, 75 per cent or more of the original A horizon. In class 3 erosion, material below the A horizon is exposed at the surface in cultivated areas and some mixing with underlying material is also observed.

Class 4 (very severe erosion) - This class consists of soils that have lost all the A horizon and in addition includes some or all the deeper horizons in most of the area. Indicate the kind or degree and class of erosion observed at the profile site in the proforma.

Surface Runoff - Surface runoff or external soil drainage refers to the loss of water from an area by flow over the land surface. Six classes are used to describe the runoff of an area.

a) **Ponded -** None of the water added to the soil as precipitation or by flow from surrounding areas escapes as runoff. This condition occurs normally in depressed areas.

b) **Very slow -** Surface water flows away **very slowly** that free water lies on the surface for long periods or enters immediately into the soil. In very slow condition, most of the water either passes through the soil or evaporates into the air. This condition is observed normally in level to nearly level areas or in very porous sandy soils.

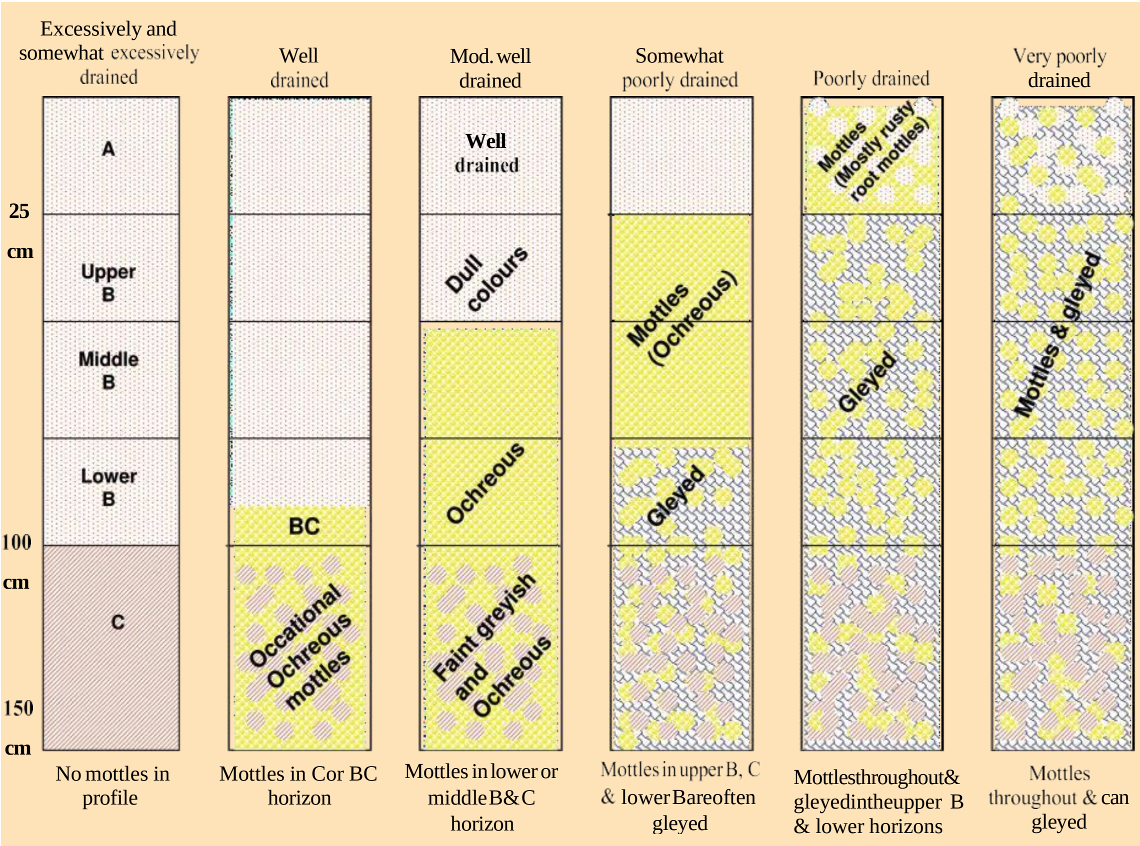
c) **Slow -** Surface water flows away **slowly** that free water lies on the surface for significant periods or enters rapidly into the soil. This condition is observed normally in nearly level or very gently sloping areas or in sandy soils.

d) **Medium -** Surface water flows away at such a rate that a moderate proportion of the water enters the soil and free water lies on the surface for only short periods.

e) **Rapid -** A large part of the rainfall moves rapidly over the surface of the soil and a small part moves through the soil profile. In this condition, water runs off nearly as fast as it is added and occur in moderately steep to steep areas and in soils with low infiltration capacity.

f) **Very rapid -** A very large part of the rainfall moves rapidly over the surface of the soil and a very small part moves through the soil profile. In this condition, water runs off as fast as it is added and are observed in steep to very steep areas and in soils with low infiltration capacity.

Drainage Classes - Natural drainage class refers to the frequency and duration of wet periods under conditions like those under which the soil developed. After completing the profile study, go through the description provided in the table and compare the soil colour and occurrence of mottles with the chart to find out the drainage class.



Morphological changes due to prolonged wetness and poor drainage

Description of various drainage classes of soil

Drainage class	*Characteristics*	*Water table (cm)*	*Mottles/gleying & other features*
Excessively drained	Water is removed from the soil very rapidly	>100	None in profile
Somewhat Excessively drained	Similar to excessively drained, but water table may not be as deep, and the soil may be slightly fine textured	>100	None in profile
Well drained	Water is removed from the soil readily but not rapidly.	at or nearer to 100	Mottles in C or BC horizon
Moderately well drained	Water is removed from the soil somewhat slowly. Soil is wet for a short time have a slowly pervious layer within one metre, periodically receive high rainfall, or both	75 - 100	Mottles in lower or middle B horizon and in C horizon

Somewhat poorly drained	The soil is wet at a shallow depth for significant periods and commonly have a pervious layer, high-water table, and/or nearly continuous rainfall	25-75	Mottles in upper B horizon; C and lower B horizons are often gleyed
Poorly drained	The soil is wet at shallow depths or remains wet for long periods. Needs proper drainage for cultivation.	< 25	Mottles throughout the profile; soil is in the upper B and lower horizons
Very poorly drained	Similar to poorly drained soils except that the soils occur on level or depressed areas and are frequently ponded	At surface or < 15	Entire profile has mottles and soil may be gleyed

Ground water depth - Indicate the depth of the water table and seasonal fluctuations of the profile site area. The water table measurements can be taken from the nearest open or bore wells or by enquiring with the farmers of the area.

Flooding - Wherever records are available they can be collected, and the frequency can be indicated and in other areas, it can be estimated based on the site characteristics and other converging evidence.

Frequency	*Classes Criteria*
None	No possibility of flooding in the area
Rare	1 to 5 times in 100 years
Occasional	5 to 50 times in 100 years
Frequent	>50 times in 100 years, *ie*, once in two years
Very frequent	Every month > 15 day in a year, used for tidal flooding

Salt / alkali (per cent surface coverage) - The presence of salinity or alkalinity can be identified based on the occurrence of barren areas, presence of salt tolerant crops like prosopis and very poor or stunted growth of plants. Presence of white encrustation on the surface of the soil is an indication of salinity and smooth or fluffy feel to the feet indicates alkalinity in the field. Observe the extent of the area covered by the saline or alkali areas and indicate the per cent surface cover in the column provided.

Soil Reaction (pH) - In the field, pH is estimated by using pH indicator papers and portable pH meter. After estimation, tick the appropriate pH values given in the column.

Electrical Conductivity (EC) - It is a measure of the concentration of water-soluble salts in soils. The occurrence of bare spots, salt tolerant crops like prosopis and uneven crop growth are indicators of salinity in the field. Portable field EC meters are used to estimate the salt content.

Surface fragments - This refers to the presence of coarse fragments (>2 mm in size) on the soil surface. The classes used are pebbles, cobbles, stones, and boulders based on their size. Gravel is a collection of pebbles that have diameters ranging from 2 to 75 mm. The size of the cobbles ranges from 75 to 250 mm (3 to 10 inches), stones from 250 to 600 mm (10 to 24 inches) and boulders above 600 mm (>24 inches). Assessment for the surface fragments is done separately for the gravel and for stones and boulders. Indicate the size of the fragments observed in the field. The gravelliness and stoniness classes used are indicated below

Gravelliness class	*% of area covered*
Non gravelly	< 15 per cent
Gravelly	15 to 35 per cent
Very gravelly	35 to 60 per cent
Extremely gravelly	60 to 80 per cent
Considered as part of the top	>80 per cent

Stoniness class	*Percentage of surface covered*
Stony (class 1)	0.01 to 0.1 per cent of the surface
Very stony (class 2)	0.1 to 3 per cent of the surface
Extremely stony (class 3)	3 to 15 per cent of the surface
Rubbly (class 4)	15 to 50 per cent of the surface
Very rubbly (class 5)	>50 per cent of the surface

Rock outcrops - The distance between the rock outcrops and their percentage coverage in the field is to be recorded as indicated below

Per cent coverage	**Description**
< 2	No rocks or very few rocks to interfere with tillage
2 to 10	Fairly rocky, sufficient to interfere with tillage but not to make inter-tilled crops impracticable. Exposures are roughly 35 to 100 m apart
10 to 25	Rocky, sufficient to interfere with tillage of inter-tilled crops impracticable. Exposures are roughly 10 to 35 m apart.
25 to 50	Very rocky, sufficient to make all use of machinery impracticable, except for light machinery. Exposures are roughly 3.5 to 10 m apart
50 to 90	Extremely rocky, sufficient rock outcrops to make all use of machinery impracticable. Exposures are about 3.5 m apart or less
Over 90	Rock outcrops

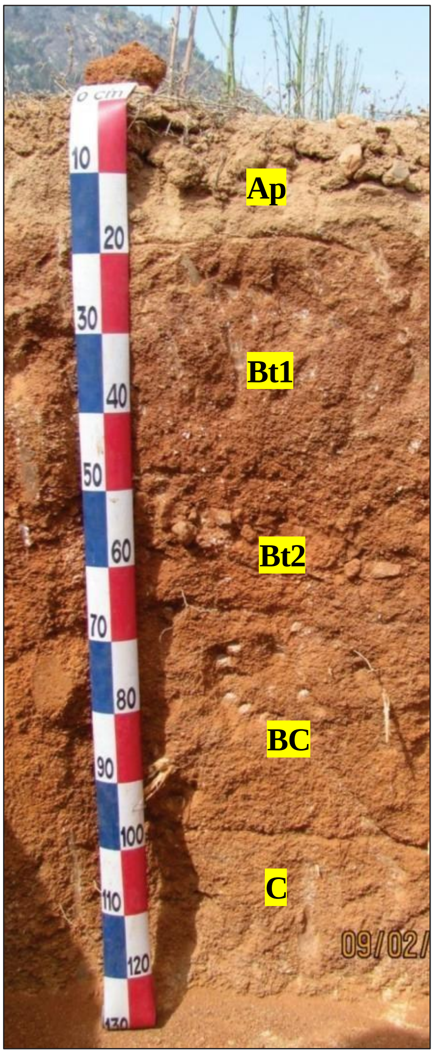
Elevation - Elevation refers to the height of a point on the earth's surface, relative to mean sea level. It can be determined from the contour maps or by using Global Positioning System (GPS). The elevation of the area is to be noted in the box based on the GPS measurement.

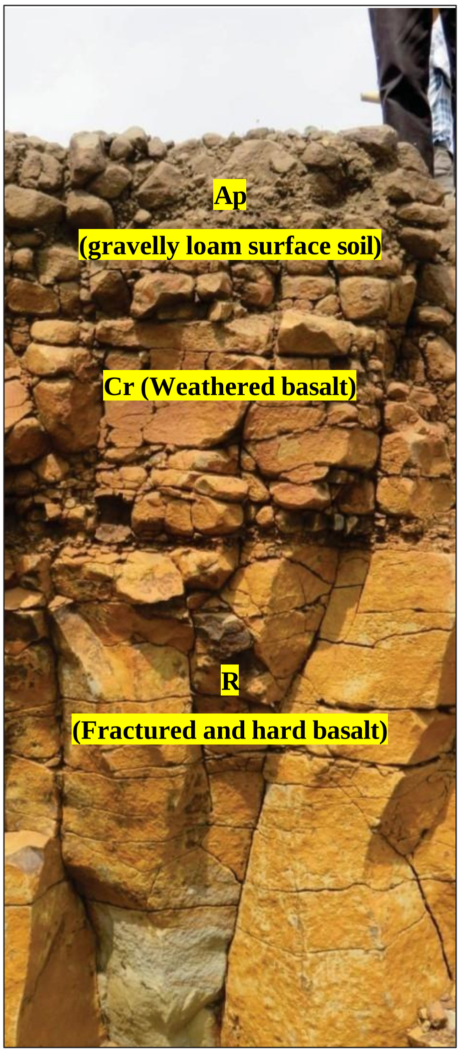
Land Use - Indicate the name of the crop or combination of crops (common names like bajra, ragi *etc*., are preferred) cultivated in the season and crops cultivated in the previous season and major and minor crops if it is a mixed one.

Vegetation - The type of natural vegetation to be described with their common names.

Soil characters

Study and description of soils is important to understand their formation and mapping. Soil properties are studied by opening a profile of 2 m length, 1m width and 2 m depth in a representative area. The profile is cleaned and examined carefully from the surface to identify any change in the morphology or other properties of the soil. Based on the changes observed, layers/horizons are identified and marked. Immediately after marking the layers photographs of the profile and surrounding features are to be completed, followed by estimation of the volume of coarse fragments and any other features that may be destroyed later during the study of the soils. Apart from profile study, road/well cuts, quarries or other fresh cuts can be used to describe the soils of the survey area.





Typical horizon designations used to describe profile development

Soil depth - Soil depth indicates the depth of the solum, which includes A and B horizons, occurring above the parent material or hard rock. Depth is measured from the soil surface. For soils with a cover of 80 per cent or more rock fragments on the surface, the depth is measured from the surface of the rock fragments. Generally, all the four faces of the pit will not be uniform, and care is necessary to select the typical or representative face of the pit for the study of the profile. The depth classes are

Very shallow	25 cm
Shallow	25-50 cm
Moderately shallow	50-75 cm
Moderately deep	75-100 cm
Deep	100-150 cm
Very deep	> 150 cm

Horizon - Horizon development indicates the extent and degree of soil formation. It will be weak in the early stages and exhibit distinct characteristics in well-developed soils.

a. **Designations for horizons -** Layers and horizons of different kinds are identified by symbols. Capital letters (O, A, E, B, C, R and W) are used to designate the master horizons. Lower case letters are used as suffixes to indicate specific characteristics of master horizons. Arabic numerals are used both as suffixes to indicate vertical subdivisions within a horizon or layer and as a prefix to indicate discontinuities.

b. Master Horizons and Layers

O horizons or layers - This layer is dominated by organic material and consist of undecomposed or partially decomposed litter, deposited on the surface of either mineral or organic soils.

A horizons - It is a mineral horizon formed at the surface or below O horizon. They exhibit obliteration of all or much of the original rock structure and show an accumulation of humified organic matter intimately mixed with the mineral fraction.

E horizons - Mineral horizon in which the main feature is loss of silicate clay, iron, aluminium, or some combination of these, leaving a concentration of sand and silt particles. This horizon is usually lighter in color than B and A horizons. The organic matter is normally less than A horizon and occurs commonly near the surface.

B horizons - Horizons that formed below an A, E, or O horizon and are dominated by obliteration of all or much of the original rock structure and show one or more the following:

1. illuvial concentration of silicate clay, iron, aluminum, humus, carbonates, gypsum, or silica, alone / in combination
2. evidence of removal of carbonates
3. residual concentration of sesquioxide
4. coatings of oxides that makes the horizons lower in value, higher in chroma, or redder in hue than overlying and underlying horizons
5. alteration that forms silicate clay or liberates oxides or both and that forms granular, blocky or prismatic structure
6. brittleness or gleying

C horizons - Horizons, excluding hard bedrock, that are little affected by pedogenic processes and lack properties of O, A, E, or B horizons. The material of C layers may be either like or unlike that from which the solum presumably formed. The C horizon may have been modified even if there is no evidence of pedogenesis.

R layers: Hard Bedrock - The R layer is coherent when moist to make hand digging with a spade impractical, although it may be chipped or scrapped.

Transitional horizons - Horizons dominated by properties of one master horizon but having subordinate properties of another. Two capital letter symbols are used to designate the transitional horizons (AB, EB, BE, BC, CB). The master horizon symbol that is given first designates the kind of horizons whose properties dominate the transitional horizon.

Combination horizons - Horizons in which distinct parts have recognizable properties of the two kinds of master horizons indicated by the capital letters. The two capital letters are separated by a slash as A/B, E/B, B/E, B/C.

Subordinate distinctions within master horizons - Lower case letters are used as suffixes to designate kinds of master horizons and some of the symbols used commonly are indicated below

Horizon suffix	*Criteria*
a	Highly decomposed organic matter. Used with O horizon
c	Concretions or nodules
e	Moderately decomposed org. matter
g	Strong gley
k	Accumulation of (pedogenic) carbonates
n	Pedogenic, exchangeable sodium accumulation
p	Plough layer or other artificial disturbance
r	Weathered or soft bedrock
ss	Presence of slickensides
t	Illuvial accumulation of silicate clay
v	Presence of plinthite
w	Weak color or structure within B (used only with B)

Conventions for using letter suffices

- Master horizon symbol (capital letter) should be followed by one or more lower case letters.
- Normally up to two suffices are used and more than three suffices are rarely used.
- B horizon with accumulation of clay and also showing evidence of colour or structure, or both, is designated as Bt and not as Btw or Bts or Btws (t has precedence over w, s, and h).

Vertical subdivision - The subdivision of a horizon or layer designated by a single letter, or a combination of letters is indicated at the end using arabic numerals. For example, the subdivision of B horizon can be shown as Bt1-Bt2-Btk1-Btk2 and not as Bt1-Bt2-Btk3-Btk4.

Discontinuities - Arabic numerals are used as prefixes (preceding A, E, B, C, and R) to indicate discontinuities in mineral soils. Discontinuity is indicated by significant or abrupt change in texture, age or mineralogy between the layers or horizons. Examples: A-Bt-C-2R, Ap-Bt1-2Bt2-2Bt3-2BC-C.

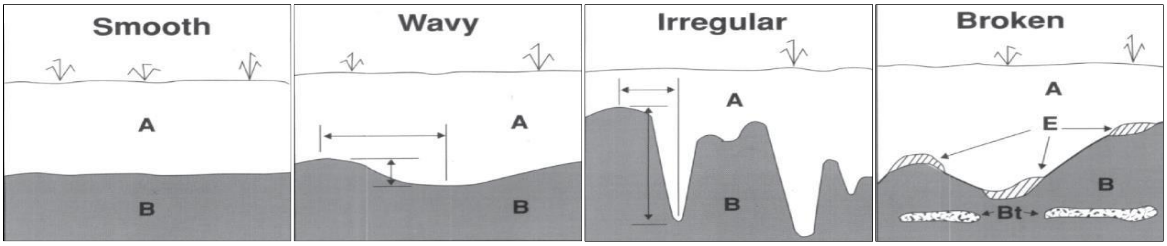
Boundaries of horizons and layers - A transitional area or layer present between two adjoining horizons or layers is known as the boundary. Boundaries vary in **distinctness** (contrast) and in **topography**.

Distinctness - Distinctness is the distance through which one horizon grades into another. It refers to the thickness of the zone within which the boundary can be located. The distinctness depends on the degree of contrast between the layers and thickness of the transitional zone. Distinctness is defined in terms of thickness of the transitional zone.

Distinctness class	*Criteria: transitional zone thickness*
Very Abrupt or sharp	Less than 0.5 cm
Abrupt	0.5 to < 2 cm
Clear	2 to < 5 cm
Gradual	5 to 15 cm
Diffuse	> 15 cm

Topography - Topography is the lateral undulation and continuity of the boundary between horizons. Topography refers to the irregularities of the surface that divides the horizons

Smooth	The boundary is a plane one with few or no irregularities
Wavy	The boundary has undulations in which the width of undulation is more than the depth
Irregular	Similar to wavy in which the depth of undulation is more than the width
Broken	Discontinuous horizons; discrete but intermingled, or irregular pockets

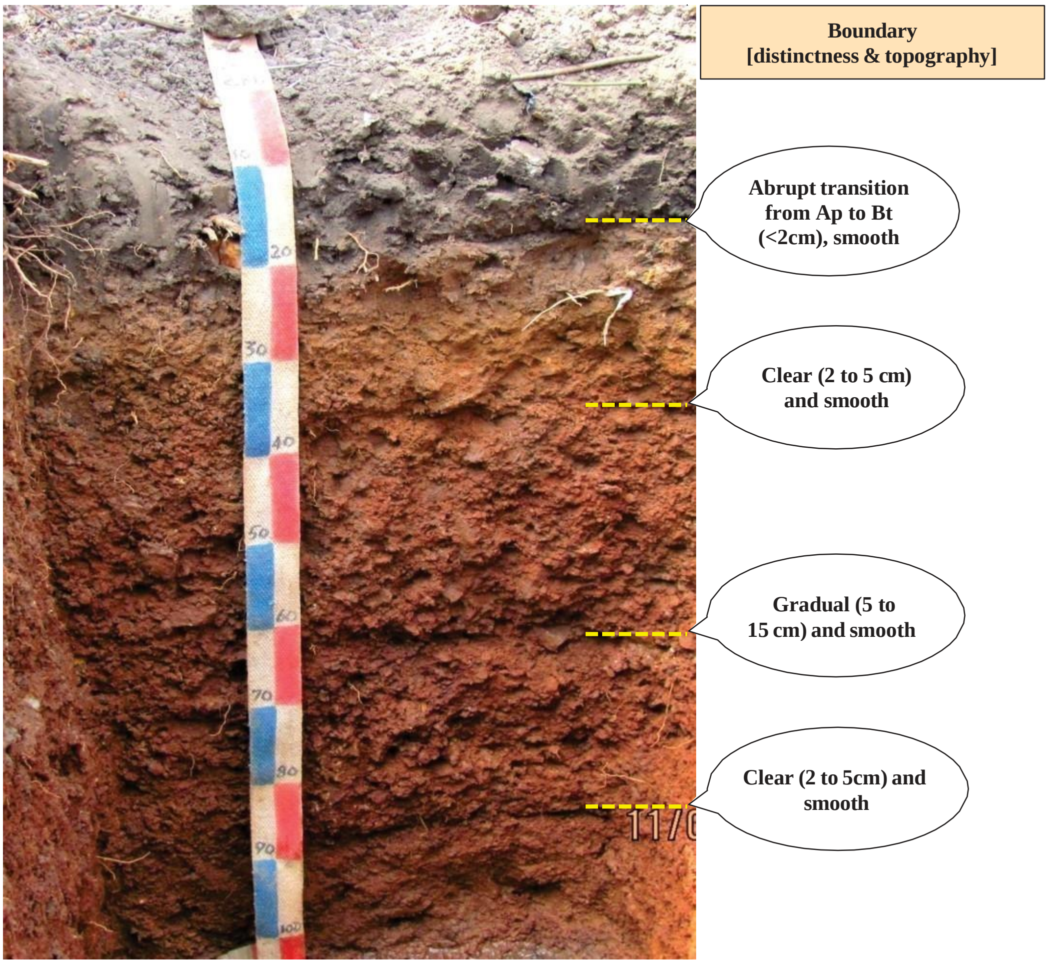


Topography of the soil boundaries as seen in the field

Soil colour - Soil colour is measured by comparing peds with Munsell Colour Chart. The notation is recorded in the form of hue, value and chroma - for example, 5YR 5/3.

1. **Hue** is a measure of the chromatic composition of light that reaches the eye.
2. **Value** indicates the degree of lightness or darkness of a colour in relation to a neutral grey scale. The value is a measure of the amount of light that reaches the eye under standard lighting conditions. **Grey** is perceived as about halfway between black and white and has a value notation of 5/.
3. **Chroma** is the relative purity or strength of the spectral colour. The scales of chroma for soils extend from /0 for neutral colours to a chroma of /8 as the strongest expression of colour used for soils

Distinctness (contrast between two layers) and topography of red soil profile



Typical soil colours in red (5YR 4/6) and black soils (10YR 3/1)

Conditions for measuring soil colour - Measurement of soil colour is affected by the quality and intensity of light, moisture content and roughness of the sample selected. Determination done either early in the morning or late in the evening will not be accurate. Also, when the sun is low or the atmosphere is smoky, the light reaching the sample and the light reflected will be more towards redder colour. Colours also appear different in the subdued light of a cloudy day than in bright sunlight. Hence, determination of soil colour is undertaken in shade by utilising the shadow of the person holding the colour chart.

Mottling - Mottles are spots of different colours which are different from colour variation associated with ped surfaces, worm holes, concretions, nodules, *etc*. Mottles are described by quantity, size, contrast, colour, and shape in that order.

Quantity - Indicates the per cent of horizon area covered by mottles

Few	< 2 % of surface area
Common	2 to 20 % of surface area
Many	> 20 % of surface are

Mottling size - Refers to dimensions as seen on a plane surface. It is measured along the greatest dimension except in linear forms. The size classes used are

Fine	< 2 mm
Medium	2 to < 5 mm
Coarse	5 to < 20 mm
Very Coarse	> 20 mm

Mottling Contrast - Refers to the degree of visual distinction that is evident between associated colours. Record the colour difference between the mottle and the dominant matrix colour and express the contrast as indicated below

Faint	Evident only on close examination. Faint mottles commonly have the same hue as the colour to which they are compared and differ by no more than 1 unit of chroma or 2 units of value
Distinct	Readily seen but contrast only moderately with the colour to which they are compared
Prominent	Contrast strongly with the colour to which they are compared

Soil texture - Soil texture refers to the relative proportion (per cent by weight) of sand, silt and clay present in a soil. Texture is estimated in the field by feel method. The texture classes range from sand to clay and some of the commonly occurring texture classes are briefly described below. Normally, sand particles feel gritty, and the grains can be seen with the naked eye. Silt has a smooth feel to the fingers both in dry and wet conditions. Clayey soils exhibit sticky and plastic characteristics. Guidelines for the assessment of soil texture in the field are indicated in the table below

Modifiers used for describing soil texture - If the soil (fine earth) contains various rock fragments, their quantity and size are recorded and used as a modifier in describing the texture of the soil.

Rock fragments % byvolume	*Modifier used for texture description*
< 15	No texture adjective is used (noun only; e,g., loam)
15 to < 35	Use adjective for appropriate size; e.g., gravelly
35 to < 60	Use "very" with the appropriate size adjective; e.g., very gravelly
60 to < 90	Use "extremely" with the appropriate size adjective; e.g., extremely gravelly
> 90	No adjective or modifier, If the soil contains < 10 % fine earth, use the appropriate noun for the dominant size class; e.g., gravel (used in lieu of texture)

Guide for assessment of soil texture in the field

Sl. No.	*Texture class*	*Feel*	*Coherence at sticky point*	*Ribbon Length [mm]*	*Other features*	*Clay %*
1	Sand	Very gritty	Nil	Nil	Single sand grains adhere to fingers	<5
2	Loamy sand	Very gritty	Slight	5	Discolour fingers with an organic stain	5-10
3	Sandy loam	Gritty	Just coherent	15-25	Medium sand readily visible	10-20
4	Loam	Neither very gritty nor very smooth	Coherent	about 25	No obvious sandiness	25
5	Silt loam	Smooth or buttery	Coherent	about 25	Silky; very smooth	25 (>25 silt)
6	Sandy clay loam	Moderately gritty	Strong	25-40	Medium sand in fine matrix	20-30
7	Clay loam	Slightly Gritty	Strong	40-50	No obvious sand grains	30-35
8	Silty clay loam	Very smooth	Coherent	40-50	Silky feeling	30-35 (>25 silt)
9	Sandy clay	Sticky	Coherent	50-75	Fine to medium	35-40
10	Silty clay	Sticky	Coherent	50-75	Smooth and Silky	35-40 (>25 silt)
11	Clay	Sticky	Coherent	>75	Smooth with slight to fair resistance to shearing	35-50
12	Heavy Clay	Very sticky	Coherent	>75	Firm resistance to shearing	>50

Rock fragments (described earlier as coarse fragments) **-** The discrete unattached pieces of rock having more than 2 mm in diameter are described by their size as indicated below.

2 - 75 mm diameter	Pebbles
75 – 250 mm	Cobbles
250 – 600 mm	Stones
> 600 mm	Boulders

Soil Structure - The arrangement of primary soil particles into aggregates is known as structure in soils. Clods and fragments in the soil are not considered as structural units. Soils lacking structure are considered as structure less soils and described as single grain or massive. The structure is described based on the shape (type), size and grade of the structural units observed in the soil.

Based on shape (type)

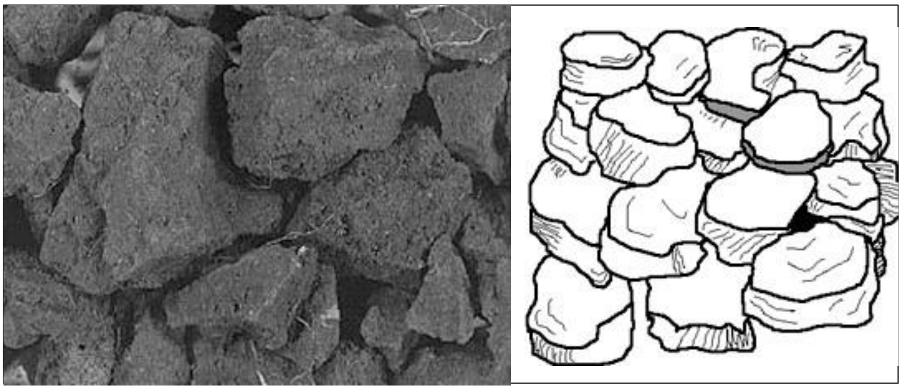
Platy	The units are flat and plate like and horizontally oriented
Prismatic	Vertically elongated units with flat tops, the individual units are bounded by flat to rounded vertical faces
Columnar	The units are like prisms and are bounded by flat or slightly rounded vertical faces and the top of columns are rounded
Blocky	The units are like blocks and considered as angular blocky if the faces intersect at sharp angles; sub angular blocky if the faces are a mixture of rounded and plane faces and the corners are mostly rounded
Granular	The units are approximately spherical or polyhedral and are bounded by curved or very irregular faces

Size - Based on size, the structural units are described as very fine, fine, medium, coarse and very coarse.

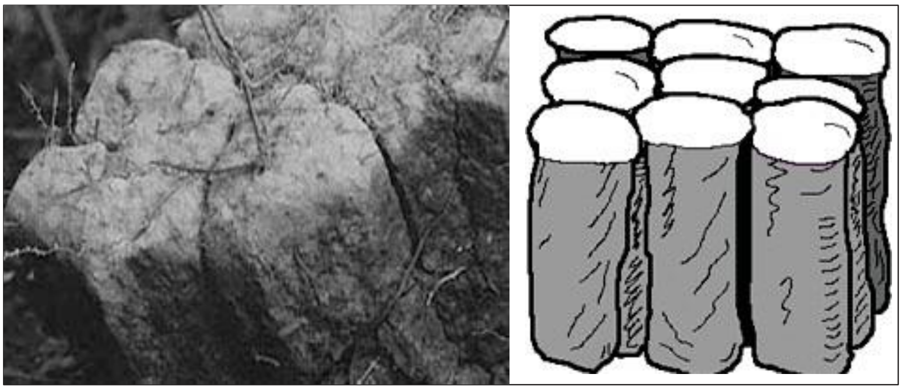
Size classes	*Grannular, Platy (mm)*	*Prismatic & Columnar (mm)*	*Blocky (mm)*
Very fine	< 1	< 10	< 5
Fine	1-2	10-20	5-10
Medium	2-5	20-50	10-20
Coarse	5-10	50-100	20-50
Very Coarse	> 10	> 100	> 50

Grade - Grades describe the degree of ped development in the soil. It is distinguished in the field by the portion of the soil appearing as peds and the ease with which the soil separates into peds and their durability. Three classes are used to describe the grade

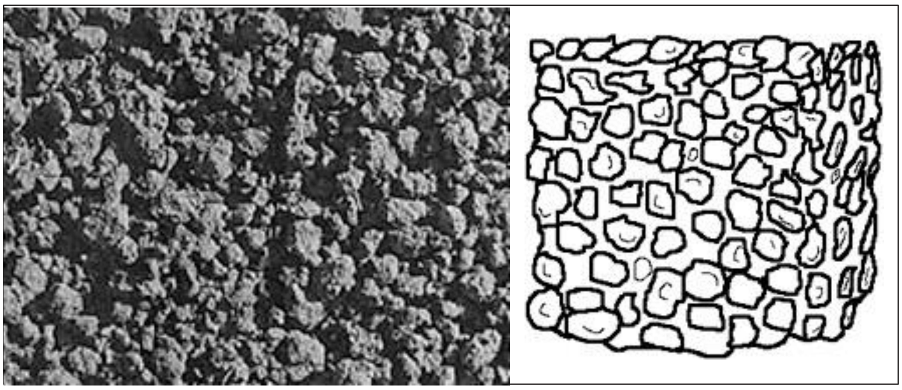
Structureless (0)	No discrete units observable in place or in hand sample
Weak (1)	Units are barely observable in place or in a hand sample
Moderate (2)	Units well-formed and evident in place or in a hand sample
Strong (3)	Units are distinct in place (undisturbed soil) and separate cleanly when disturbed



Blocky - Irregular blocks that are usually 1.5 - 5.0 cm in diameter



Columnar - Vertical columns found in arid climate



Granular - Resembles crumbs and seen in surface horizons

Consistence - It refers to the degree and kind of cohesion and adhesion and/or the resistance of soil to deformation or rupture when stress is applied. Every soil has this property, irrespective of their nature and moisture status. In the field, consistence is assessed based on resistance of soil material to rupture, resistance to penetration, plasticity, toughness, and stickiness of puddled soil material, and the way the soil material behaves when subject to compression. Consistence is highly dependent on the soil-water state, and it is observed for dry and moist soil in the field separately.

Dry Class	*Moist Class*	*Specimen fails under*
Loose	Loose	Intact specimen not available
Soft	Very friable	Very slight force between fingers
Slightly hard	Friable	Slight force between fingers
Moderately Hard	Firm	Moderate force between fingers
Hard	Very firm	Strong force between fingers
Very hard	Extremely firm	Moderate force between hands
Extremely hard	Slightly rigid	Foot pressure by full body weight
Rigid	Rigid	Cannot be failed underfoot by full body weight

Plasticity is the degree to which puddled or reworked soil can be permanently deformed without rupturing. The evaluation is made by forming a roll (wire) of soil at a water content where the maximum plasticity is expressed

Non plastic (po)	Will not form a roll 6 mm in diameter, or if a roll is formed, it can't support itself if held on end
Slightly Plastic (ps)	6 mm diameter roll supports itself
Moderately Plastic (p)	4 mm diameter roll supports itself; 2 mm diameter roll does not
Very Plastic (vp)	2 mm diameter roll supports its weight

Stickiness - refers to the capacity of a soil to adhere to other objects. The determination is made on puddled soil material at the water content at which the material is stickiest. The sample is crushed in the hand, water is applied while manipulation is continued between thumb and forefinger until maximum stickiness is reached.

Stickiness Class	*Code*	*Criteria-Description*
Non-sticky	so	After release of pressure, practically no soil material adheres to fingers
Slightly sticky	ss	Soil adheres to both fingers, after release of pressure. Soil stretches little on separation of fingers.
Moderately Sticky	ms	Soil adheres to both fingers, after release of pressure. Soil stretches some on separation of fingers.
Very Sticky	vs	Soil adheres firmly to both fingers, after release of pressure. Soil stretches greatly on separation of fingers

Redoximorphic Features (RMF) - Mottles are already described under the section soil colour. RMF mottling is normally associated with wetness. The colour pattern of RMF, is due to depletion or concentration of pigments compared to the matrix colour and formed by oxidation/reduction of Fe and/or Mn coupled with their removal, translocation, or accrual; or a soil matrix colour controlled by the presence of Fe^{2+}. RMF are described separately from other mottles, salt concentrations or clay films.

RMFs include the following:

1. **Redox Concentrations -** Localized zones of enhanced pigmentation, formed due to the accumulation of Fe-Mn minerals in the form of

- **Masses** - Non cemented bodies of enhanced pigmentation that have aredder or blacker color than the adjacent matrix.
- **Nodules or Concretions** - Cemented bodies of Fe-Mn oxides.

2. **Redox Depletions -** Localized zones of “decreased" pigmentation that are greyer, lighter, or less red than the adjacent matrix. Redox depletions (chroma ≤ 2) are used to define aquic conditions and to infer the depth of saturation in soils. Types of redox depletions in the soil are:

- **Iron Depletions** - Localized zones that have a yellower, greener; or bluer hue; a higher value; or a lower chroma than the matrix color. Color value is normally ≥ 4. Loss of pigmentation results from the loss of Fe and/or Mn.
- **Clay Depletions -** Localized zones that have either a yellower, greener or bluer hue, a higher value; or a lower chroma than the matrix color. Color value is normally ≥ 4. Loss of pigmentation results from a loss of Fe and or Mn and clay.

3. **Reduced Matrix -** A soil horizon that has an *in-situ* matrix chroma ≤ 2 due to the presence of Fe^{2+}. Color of a sample becomes redder or brighter (oxidizes) when exposed to air.

RMF are described separately from other color variations, mottles or concentrations. Record Kind, Quantity (% of area covered), Size, Contrast, Color, Shape, Location, Hardness *etc*. in the proforma

Quantity (% of area covered)

Class	*Code*	*Criteria: % of surface area covered*
Few	F	< 2
Common	C	2 to < 20
Many	M	≥ 20

Size (Refer size class under mottles or concentrations)

Size Class	*Code*	*Criteria*
Fine	1	< 2 mm
Medium	2	2 to < 5 mm
Coarse	3	5 to < 20 mm
Very Coarse	4	20 to < 76 mm
Extremely Coarse	5	≥ 76 mm

Contrast - Describe the contrast as faint, distinct or prominent as provided for the mottles

Colour - use the Color chart to describe them

Concentrations - Concentrations are formed by accumulation of material during soil formation due to dissolution, precipitation, oxidation, and reduction and physical and/or biological removal, transport, and accrual. Types of concentrations include

a. **Finely Disseminated Materials** are patches of precipitates (e.g. salts, carbonates) dispersed throughout the matrix of a horizon and can be detected by a chemical reaction (e.g. effervescence of $CaCO_3$ by HCl).

b. **Masses** are non-cemented accumulation that cannot be removed from the soil as discrete units, and consist of calcium carbonate, fine crystals of gypsum or more soluble salts or iron and manganese oxides.

c. **Nodules are** cemented bodies of various shapes that can be removed as discrete units from soil.

d. **Concretions** are cemented bodies like nodules, except for the presence of visible concentric layers of material around a point line or plane.

e. **Crystals** are crystalline forms of relatively soluble salts (e.g. halite, gypsum, carbonates) that form *in situ* by precipitation from soil solution.

f. **Biological Concentrations** are discrete bodies accumulated by a biological process like fecal pellets, or insect casts formed or deposited in soil.

g. **Plinthite** is iron-enriched reddish bodies that are low in organic matter and are coherent enough to be separated readily from the surrounding soil. It is firm or very firm when moist, hard, and very hard.

Field description of concentrations - The description of concentrations is like that of the mottles or redoximorphic features present in the soil.

a. Kind - Identify the composition and the physical state of the concentration in the soil. A rough field guide to identify the materials is given below

- Finely disseminated - Carbonates, salts
- Masses - non-cemented Carbonates, Gypsum, Salts
- Nodules - cemented Carbonates, Gibbsite
- Concretions - cemented Carbonates, Gibbsite, Titanium oxide
- Crystals - Calcite, Gypsum, Salt (NaCl, Na-Mg sulfates)
- Biological concentrations **- f**ecal pellets, insect casts, root sheaths, worm casts

b. Quantity (% area covered) - Refers to the relative volume of a horizon or other specified unit occupied by the bodies. The classes used are the same as that used for estimating the quantity of mottles and redoximorphic in the soil.

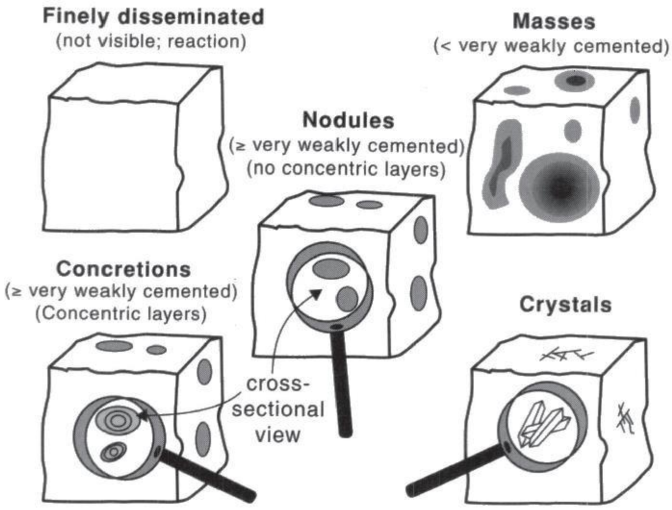
c. Size is like the classes used for describing mottles.

d. Contrast is like describing Mottle or RMF present in the soil.

e. Colour chart to describe the colour.

f. **Location** is described as on the matrix, ped faces, pores, cracks *etc.*

g. **Composition** of the material like carbonates, iron, manganese *etc.*



Types of concentrations present in soil

Coats/Films/ Stress Features (Internal Surface Features) - These features include coats/films, or stress features and formed by translocation and deposition, or shrink-swell processes. The kind, amount, continuity, distinctness, location, and thickness of the feature is described.

a. **Kind -** Includes carbonate coats, clay films, organic stains *etc.*
b. **Amount of ped and void surface features** - Estimate the relative per cent of the visible surface area that a ped surface feature occupies in a horizon

Amount	*Code*	*Criteria: % of surface area*
Very few	vf	<5
Few	f	5 to<25
Many	m	25 to<50
Common	c	50 to<90

c. **Continuity -** It is described as continuous if the feature covers the entire surface, discontinuous if only partially covered and patchy if in isolated patches.

d. **Distinctness -** The relative extent to which a ped surface feature visually stands out from the adjacent material is known as its distinctness. The classes used are

Distinctness Class	*Code*	*Criteria*
Faint	f	Visible with magnification only (10X hand lens); little contrast between materials.
Distinct	d	Visible without magnification; significant contrast between materials.
Prominent	p	Markedly visible without magnification; sharp visual contrast between materials.

Roots - Quantity, size, and location of roots in each layer are to be recorded. Describe the quantity (number) of roots for each size class. The unit area that is evaluated varies with the size class of the roots being considered. The unit area for different root size classes is: 1 sq cm for very fine and fine roots, 1 sq dm (10 x 10 cm) for medium and coarse roots, and 1 m^2 for very coarse roots.

Quantity Class	Code	Average Count (per assessed area)
Few	f	<1 per area
Common	c	1 to<5 per area
Many	m	≥ 5 per area

Size of Roots (and Pores)

Size Class	*Code*	*Diameter*	*Soil Area Assessed*
Very Fine	vf	<1 mm	1 cm^2
Fine	f	l to<2 mm	1 cm^2
Medium	m	2 to<5 mm	1 dm^2
Coarse	c	5 to< 10 mm	1 dm^2
Very Coarse	vc	≥ 10 mm	1 m^2

Pores - Pores are the air or water filled voids present in the soil. It is difficult to assess very small size pores (e.g. < 0.05 mm) in the field. So, field observations are limited to those pores that can be seen through a 10X hands lens or larger. Pores are described by their quantity and size. Quantity classes pertain to number of pores per unit $area^{-1}cm^2$ for very fine and fine pores, 1 dm^2 (10 x 10 cm) for medium and coarse pores, and 1 m^2 for very coarse. The quantity and size classes are similar to the classes used for roots.

Cracks - Are fissures primarily associated with clayey soils and are most pronounced in high shrink-swell soils. Record the Relative Frequency **(**estimated average number per m^2) and Depth.

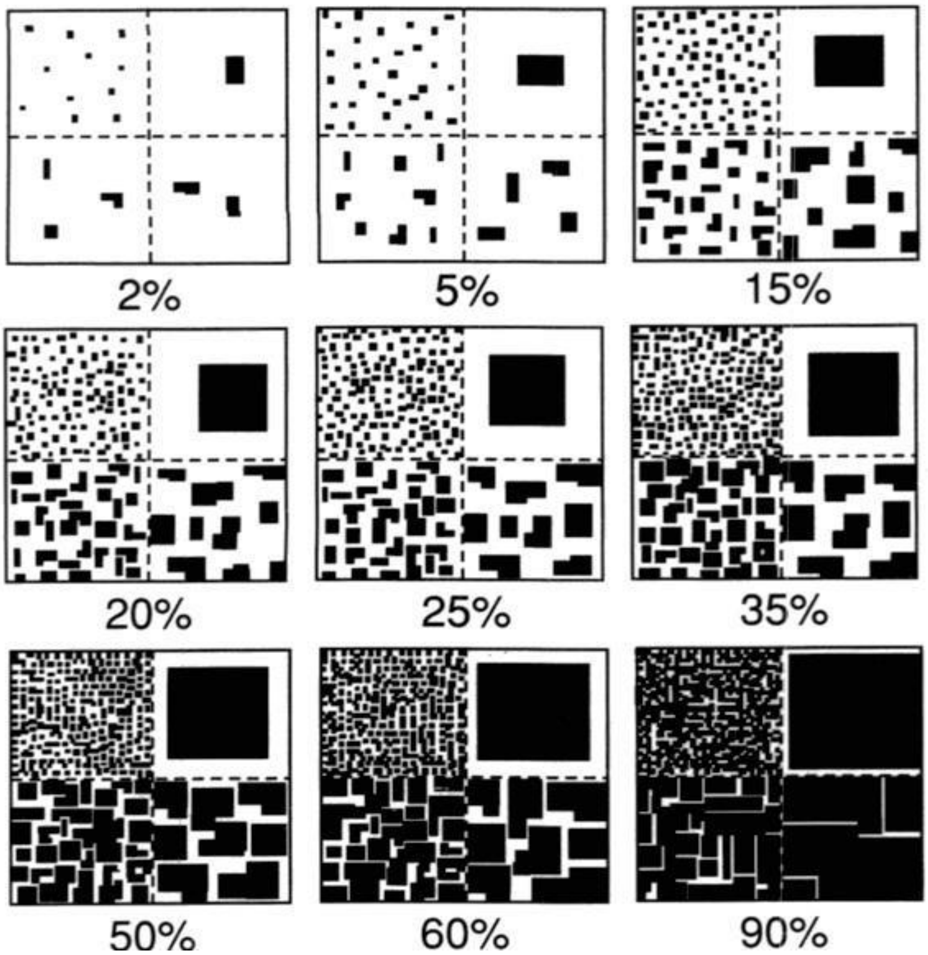
Soil crusts - A soil crust is a thin (e.g. <1 cm up to 10 cm thick) surface layer of soil particles bound together by living organisms and / or by minerals into a horizontal mat or small polygonal plates. Soil crusts form at the soil surface and have different physical and /or chemical characteristics than the underlying soil material. Typically soil crusts change the infiltration rate of the mineral soil and stabilize loose soil particles and aggregates. There are two general categories of soil crusts: Biological crusts, and Mineral crusts. Record the type of (kind) surface crust present in the soil.

Soil reaction (pH) - Both colorimetric and electrometric methods can be used for measuring pH. Colorimetric methods are simple and inexpensive. Record the pH and method of observation.

Effervescence - The gaseous response of soil to cold dilute (about 1:10 dilution) hydrochloric acid is used to test the presence of carbonates in the field. The amount and expression of effervescence is affected by distribution and mineralogy as well as the amount of carbonates present in the soil. The effervescence classes used are very slight, slight, strong, and violent.

Other features - Like presence of small animals, termite mounds, ant hills, heaps of excavated earth, the openings of burrows, paths, feeding grounds, earthworm or other castings *etc*., as special notes to be recorded in the proforma.

For estimation of per cent of area covered in soil



The above graphic can be used to assess the amount or quantity of mottles, concentrations, redoximorphic features and ped and void surface features present in the soil. Within any given box above, each quadrant contains the same total area covered, but with by different sized objects.

PEDON DESCRIPTION FORM – SITE CHARACTERISTICS

NBSS & LUP	**Agricultural University**	**Dept. of Agriculture**	**Author:** **Date :**

Series Name:	Map unit Symbol:	Soil Classification:

Observation No.:	Topo sheet No.:	Imagery No.:	Base map: Scale:	Cadastral Sheet No.:

Location:	Latitude: ° ′ ″ Longitude: ° ′ ″	Plot (Survey) No.:	Village: Taluk:	Block: District:

Physiographic division:	Geology:	Parent material:

Topography of the surrounding country: Level / Nearly level / Undulating / Rolling / Hilly / Steep / Very steep	Landform:	Microfeatures:	Profile position:

Soil slope														
Gradient (%)	0-1 A	1-3 B	3-5 C	5-10 D	10-15 E	15-25 F	25-33 G	>33 H	**Erosion**	Very slight	Slight	Mod.	Sev.	V. Sev
Length (m)	0-50	50-150	150-300	300-600	>600				**Runoff**	Ponded	V.Slow	Slow	Med	Rap	V.Rap

Drainage	V. Pr	Pr	Some what Pr.	M. Well	Well	Some what excessive.	Ex.	**G.Water depth (m)**	<1	1-2	2-5	5-10	10-25	25-50	>50

Flooding	No	Occassional	Frequent	Very Frequent	**Salt/Alkali (% sur. coverage)**	No	<20	20-50	>50

pH	<4.5	4.5-5.5	5.5-6.5	6.5-7.5	7.5-8.5	8.5-9.5	>9.5	**E.C.**	<2	2-4	4-8	8-15	15-25	25-50	>50

Surface fragments	Dia (cm)	<2	2-7.5	7.5-25	25-60	>60	**Rock out-crops**	Dist. Apart (m)	No	35-100	10-35	3.5-10	<3.5	
Coverage of gravels (<25cm)	(%)	<15	15-35	35-60	>60			Coverage(%)	<2	2-10	10-25	25-50	50-90	>90
Coverage of stones&boulders	(%)	0.01-0.1	0.1-3	3-15	15-50	50-90	Elevation above MSL(m):							

LAND USE / VEGETATION

Crop	Season	Yield	Management

Vegetation
Nine fold classification
Forests : evergreen / deciduous / shrub
Area put to non agricultural uses
Barren and uncultivable land
Permanent pastures & other grazing land
Land under misc.tree crops and groves
Culturable wasteland
Fallow lands other than current fallows
Current fallows
LCC

FIELD NOTES	SKETCH
	cm
	50
	100
	150
	200

Notes :

1

Observation Method:		Auger	Minipit	Roadcut

	Depth (cm)	Horizon	Bnd[1] D T	Diag. Hori.	Matrix Colour Dry	Matrix Colour Moist	Texture[2]	% clay	Rock Frags[3] Sz Knd Vol	Structure[4] Grade Sz Type	Consistence[5] Dry	Mst	Stk	Pls
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

	Mottles/ Redox features[6] Qty Sz Cn Col Sp Loc	Coats/Films/Stress Features[7] Amt Dst Cont Kd Loc Col	Concentrations[8] (Conca, Conir, etc.,) Qty Sz Cn Kd Col	Roots[9] Qty Sz Lc	Pores[10] Qty Sz Shp	pH	Effer[11] (dil Hcl)- 1,2,3	Sample bag No.
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

1. **D-Distinctness:** a-abrupt, c-clear, g-gradual, d-diffuse, **T-topography:** s-smooth, w-wavy, i -irregular, b-broken
2. **Texture:** s-sand, ls-loamy sand, sl -sandy loam, l -loam, sil -silt loam, si-silt, scl -sandy clay loam, cl -clay loam, sicl -silty clay loam, sc-sandy clay, sic-silty clay, c-clay.
3. **Size:** fg- fine gravel(<2cm), cg-coarse gravel(2-7.5cm), cb-cobbles(7.5-25cm), st-stones(25-60cm), b-boulders(>60cm).
4. **Grade:** 0-structureless, 1-weak, 2-moderate, 3-strong; **Size:** vf-very fine, f-fine, m-medium, c-coarse, vc-very coarse **Type:** gr-granular, cr-crumb, clr-columnar, pr-prismatic, pl-platy, abk-angular blocky, sbk-subangular blocky, sg-single grain, m-massive, c-cloddy.
5. **Dry:** l-loose, s-soft, sh-slightly hard, h-hard, vh-very hard, eh-extremely hard, **Moist:** l-loose, vfr-very friable, fr-friable, fi-firm, vfi-very firm, efi-extremely firm, **Stickyness:** so-non-sticky, ss-slightly sticky, ms-moderately sticky, vs-very sticky, **Plasticity:** po-non-plastic, sp-slightly plastic, mp-moderately plastic, vp-very plastic.
6. **Quantity(qty):** f-few(<2%), c-common(2-20%), m-many(>20%); **Size(sz):** 1-fine(<2mm), 2-medium(2-<5mm), 3-coarse (5-<20mm), 4-very coarse(>20mm); **Contrast(cn):** f-faint, d-distinct, p-prominent ; **Colour(col); Shape(sp):** c-cylindrical, d-dendritic, i-irregular, p-platy, s-spherical, t-threads, r-reticulate; **Location(Loc)**-matrix/ped/pores/others.
7. **Amount(Amt):** vf-very few(<5%), f-few(5-<25%), c-common(25-<50%), m-many(50-<90%), vm-very many(>90%);**Distinctness(Dst):** f-faint, d-distinct, p-prominent; **Continuity(Cont):** c-continuous, d-discontinuous, p-patchy; **Kind(Kd):** Type of coating/stress features; **Location(Loc)**: on bottom/top or all faces of peds; **Colour(Col)**: Munsell
8. **Concentrations:** Quantity(qty), Size(sz), Contrast(cn) and Colour are to be described similar to that of the mottles; **Kind(Kd)**: Disseminated materials, Masses, Nodules, Concretions, Crystals and Biological concentrations.

9 & .10. **Roots/Pores: Quantity**: f-few(<1 per area), c-common(1-5), m-many(>5); **Size**: vf-very fine, f-fine, m-medium, c-coarse; vc- very coarse; **Location(Loc):** between peds(p), in cracks(c), throughout(t); **Shape(Shp):** tubular/irregular/vesicular/interstitial. 11. **Effervescence:** 1-slight, 2-strong, 3-violent.

2

Soil series establishment and phase map preparation

Grouping of similar kind of soils called soil series and it is a basic mapping unit in detailed soil survey. Soils which are similar in surface characteristics (Texture, Slope, Erosion and gravelliness) are grouped as phases.

Following Institutes are supporting REWARD in Karnataka for generation of data required for scientific planning of watersheds

NBSS&LUP, Regional Centre, Bengaluru	Lead Partner for LRI
University of Agricultural Sciences, Bangalore	Partner for LRI and hydrology
University of Agricultural Sciences, Dharwad	Partner for LRI and hydrology
University of Agricultural Sciences, Raichur	Partner for LRI and hydrology
University of Agricultural Sciences, Bangalore	Partner for LRI and hydrology
University of Agricultural & Horticultural Science, Shivamogga	Partner for LRI and hydrology
University of Horticultural. Science, Bagalkot	Partner for LRI and hydrology
Indian Institute of Science, Bengaluru	Lead Partner for Hydrology
Karnataka State Remote Sensing and Application Centre, Bangalore	RS and GIS
Karnataka State Natural Disaster Management Centre, Bengaluru	Meteorological aspects

Output of LRI approach

The atlas contains basic information on kinds of soils, their geographic distribution, characteristics and classification. The soil map and soil based thematic maps derived from data on soil depth, soil texture, soil gravelliness, slope, erosion, land capability, land suitability for various crops and land use maps are presented. The maps on fertility status *viz*., soil reaction, salinity (EC), organic carbon, nitrogen, phosphorus, potassium, sulphur, exchangeable calcium and magnesium, available copper, manganese, zinc, iron and boron were derived on analysis of surface soils sampled at 320 m grid spacing within the micro watershed. The atlas illustrates maps and tables that depict the soil resources of watershed and the need for their sustainable management.

The user, depending on his/her requirement, can refer this atlas first by identifying his/her field and survey number on the village soil map and by referring to the soil legend which is provided in tabular form after the soil map for details pertaining to his/her area of interest.

The atlas explains in simple terms the different kinds of soils present in the watershed, their potentials and problems through a series of thematic maps that help to develop site-specific plans as well as the need to conserve and manage this increasingly threatened natural resource through sustainable land use management. The Land Resource Atlas contains database collected at land parcel/survey number level on soils, climate, water, vegetation, crops and cropping patterns, socio-economic conditions, marketing facilities etc. helps in identifying soil and water conservation measures required, suitability for crops and other uses and finally for preparing viable and sustainable land use options for each and every land parcel. LRI also helps in grouping together areas where similar land resource exists on ground, which require the same kind of management, the same kind and intensity of conservation treatment and same kind of crops, pasture or forestry species, with similar yield potentials.

Data products of LRI atlas

1. **Location and extent:** Indicate the location of watershed with latitude, longitude along with total area cover and area bounded.
2. **Agro Ecological Sub Region of watershed:** Represent the Agro Ecological Sub regions of watershed among different Agro Ecological Sub regions of India.
3. **Agro-climatic Zone of watershed:** Indicate the Agro-climatic Zone under which the watershed falls along with the total geographical area, total cultivable area under irrigation, mean sea level (MSL), average annual rainfall, major soil types and main cropping season of that particular Agro-climatic Zone.
4. **Base maps, satellite images and cadastral maps:** Before start of an inventory, there is a need for the data resources like base maps, satellite images and cadastral maps to study the location features and existing situation.

a. **Base map:** A base map is the graphic representation at a specified scale of selected fundamental map information; used as a framework upon which additional data of a specialized nature may be compiled (American Society of Photogrammetry, 1980).

b. **Satellite image:** Satellite images are images of earth collected by imaging satellites. At present for survey (inventory), we (Karnataka) are using maps in the False Colour

Composite (FCC) form at 1: 8000 scale from Karnataka State Remote Sensing and Application Centre (KSRSAC), Bengaluru.

5. **Cadastral map:** Cadastral Maps are a digital form of land records that show all the boundaries of different parts of land (survey number of land parcels).

   The above said satellite image and cadastral maps overlaid with and without grid are used for the survey.

6. **Rainfall trend in watershed area:** The watershed area temperature, annual rainfall, South West monsoon, North East monsoon and pre monsoon data to be recorded, which will be further useful in suggesting the crop plans and conservation measures.

7. **Geology:**

a. **Geology of State:** Information on the geology of the State helps to know the distribution of different types of rocks and minerals, weathering stages in soil, dominant rocks, minerals and major soil types.

b. **Geology of watershed area:** Study of the geology of the particular watershed area helps to know the predominant rocks and minerals, weathering stages and major soil types.

8. **Current land use map:** The information on present serve (use) of the land (*i,e.,* cultivable land, non-cultivable land (fallow land) and use for construction, *etc*.) under particular watershed will be collected and represented in the map to know the percent usage of land.

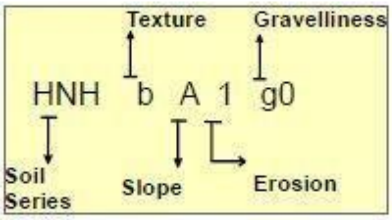
9. **Location of wells map:** The total number of wells (open wells and bore wells) existing in the particular watershed area will be indicated in the maps along with their location.

10. **Existing Structures:** Existing soil and water conservation structures (agronomical and mechanical), water harvesting structures (farm pond, gokatte, *etc*.) will be recorded.

11. **Soil characteristics:** During land resource inventory, data/observations on surface soil features like soil texture, slope, soil erosion, gravelliness and subsurface features like soil depth and profile characteristics as per pedon description form will be recorded and represented in the form of thematic maps.

12. **Mapping unit description:** Mapping units are represented in the form of surface characteristics combined with series code on map, that should be described clearly in the atlas. Also, extent of area occurring in the mapping unit to be mentioned.

Ex: HNHbA1: Moderately shallow, non-gravelly (0-15%) loamy sand, derived from granite gneiss, occurring on nearly level land, slope 0-1 per cent and slight erosion.



13. **Soil fertility description:** It represents the status and distribution of different soil fertility parameters like pH, electrical conductivity, organic carbon, available nitrogen,

phosphorus, potassium, sulphur, exchangeable calcium, magnesium, DTPA extractable iron, manganese, copper, zinc and hot water-soluble boron in the particular watershed area, which will be further helpful to correct the deficit nutrient through proper nutrient management techniques.

14. **Land capability classes:** Land capability classification is a system of grouping soils primarily on the basis of their capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time. There are eight land capability classes

    Class I- Class IV: Suitable for cultivation

    Class V- Class VIII: Not suitable cultivation and suitable only for pasture and recreation.

Classification of soils based on their capability helps to know the usefulness of the land

15. **Land suitability for different crops:** Under this section we can assess the suitability of land/soils for cultivation of particular crops *viz*., cereals (paddy, ragi, maize *etc.*), pulses (red gram, black gram, cowpea *etc.*), oilseeds (groundnut, sunflower *etc.*), plantations (tea, coffee, coconut, *etc.*) and commercial crops (sugarcane, cotton *etc.*).
16. **Land management units (LMU):** It is the grouping of different soils into single management unit based on their similar characteristics' features. It helps to propose similar management practices. The number LMUs we can get in a particular watershed area is based on the variability in management requirements of lands. If the variation in the land features is more, more the number land management units.

Ex: LMU-1, LMU-2, LMU-3 *etc.*

17. **Proposed crop plan based on LMU:** After grouping of soils into LMUs, suitable crops for cultivation to that particular watershed area is to be proposed which helps to exploit the yield potentials of the crops. Along with suitable crop plan, suitable interventions like cultivation on raised beds with mulches and irrigation system with suitable soil and water conservation measures and application of amendments if needed is to be proposed.
18. **Economic land evaluation of different land use types:** Economic evaluation of the land is very much important and it will be done based on benefit cost ratio (B:C ratio) and land suitability classes.

The FAO framework defines two suitability orders: 'S' (suitable if Benefit Cost Ratio (BCR) >1) and 'N' (not suitable if BCR< 1), which are divided into five economic suitability classes: 'S1' (highly suitable if BCR >3), 'S2' (moderately suitable if BCR >2 and < 3), 'S3' (marginally suitable if BCR >1 and < 2), 'N1' (not suitable for economic reasons but physically suitable), and 'N2' (not suitable for physical reasons).

19. **Runoff distribution:** Knowing runoff status of the particular watershed area is important to adopt the proper conservation measures.
20. **Conservation plans:** After knowing all the variation in the particular watershed area, suitable conservation plans will be proposed.
21. **Conclusion:** Correction of variation in the particular watershed area with suitable technologies helps to conserve the natural resources effectively and exploit the potentials of the area economically.

3. An over view of Hydrology studies - meaning, importance, process of data generation and Output

Importance of Agro-hydrological Monitoring

Agro-hydrology can be regarded as the study of hydrological processes and the collection of hydrological data, aimed at increasing the efficiency of crop production, largely by providing beneficial soil moisture conditions. However, the influences on the production of runoff and the ways that runoff affects the environment within which crops grow are very diverse and agro-hydrological study, of necessity, also includes the collection of information on climate, soils, vegetation, and topography. Rainfall amount and its spatial and temporal distributions determine the quantity of water that reaches the land's surface. Temperature and humidity, the type, amount and distribution of vegetation cover determine what proportion of this water re-evaporates. Vegetation, soil conditions and topography determine how much water infiltrates into the soil, how much runs off the land's surface and where it goes. It is the interaction of these complex processes and the volumes of runoff that these processes produce that form the core research of agro-hydrology. Knowledge of the hydrological environment is necessary to determine whether or not opportunities to create optimal soil moisture conditions exist, and how these opportunities can be exploited.

Hydrological Field Measurements in the Selected Micro Watersheds Installation of the equipment's

To provide precise weather-related information, forecast and advisory to the farmers for planning agricultural activities and to minimize crop loss due to adverse weather conditions, automatic weather stations are set up in every model micro watershed. Rainfall information at every 15 minutes time interval will be captured. In addition to this, weekly rainy days, daily temperature, relative humidity, evapotranspiration, mean wind speed, etc. are recorded and effectively will be used in the REWARD project. The hydrological instruments (diver for runoff and groundwater measurement) will be installed at model micro watersheds to get periodical hydrological information and to support hydrological studies. The agro-hydrological parameters measured and monitored include soil moisture (surface and profile), groundwater levels, bore wells discharge and yield, water quality surface and groundwater, and canopy variables (LAI, biomass, crop yield, crop management activities).
In an experimental watershed, the following agro-hydrology components are monitored or measured:

Soil Moisture

Surface Soil Moisture (SSM) plays a vital role in various processes occurring on the soil atmosphere interface. The evaporation is controlled directly by the surface soil moisture; the transpiration is controlled by the soil moisture present in the root zone. The precipitation passes through surface soil moisture to reach the root zone. Hence, surface soil moisture could be able to provide some insight into the root zone soil moisture. This means that surface soil moisture may be a useful variable to predict the hydrological cycle over land. Apart from hydrology, it is also useful in various other applications e.g., agronomy, drought management and in the improvement of disaggregation/downscaling of precipitation etc.

Surface soil moisture

Currently, surface soil moisture is assessed for the following three main reasons:

- ✓ To validate the radiometer satellite data
- ✓ To calibrate the STICS crop model
- ✓ Calibration/Validation of SAR satellite data

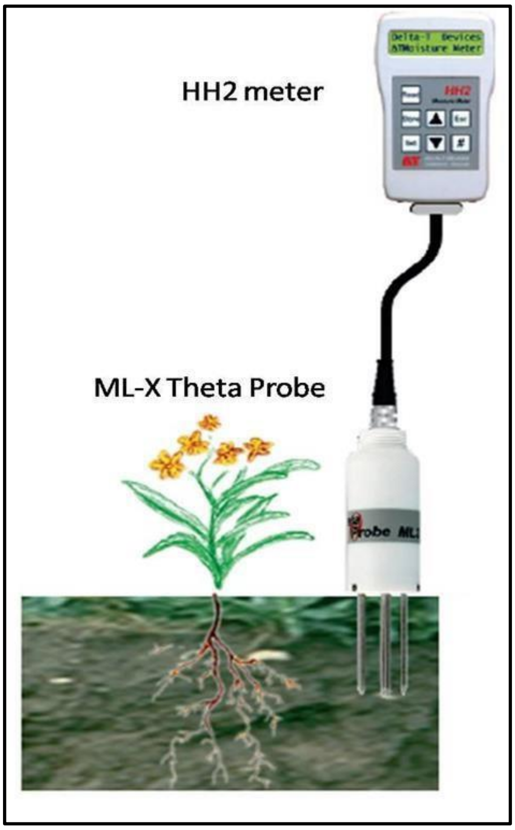
The two methods for measuring the surface soil moisture are detailed in the following two subsections:

Volumetric Soil moisture measurement (Theta Probe)

Surface soil moisture is measured using ML2x theta probe (Delta-T devices, Delta-T Devices Ltd, Cambridge, UK), which measures soil moisture averaged over 0 to 5 cm depth and equipped with a HH2 meter for spot measurements and display. Accuracy of measurements is ± 1 %. Figure depicts a Theta probe and HH2 meter (Delta T Devices) assembly. The operating principle, steps to be employed during measurements etc. of this probe is given below.

Operating Principle

Theta Probe measures soil parameters by applying a 100 MHz signal via a specially designed transmission line whose impedance is changed as the impedance of the soil changes. This impedance has two components; the apparent dielectric constant and the ionic conductivity. The signal frequency has been chosen to minimize the effect of ionic conductivity, so that changes in the transmission line impedance are dependent almost solely on the soil's apparent dielectric constant. These changes cause a voltage standing wave to be produced which augments or reduces the voltage produced by the crystal oscillator, depending on the medium surrounding the measurement prongs. The difference between the voltage at the oscillator and that reflected by the rods is used by Theta Probe to measure the apparent dielectric constant of the soil. A linear correlation exists between the square root of the dielectric constant, (Ve), and volumetric moisture content, (0), which is used to convert the measured dielectric constant to soil moisture.

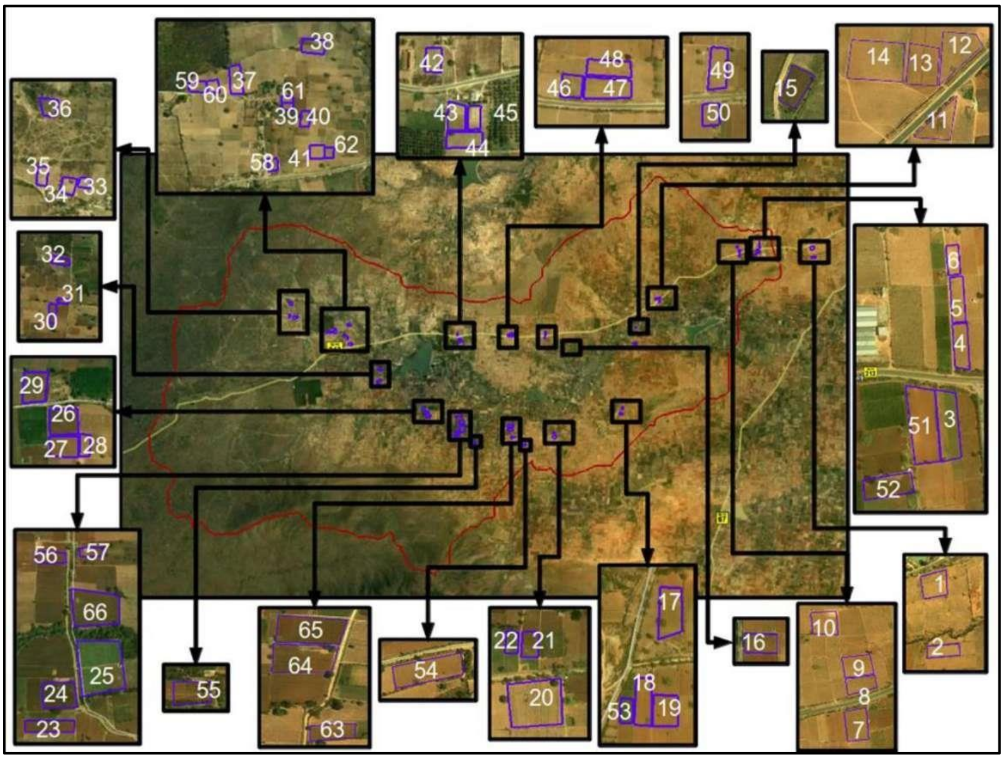


Theta probe and HH2 meter (Delta T Devices)

Steps to be employed for the measurement

- ✓ The theta probe needles should be inserted (penetrated) fully into the soil vertically. Take care while inserting the probe in stony soils as it may damage the needle. In such cases if it is difficult to insert the probe in a particular location try a few other locations in the plot where the needles can penetrate without much force being applied.
- ✓ Three readings should be taken for each plot (soil unit), to get the mean value that is representative of the field plot and variability.
- ✓ If the plot is with furrows and ridges (as in the case of turmeric), then take one reading at the top of the furrow, one in the ridge, one at another representative location.
- ✓ If the plot is partially irrigated, take at least two measurements in the irrigated area and mark the reading as irrigated.
- ✓ If the plot is irrigated the previous day of measurement, note it down in the field note. At least one measurement has to be made within the 2 sq.m area adjoining the location where the access tube is installed.
- ✓ Note down the label number of the Delta-T probe. (Usually, each Theta probe is given an identification number by the field team, this will help us in calibration) Do not take soil moisture reading too close to a crop, as the probe may penetrate the root and measurements may be misleading.
- ✓ Do not take soil moisture reading in the loose soil as the presence of air gaps may affect the measurements.

- ✓ If the reading cannot be taken for the dry soil (hard to penetrate the needles), note down that in your diary. (This usually occurs in summer season in most soils) Note down the crop type.



Map showing a Typical Layout for Soil Moisture Monitoring Field-Plots

Soil Moisture Profile

The procedure for profile soil moisture measurements, the instruments used and their operating principle, calibration techniques are discussed below. Profile soil moisture are being monitored/measured either continuously or intermittently at regular frequency in a watershed for cropped and uncropped areas.

TRIME-PICO IPH Soil moisture Sensor

Operating Principle

The TRIME device generates a high-frequency pulse (up to 1GHz) which propagates along the metal shells, generating an electromagnetic field around the probe. At the end of the shells, the pulse is reflected back to its source. The resulting transit time (3ps...2ns!) can be measured and enables determination of the propagation velocity, which is primarily dependent on the water content. The volumetric water content is then calculated by the velocity and is shown on the display panel immediately. The particular probe that is used to depict the procedure is T3/44, which has moisture measuring range from 0 to 60 % (volumetric water content) and an accuracy of ± 2%. Measuring volume: The effective penetration depth of the probe T3 is about 15 cm with the highest sensitivity in the immediate vicinity of the access tube, and decreases exponentially as distance increases.

Installation of Access Tubes

Access tube of TRIME contains three parts, the tube (1 m or 2 m long) with a metal ring at the bottom, a rubber cork (to seal the bottom of the tube) and a plastic cap to cover the top of the tube. It is necessary to maintain close contact between the access tube and the soil material for reliable measurements; hence the tubes should be installed as recommended by the manufacturer. Alternatively, the access tubes can be installed by following the steps below.

- ✓ Fix the rubber cork tightly inside the metallic ring at the bottom of the access tube, this can be fixed with the help of the auger provided with the instrument. (The specially designed auger has provision for tightening the rubber cork). Additionally, it is better to seal the bottom with cello tapes to ensure that no water seeps into the tube from the bottom. Close the top of the access tube with the plastic cap.
- ✓ Drill a hole to the required depth (1 m or 2 m) using the auger provided by the manufacturer. Save soil in a small bucket to mix with water to form a well-blended mud. Pour the mud back into the hole until it is full.
- ✓ Insert the Access Tube in an auger hole. Move the tube up and down (inside the hole) a few times to remove all air. Mud should come up to above surface level
- ✓ Fix the access tube in this position and insert the Probe into the access tube, slowly lower it to the bottom and note the readings, since the readings are taken immediately after installation all the readings should be in the high (40 to 50 %) and consistent.
- ✓ Lower readings indicate the presence of air gaps which should be fixed immediately by following step 3.
- ✓ Installation of access tubes can be carried out at least two weeks before the intended start of the experiment, since the newly installed access tube may take at least 10 days to settle.

TRIMEPICO IPH for Profile Soil Moisture Measurements

How to Measure

- ✓ Open the cap of the access tube and insert the sensor slowly into the tube till the sensor is fully below the ground level. Note down the reading from the data logger.
- ✓ Now slowly push the sensor further down to the required depth (depth is marked in the cable with a white tape) and continue taking measurements. Continue this process till the whole of the access tube (1 m or 2 m) is covered.
- ✓ Note the reading and depth of measurement each time.
- ✓ Note also the crop type and general condition of the plot (like irrigated or rained etc.).
- ✓ In dry soil, sometimes it will be difficult to push the sensor inside the access tube, in such cases it is better to avoid taking measurements since the sensor may get struck inside the access tube and pulling it back by force may damage the connecting wires.
- ✓ Do not make the sensor or the data logger to hang from the cable while taking for field measurements since this will lead to wear and tear in the connecting cable and eventually the sensor unit may be disconnected from the logger. Always support the sensor and logger with hand or use the instrument box each time.

Continuous Soil Moisture Monitoring

Continuous monitoring of surface and profile soil moisture is essential to understand the controls of soil moisture in the watershed. Such data can help in irrigation scheduling, calibration, and validation of satellite soil moisture products and in predicting drought.

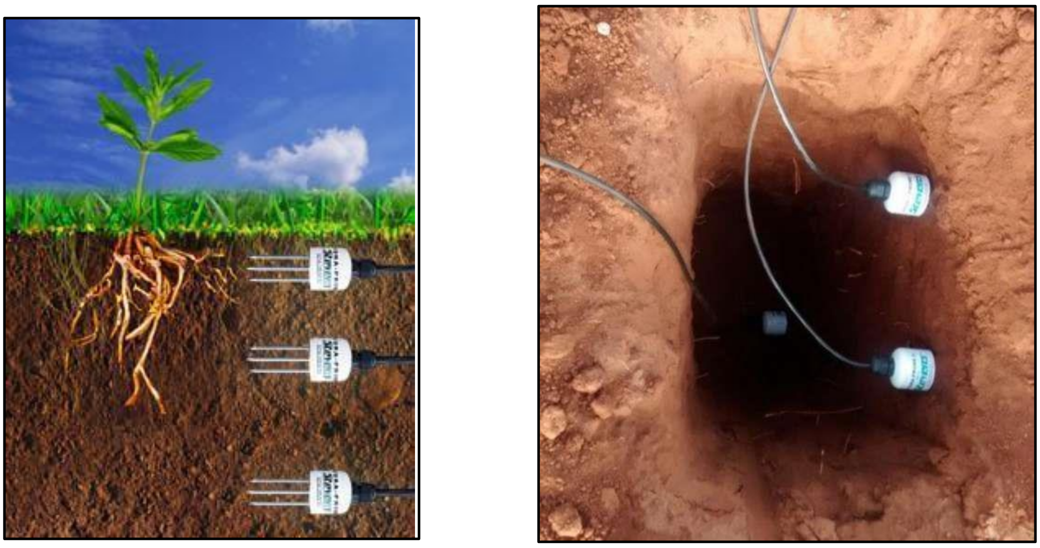
HYDRA Probe Soil Moisture Sensor

The Hydra Probe sensor uses the Coaxial Impedance Dielectric Reflectometry method in soil moisture measurement. The Coaxial Impedance Dielectric Reflectometry method of soil moisture measurement employs an oscillator to generate an electromagnetic signal that is propagated through the unit (usually by metal tines or other wave guide) and into the soil. The probe sends electrical signals into the soil, measures the responses, and relays this information to a data collection device known as a data logger. Part of this signal will be reflected to the unit by the soil, and the sensor will measure the amplitude of this reflected signal and the incident signal in volts. The ratio of these raw voltages is used in a mathematical numerical solution to Maxwell’s equations to first calculate the impedance, then both real and imaginary dielectric permittivity which in turn is used to accurately estimate soil water content.

Installation and Calibration

- ✓ Excavate a hole no larger than 25” x 25” square and 25” deep for the sensor installation pit. To best re-create the original soil horizons, these soil layers should be replaced in the pit in the same order they were removed.
- ✓ Trench from the location of the power source and data logger to the sensor installation pit. Assemble rigid or flexible PVC conduit to protect the sensor wires.
- ✓ Check that there is enough cable length to reach up through the soil pit and through the conduit to the data logger. Label sensor wires with sensor depth or position at both ends – the sensor end and the end that will be hooked up to the data logger.

- ✓ Before installing sensors into the soil, connect the wires to the data logger and power source. Test each sensor separately in moist soil to make sure that it is working as expected. A small cup with moistened soil works well for testing because each sensor should give very close to the same reading for soil moisture and temperature.
- ✓ Install the 50cm, 5cm, and 5cm sensors along the pit face in a staggered pattern, carefully backfill the soil in the rest of the pit and leave drip loops in all the wires.
- ✓ Gather all the wires together at the surface and seal the end of the conduit with duct seal putty. When all the sensors are in place and the installation is complete, bury the conduit in the trench

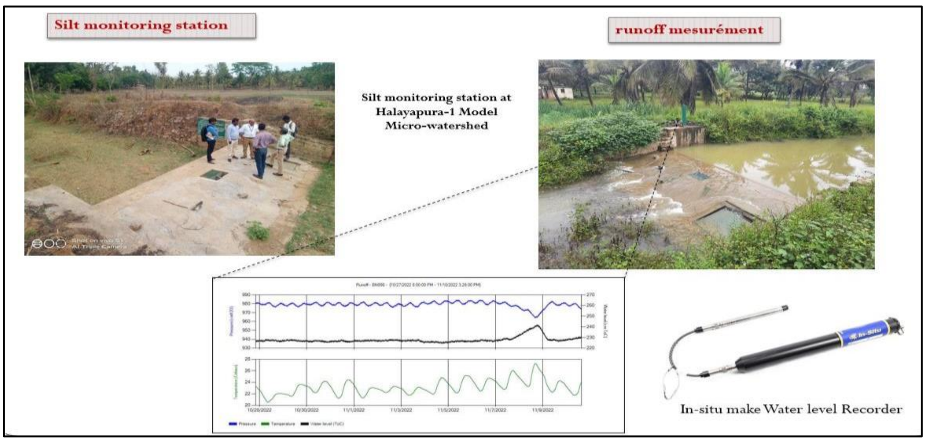


Schematic of HYDRA Probe Soil Moisture Sensor

Measurement of Runoff

The detailed monitoring surface runoff at the outlet of the micro watershed will be measured using a CTD diver and analysis will be done by using check dam weir formulae.

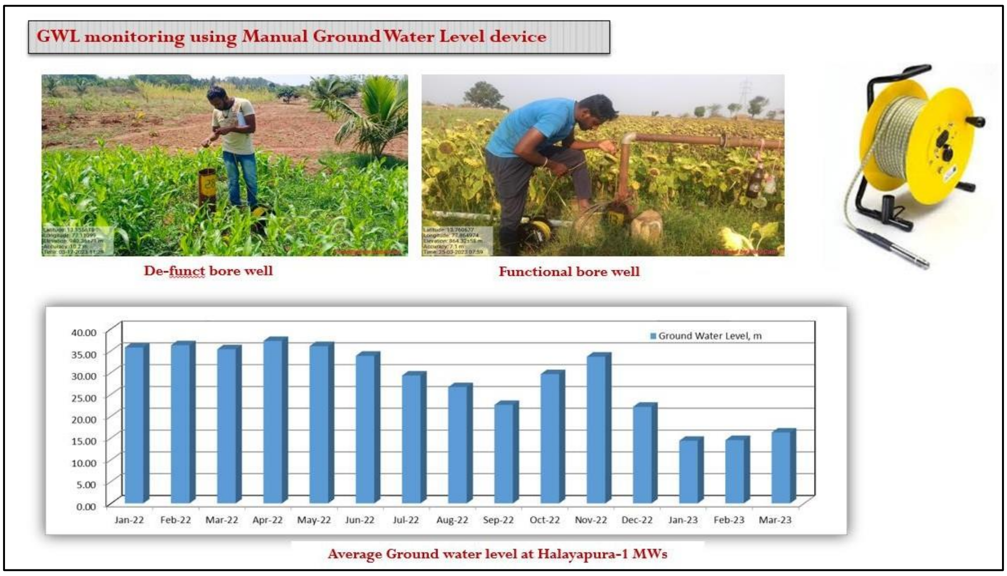
An in-situ water level recorder is a device designed to measure and record changes in water level within natural water bodies such as rivers, lakes, and wells. It is typically placed directly in the water or in a well, allowing it to accurately monitor fluctuations in water levels over time. This instrument is essential for hydrological studies, flood forecasting, and resource management, providing valuable data for understanding water availability and changes in water storage within various aquatic environments.



Runoff measurement and silt monitoring station at outlet of the micro-watershed

Groundwater studies

The detailed monitoring of hydrological characteristics like water table fluctuation (Monthly) and water yield (seasonal) in the model micro watersheds will be observed. Totally 75 (including function, and defunct) wells will be selected for monitoring the groundwater table. The groundwater samples will be collected seasonally (Kharif, Rabi and Summer) and analysis will be done for different chemical parameters viz., pH, EC, Cl, SAR, and RSC to assess its quality for irrigation purposes.



GWL monitoring using manual ground water level device and readings

Evapotranspiration

The demand for fresh water is on a steady rise due to ever expanding human activities. Moreover, in the light of climate change; least and less developed nations are facing the threat of acute shortage of water in the future decades. The distribution of water is not the same across the globe and it is the top priority of the scientists in the field to understand the different processes of the hydrologic cycle and estimating the quantum of water available in each phase of the cycle at regional and country levels. In India, though stream flows and groundwater levels are observed periodically, reliable data on the quantity of water reaching the atmosphere through evapotranspiration (ET) is not available. This lack of data causes high uncertainties in closing the water budget and estimating the quantum of water available for human consumption. ET is a critical component of the hydrologic cycle and moreover, it is the terrestrial link to the atmosphere as it connects the energy and water cycle. Accurate estimation of ET is a major requirement for land surface modeling, numerical weather prediction and irrigation supply to crops etc. ET is the combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration. Evaporation is the process whereby liquid water is converted to water vapor (vaporization) and removed from the evaporating surface (vapor removal). Transpiration consists of the vaporization of liquid water contained in plant tissues and the vapor removal to the atmosphere

ET Measurement using Agro-Meteorological Stations

Evapotranspiration is not easy to measure. Specific devices and accurate measurements of various physical parameters or the soil water balance in lysimeters are required to determine evapotranspiration. The methods are often expensive, demanding in terms of accuracy of measurement and can only be fully exploited by well-trained research personnel. However, there are other indirect methods like the Bowen ratio energy balance and the eddy covariance available to estimate ET. These indirect methods require input from data on several variables measured in Agro-Meteorological Stations install in the field. ET is estimated at any given site using the measurements from the 10 m tall micrometeorological tower (popularly called Agro-Met Station and abbreviated as AMS). The various instruments and the measured variables are listed in Table. Figure presents a picture of the AMS tower. All the parameters are measured at 5 m intervals and averaged for 30 m. The data for every half hour is stored in a data logger and transmitted through a yagi antenna to pre-determined server.

List of Different Instruments and Observed Weather Variables at The AMS Tower

Sl. No.	Observed parameter	Instrument	Height(s) of installation
1	Air temperature	Platinum resistance thermometer	2 m, 4 m and 6 m
2	Relative Humidity	Capacitor Type	2 m, 4 m and 6 m
3	Wind speed and wind direction	Cup Anemometer	2.5 m, 5 m and 10 m
4	Atmospheric pressure	Transducer	2 m
5	Rainfall	Tipping Bucket rain gauge	1 m
6	Net radiation • Shortwave incoming • Shortwave outgoing • Longwave incoming • Longwave outgoing	Four component net radiometer	3 m
7	Diffuse radiation	Shaded pyranometer	3 m
8	Soil heat flux	Flux plate	-0.05 m, -0.2 m
9	Soil temperature	Soil Thermometer	-0.05 m, -0.15 m and -0.3 m

AMS Tower Installed in the Field

Preparation of Hydrologic Atlas/Outcomes

Integrated hydrological assessment and monitoring involves hydrological data gathering, behavior mapping & processes understanding at micro-watersheds scale. The objective is that the hydrological monitoring aided by advanced hydrological data & customized models developed in the process will aid in producing hydrological budgets at relatively higher temporal frequency (e.g., weekly/monthly) and at the desired spatial granularity in small/micro watersheds, for improved sustainable water management. The focus is to assess the links between groundwater conditions in the watersheds and design of soil & water conservation measures; groundwater level changes & water yields in hard rock aquifers; impacts of water stress on crop productivity; and land management changes and impacts on groundwater recharge & runoff. Further the additional objective is to integrate the hydrological variables & water budgets with the land resource inventory mapping for developing robust integrated watershed management plans.

Once the procedures are implemented for a given watershed and compilation of required primary and secondary data is done, the next step is to use these data to prepare several elements for the hydrological atlas for the watershed. Below section, methodology for computation and analysis associated with the preparation of hydrologic atlas is discussed.

Location and Index Maps for the Study Area

At the very beginning of the study several hydrological and other required information are collected about the study area. Some of these are boundary and geographical location, location of monitoring sites, drainage network, habitation, cadastral boundaries, sub-watershed boundaries etc. This information is then transformed into several thematic GIS layers and then show them in map.

Rainfall indices

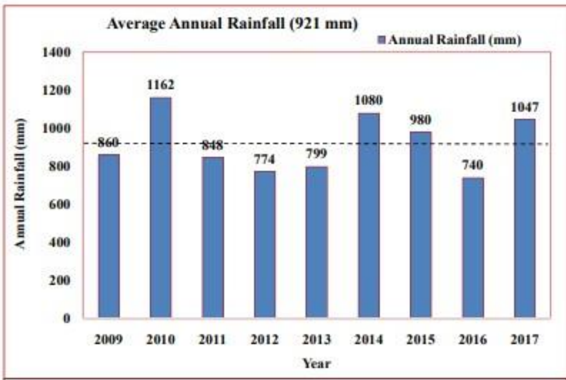
The first task is to compile a catchment-averaged time series by combining the available rainfall data from several sources with lowest possible frequency and longest possible record. Depending upon data availability and context of the project objectives multiple such rainfall series may be prepared. Once that is done, many types of summary time series are to be prepared for the hydrological Atlas.

Summary Time Series Plots

For the Maidalakere sub watershed following four types of summary time series plots are prepared using the available rainfall data.

- ✓ Annual Rainfall Time Series: These are prepared by aggregating the available daily (and sub-daily, as the case may be) rainfall over the calendar year for the period of record.
- ✓ Kharif Rainfall Series: The period from June to September has been considered as Kharif season for a particular calendar year and the corresponding time series is to be prepared in similar way as that of the annual series.
- ✓ Rabi Rainfall Series: The period from October to January has been considered as Rabi Season for a particular calendar year and the corresponding time series is to be prepared in similar way as that of the annual series.
- ✓ Summer Rainfall Series: The period from February to May has been considered as Summer Season for a particular calendar year and the corresponding time series is to be prepared in similar way as that of

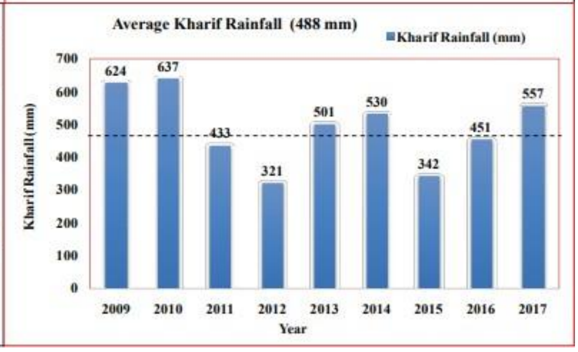
RAINFALL INDEX



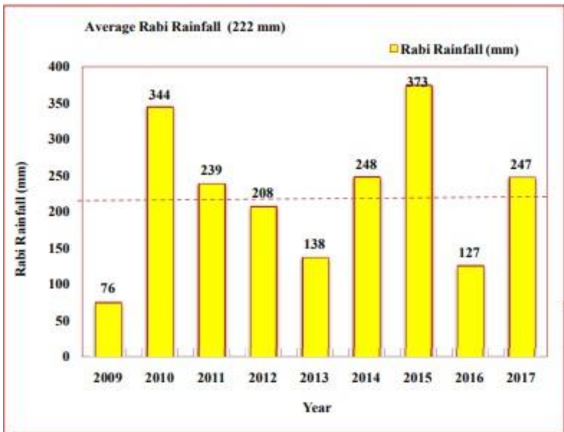
The average annual rainfall observed from the Uradigere rain gauge station found near to Maidalakere SWS in Tumkur taluk was 921.0 mm. 2009 (6.6%), 2011 (7.9%), 2012 (16.0%), 2013 (13.3%) and 2016 (19.7%) were recorded as deficient years during the period 2009-2017.

The *kharif* rainfall (June-Sept) is about 53.0% of the average annual rainfall and it typically follows the annual rainfall patterns.

The years 2009 (21.7%), 2010 (23.4%), 2013 (2.5%), 2014 (7.8%) and 2017 (12.3%) had received excessive rainfall.

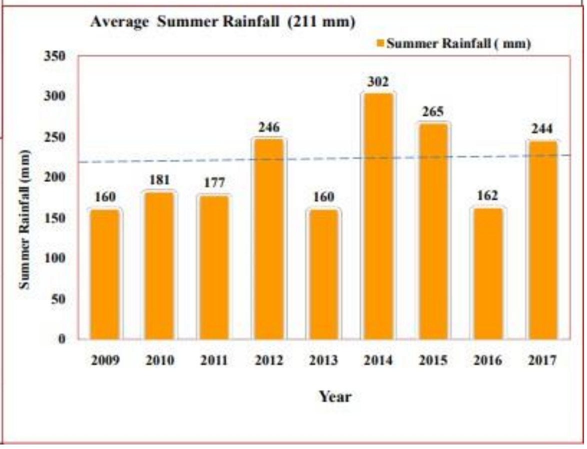


RAINFALL INDEX



The *Rabi* rainfall (Oct-Jan) is about 24.1% of the annual rainfall. 2009 (65.7%) recorded lowest and 2015 (40.5%) year recorded high rainfall. Four years recorded low *Rabi rainfall*.

The *Summer* rainfall (Feb-May) is about 22.8% of the average annual rainfall. 2009, 2010, 2011, 2013 and 2016 found very low rainfall. While 2012, 2014, 2015 and 2017 years had received the higher rainfall than average.



Summary Time Series Plots for Rainfall

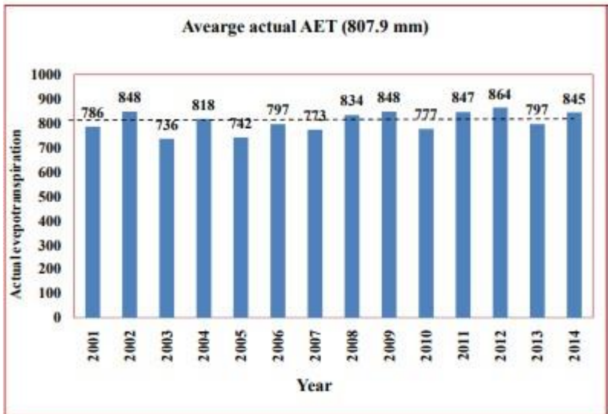
Evapotranspiration and Associated Indices

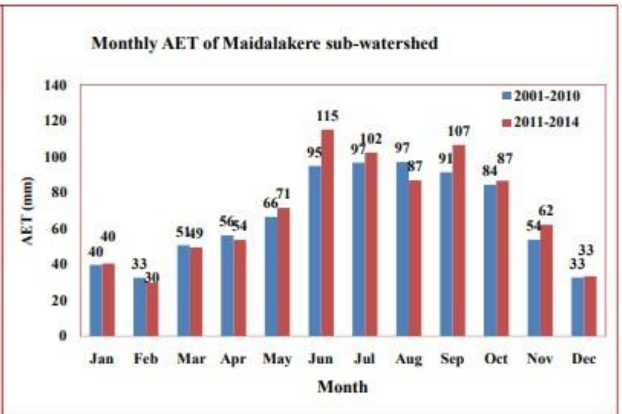
Several types of indices are developed using available time series of Actual Evapotranspiration (AET). Generally, AET time series are compiled at daily time step and with catchment-averaged values. Using this time series data following summary time series are prepared and presented in graphical & tabular forms as part of the Atlas.

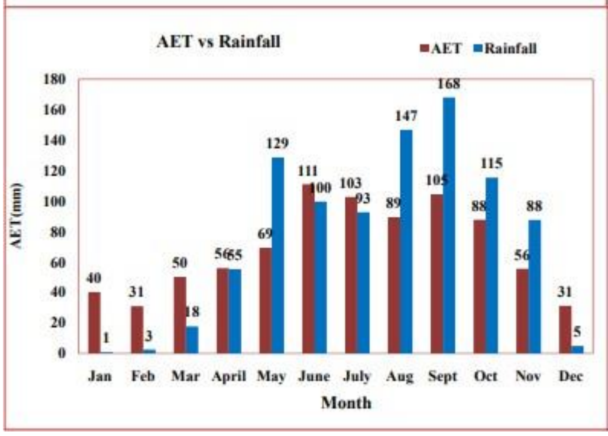
Summary Time Series Plots

- Annual total AET series over the period of record; from this series Annual Average value of AET for the given catchment is also computed.
- Annual Average AET series for each of the calendar month. In this case, temporal averaging is done over all the years in the period of record. Using this Monthly Average AET series following two types of summary plots are prepared:
- Month wise comparison of AET and Rainfall over the period of record.
- Month wise of variation in AET over two consecutive decades, depending upon the length of available time series of AET.

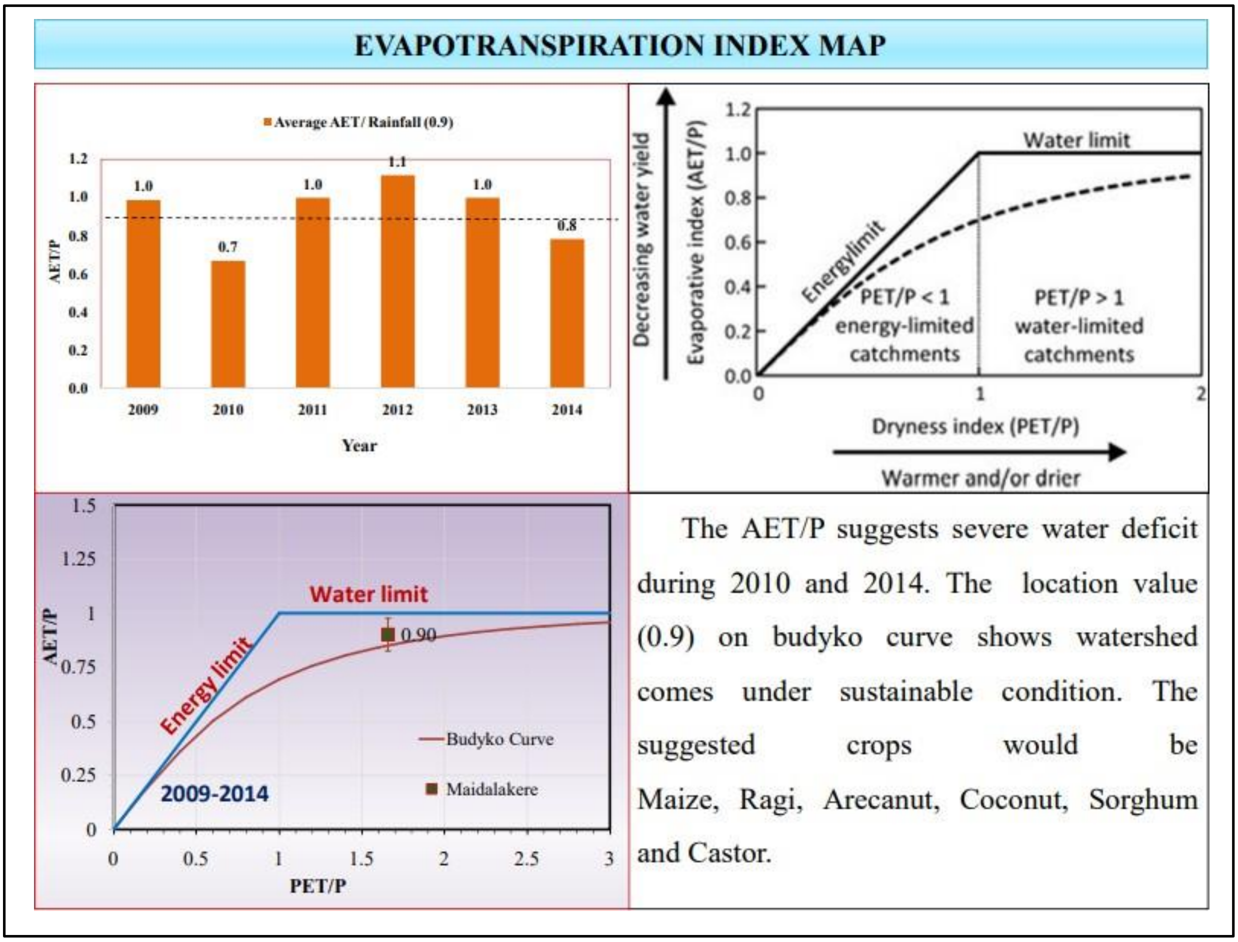
EVAPOTRANSPIRATION







During 2009 to 2014 the average annual AET (829.4 mm) is lower than the average rainfall (920.4 mm). Hence runoff can occur in the watershed. It indicates to change the cropping pattern to maintain AET. During *Kharif*, average rainfall and AET found to be 507.3 mm and 407.7 mm respectively, whereas in *Rabi*, they were 208.7 mm and 215.0 mm. During May, August, September, October and November month AET is less than Rainfall.



Evapotranspiration and associated indices of Maidalakere sub-watershed

Surface Soil Moisture Data

Surface soil moisture data are generally depicted either as time series plot or as raster maps over the whole watershed.

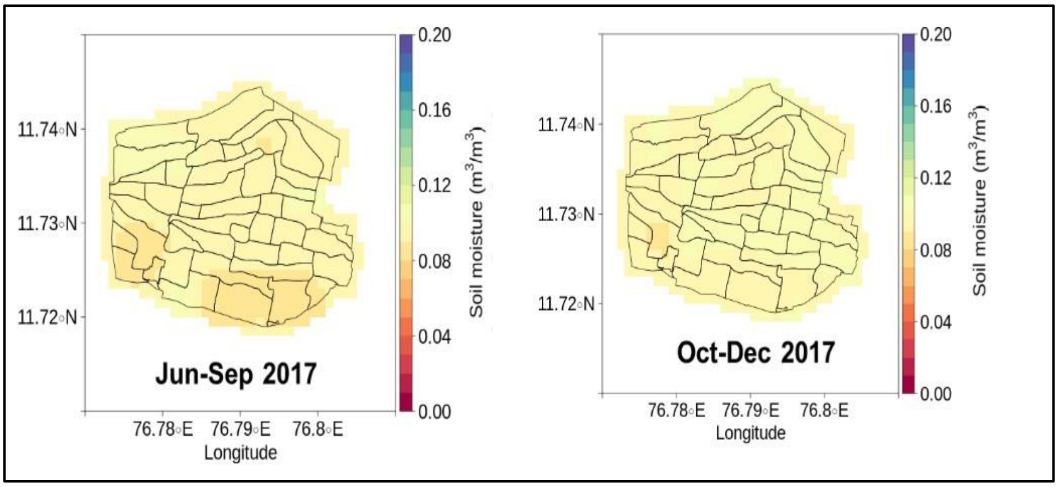
Spatial Maps

Surface soil moisture maps over a given micro-watershed for Kharif and Rabi Seasons is given below. These maps are prepared using satellite remote sensing products. The following facts are to be noted:

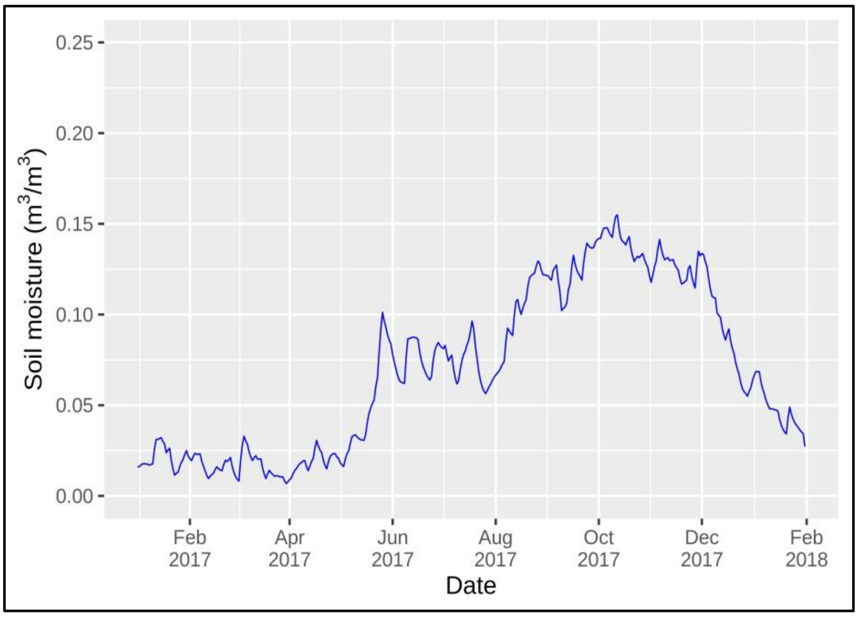
- Seasonal maps are prepared by aggregating multiple images over the watershed.
- Cadastral maps are always overlaid on top of soil moisture rasters.

Time Series Plots

Aggregating the surface soil moisture data over the study watershed a catchment aggregated soil moisture time series are prepared to assess the temporal variability.
Soil moisture comparison plots should also be created to evaluate the coincidence of the field and satellite observations to cross-check the data accuracy from both the sources

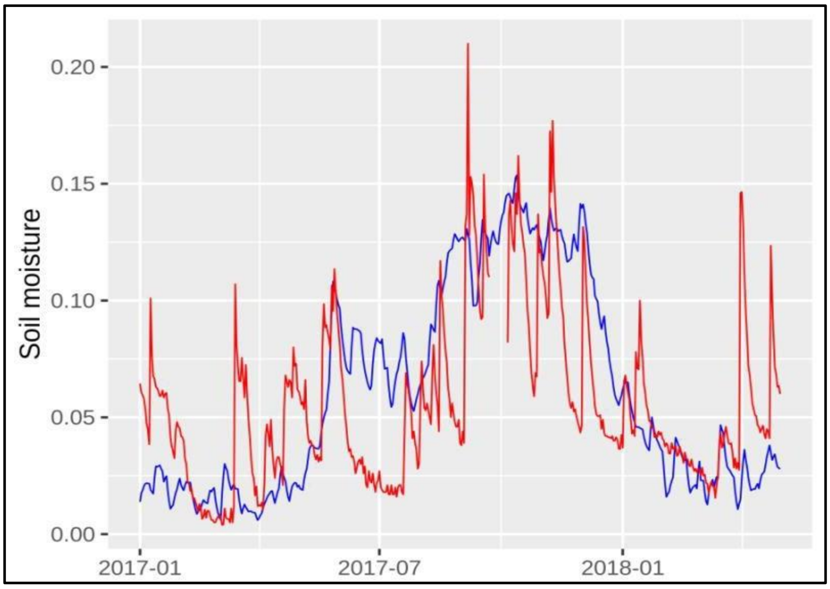


Satellite-derived Surface Soil Moisture Maps over a Study Watershed for Kharif and Rabi Seasons

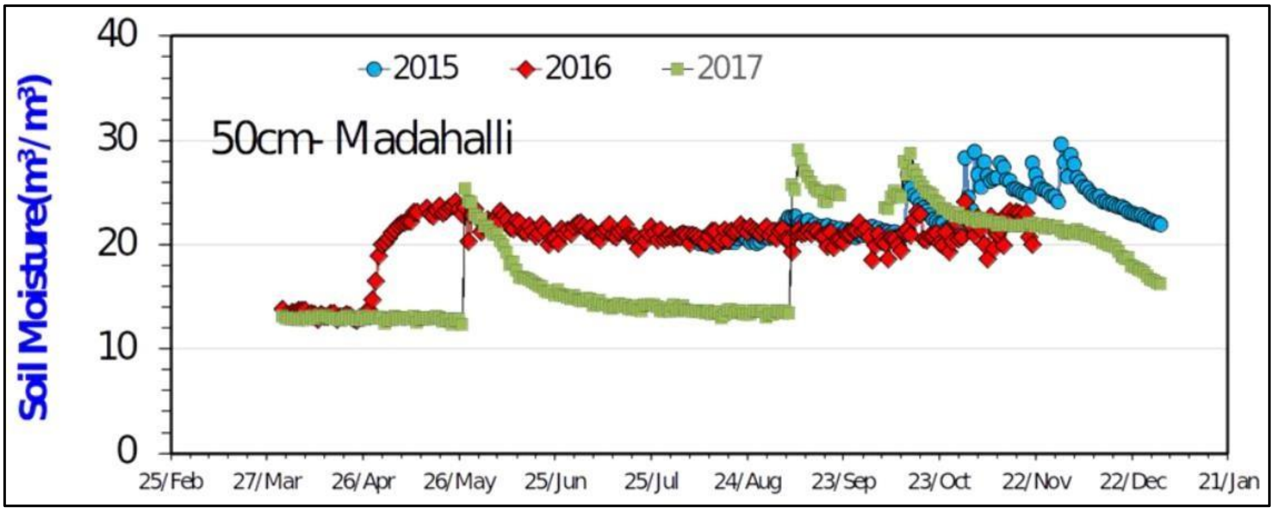


Time Series Plot of Surface Soil Moisture over a Study Watershed

The root zone soil moisture data is observed for dominant field crops in rainfed conditions. Subsistence irrigation may be required for attaining the potential productivity of these crops currently in practice.



Comparison of Satellite-based and Manual Observation-based Surface Soil Moisture Data

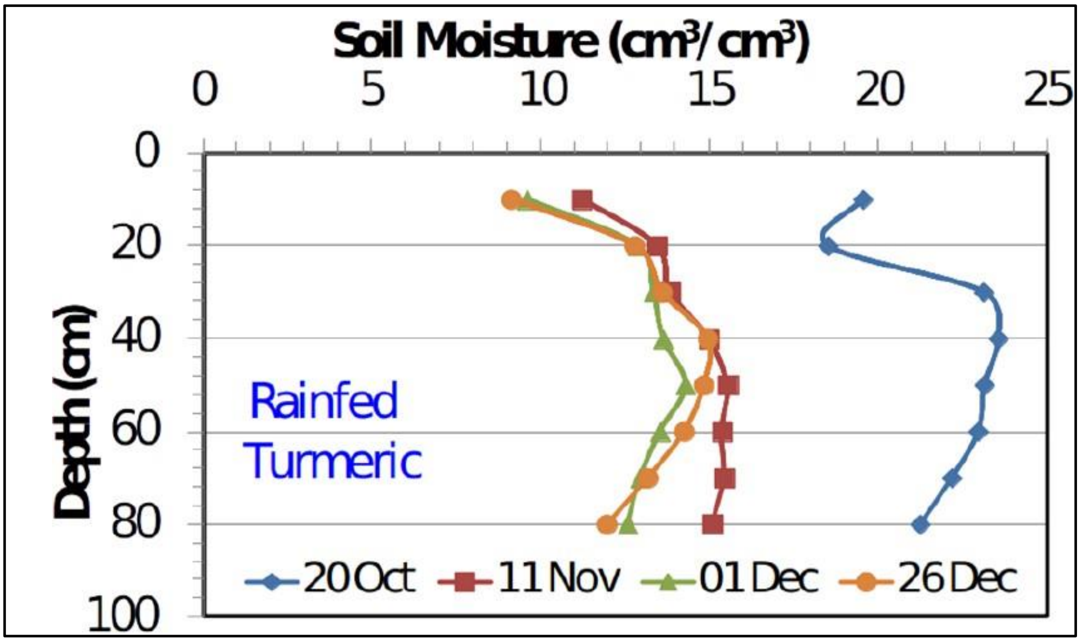


Root Zone Soil Moisture Time Series Plot at the location in the study watershed

Profile Soil Moisture Data

The following two considerations are to be noted for profile soil moisture data,

- Profile soil moisture should be observed every 10 days.
- Depth-wise measurements should be taken for an increment of 5 cm, up to the depth of 90 cm.



Sample Profile Soil Moisture Plot

Spatial Distribution of Depth to Groundwater

DGW is point data and needs to be interpolated to prepare the spatial maps. Any of the following approaches can be used to convert the point data into spatial maps:

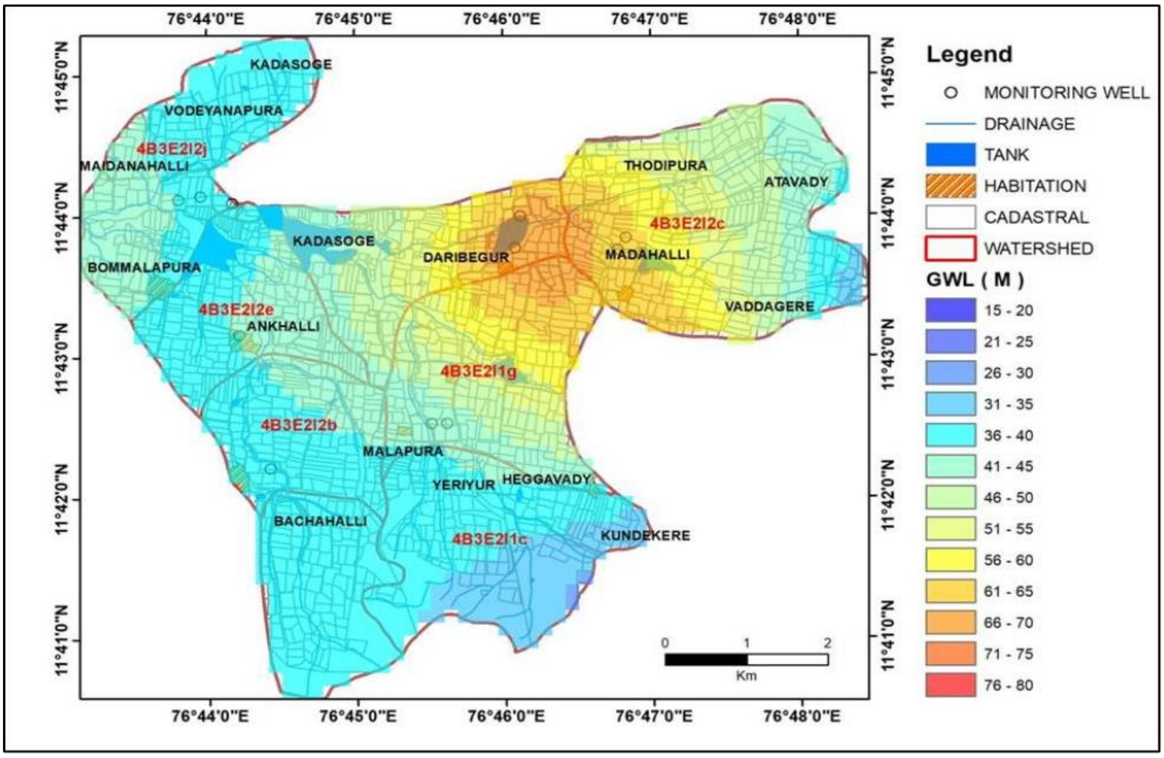
- Inverse Distance Weighted (IDW) Approach: In IDW, the value at an unknown point is estimated by giving weights proportional to the inverse of the distance (between the known locations and the unknown location) raised to the power value p. Typically, a value of p=2 is used; however, care should be taken that it should not result in spurious behavior in any part of the map. In that case, different values of p should be tried.
- Kriging-based Interpolation: Kriging provides the best linear unbiased estimation at an unknown point giving the values at known locations. Before performing the Kriging, variogram analysis is performed to understand the underlying statistical distribution of the process.

Ground Water Recharge

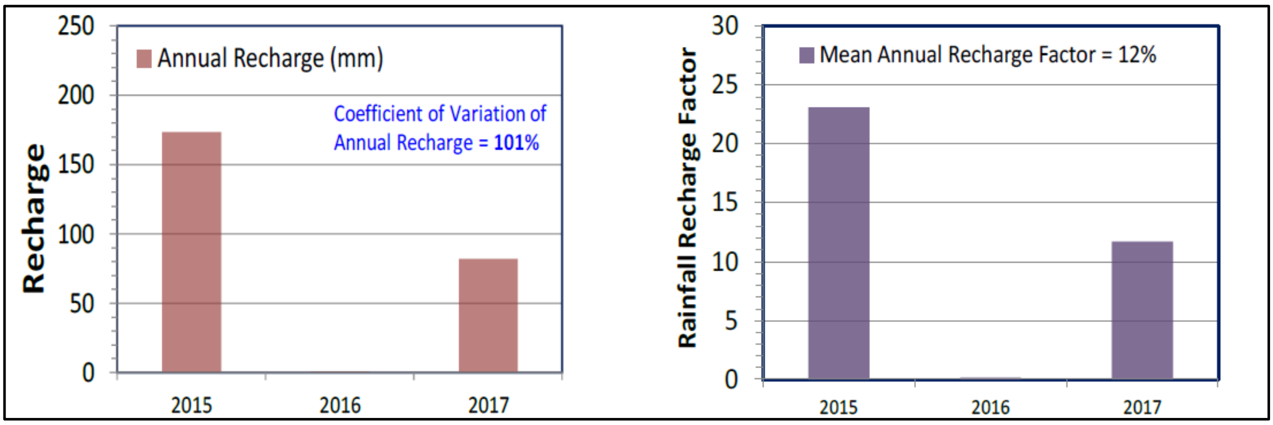
Figure shown below depicts Annual Recharge and Mean Annual Recharge Factor computed for Madahalli Micro-Watershed.

Well Yield

The yield of the well should be monitored by filling a container of known volume and measuring the time required to fill the container. By taking the data of each monitoring well, a map of groundwater well yield shall be prepared following the IDW or Kriging method of interpolation.

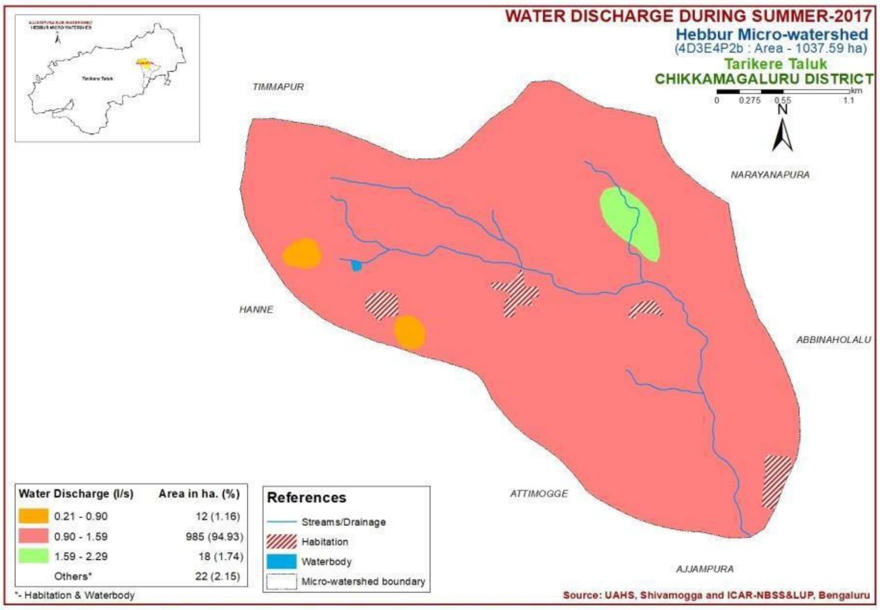


Spatially interpolated map of DGW values over the Madahalli micro-watershed

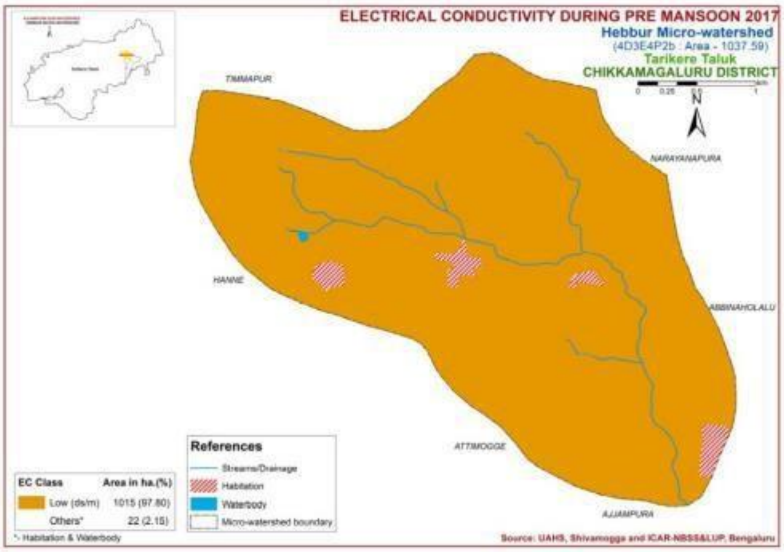


Sample Plot showing Annual Recharge and Mean Annual Recharge Factor for Madahalli Micro-Watershed

Water Quality Maps-The prepare the map of groundwater quality parameters following the IDW or Kriging method of interpolation. For example, Figure below shows spatially interpolated values of Electrical Conductivity over Hebbur Micro-Watershed.



Sample Plot showing Spatially Interpolated Well Yield Values for the Hebbur Micro-Watershed

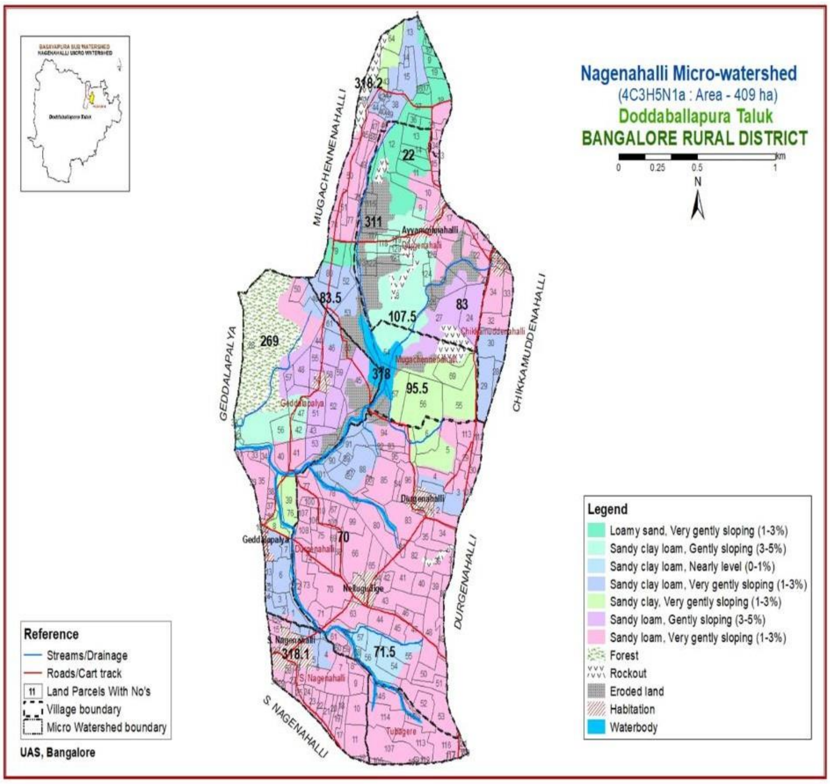


Sample Plot showing Spatially Interpolated Electrical Conductivity Values for the Hebbur Micro-Watershed

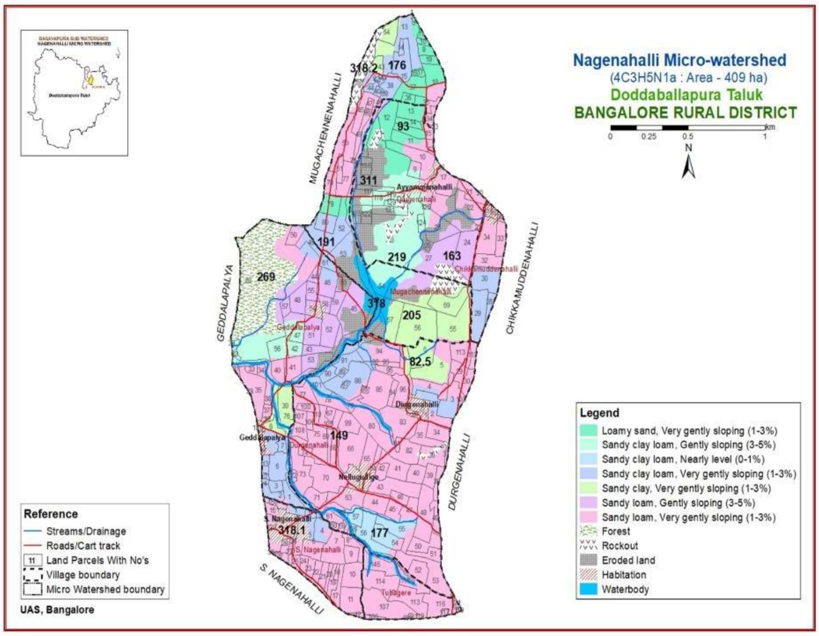
Runoff Potential

Mapping unit wise runoff availability with effective interventions and with existing conditions for the target watershed is computed using infiltration intensity method. The runoff potential information is thus generated are then converted into spatial maps.

Figure shown below depicts with effective interventions and with existing conditions the simulated runoff for Nagenahalli micro-watershed using infiltration intensity method. The average annual rainfall of Nagenahalli micro watershed is 914 mm. This was approximately same for various years since the higher intensity rain events were about the same in each year.



Mapping unit wise runoff availability with effective interventions against 914 mm (Average) rainfall during 2019



Mapping unit wise runoff availability with existing conditions against 914 mm (Average) rainfall during 2019

Water Budgeting

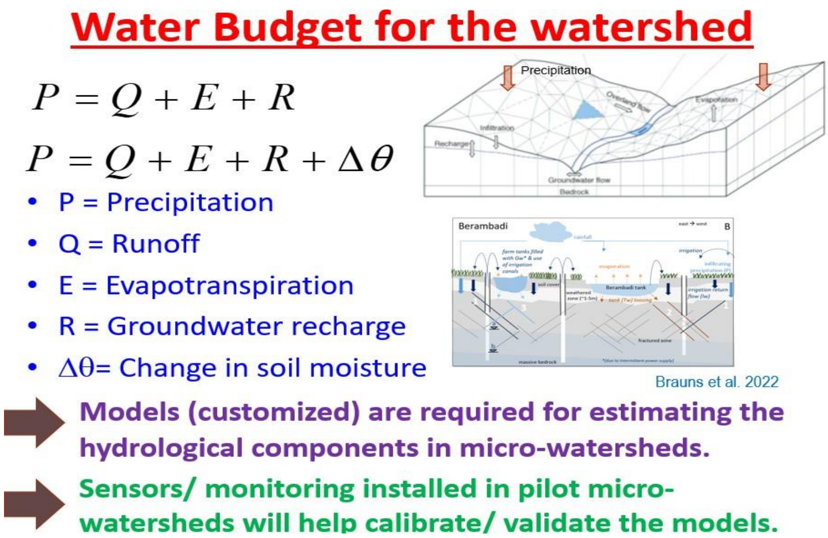
The concept of Water Budgeting aims to use water judiciously for people, agriculture and livestock with a view to optimizing benefits in the context of climate variability, erratic rainfall and drought. Water budget studies consider the volumes of water within the various reservoirs of the hydrologic cycle and the flow paths from recharge to discharge. Water budgets need to consider this information on a variety of spatial and temporal scales.

In simple terms a water budget for a given area can be looked at as water inputs, outputs and changes in storage. The inputs into the area of investigation (precipitation, groundwater or surface water inflows, anthropogenic inputs such as waste effluent) must be equal to the outputs (evapotranspiration, water supply removals or abstractions, surface or groundwater outflows) as well as any changes in storage within the area of interest. So, given a watershed under consideration, a water budget equation may be developed over various time periods, Monthly, Seasonal, Annual etc., depending upon the context.

For example, using the available concurrent data on Precipitation (P), Runoff (Q), Actual Evapotranspiration (AET) and Ground Water Recharge (R) for the period April-October over the years 2015-2018 following water budget equation has been developed for the Madahalli Watershed,

$$P=Q+AET+R+S$$

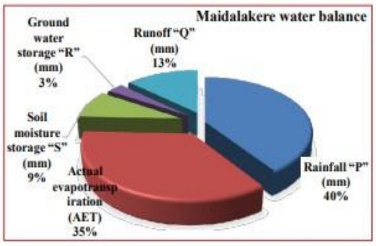
where all the variables are expressed in mm unit. Inserting following known values, P=501, Q=44, AET=540, R=85 into this equation, we get, S=−168 mm. This implies that over the considered time period, precipitation was lower than evapotranspiration. This negative balance when combined with runoff and recharge results in a net negative soil water store for the Rabi season.



WATER BUDGET

$$Q = P - E - R - S$$

1	Rainfall "P" (mm)	921.0
2	Actual evapotranspiration (AET)	807.9
3	Soil moisture storage "S" (mm)	192.1
4	Ground water Recharge "R" (mm)	64.5
5	Runoff "Q" (mm)	300.3



During May, August, September, October and November months the Precipitation is higher than Evapotranspiration. Hence, Runoff (300.3 mm) can occur in the watershed.

Runoff distribution in SWS

Sl. No	Particulars	Runoff distribution (mm)
1	Rainfall (2015)	980.0
2	Runoff availability with existing conditions	300.3
3	Runoff availability with effective interventions	216.3
4	Runoff excess for harvesting by construction of structures	173.0
5	Runoff allowed as environmental flow at the outlet	43.3

Water budget of Maidalakere sub-watershed

4. Digital library and LRI portal for accessing information

The success and impact of all land-based programmes and interventions, whether it is soil and water conservation, productivity improvement of annual, perennial, or horticultural crops, improvement of soil health, drought proofing, climate mitigation or empowerment of farmers and youth in Agriculture depends on the availability of site-specific land resource information (on soil, surface and ground water, crops, weather, socio-economic data etc.) and advisories on real time basis. The lack of such site-specific information and advisories is found to be the major cause for the failure of many flagship programmes launched with huge plan outlays in the country. In this regard, the generation of farm level land resource information and development of Land Resource Inventory Portal, Decision Support System (DSS) and Mobile Applications, as part of the World Bank supported Sujala III project in Karnataka is a game changer by providing site-specific, farmer centric land resources information and advisories to farmers, planners, research institutions and other stake holders on real time basis.

This has brought in a paradigm shift in planning and implementation of soil and water conservation programs, crop selection, nutrient management, water budgeting etc., and convergence of all land-based programs at the field level by Watershed and other line departments. This was accomplished through

- Land Resource Inventory (LRI) to generate farm level site-specific soil, water (soil moisture, ground water), weather, crops, vegetation, land use, socio-economic database, and Thematic outputs by using state of art RS, GIS & Mapping techniques by a consortium of scientific and technical partners
- Integration of multiple spatial and non-spatial data sets generated through LRI in disparate locations into a seamless state-wide data set on a unified platform as Digital Library
- Facilitating easy access (over web and mobile applications) of the seamless data available to all the line departments, farmers and youth and other stakeholders for immediate use including planning, designing, monitoring, etc. through the establishment of LRI Portal
- Facilitating access of the data over mobile platforms to all the stakeholders for immediate use (from planners to the farmers and youths)
- Extending decision support to multiple stakeholders by modelling and analyzing the data from digital library for conservation planning, crop selection, nutrient and pest management and other uses through the development of appropriate DSS
- Dissemination of LRI information and advisories to reach every farmer and youth in about 1.4 million hectares of rainfed area in the state through LRI cards, thematic maps, videos, mobiles, and other ICT outreach programmes.

To generate site-specific soil, site, land use, ground water, cropping pattern, socio economic conditions, and other resources at farm level, georeferenced cadastral map overlaid on high resolution imagery was used as a base followed by traversing, profiling and studying soil-site characteristics, grouping similar fields or areas into one mapping unit and showing their distribution on the cadastral map. This map output forms the basis for making all land use decisions at the farm level. Then by pooling and integrating all the spatial and non-spatial land resources information available in the state and the cadastral level information generated from 14 lakh ha, LRI Portal was established.

Apart from the above, all the cadastral maps of the state, high resolution remote sensing imagery at different scales and resolutions, state-wide maps and datasets related to geology, geomorphology, landforms, land use, climate, socio- economic conditions, demographic details, marketing, and other details relevant for the management of the land resources of the state are migrated and integrated with the database already housed in the portal. It is a one stop portal that provides not only the data requirements of the line departments, but importantly, the critical advisories and inputs needed to the farmers and other stakeholders at the grassroots level in selecting the best suited crop, conservation practices, nutrient and crop water requirement, water budgeting etc., on a real time basis.

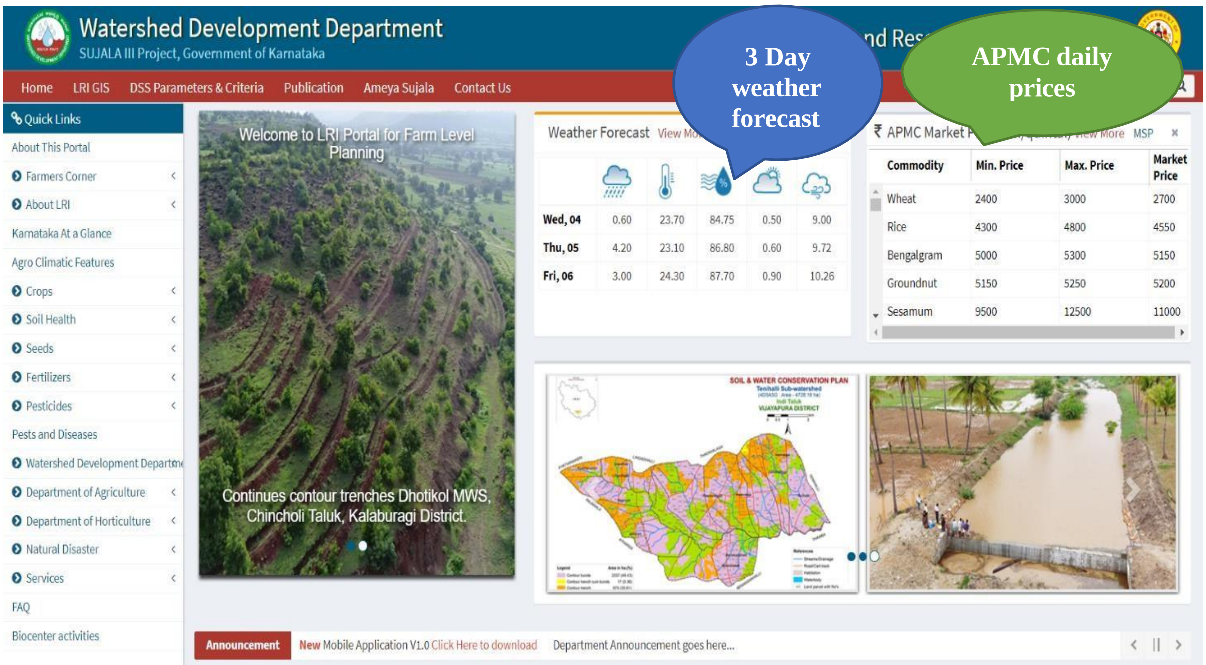
LRI portal

This portal includes the Land Resource Inventory for Watershed Planning and Decision Support Systems for Soil & Water conservation plan, Crop Selection, Land Capability Classification, Nutrient Management, Surface Runoff, Designing of Size & selection of Farm Ponds and Check Dams, Crop Water Requirement, Water Balance and Water Budgeting.

LRI Digital Library

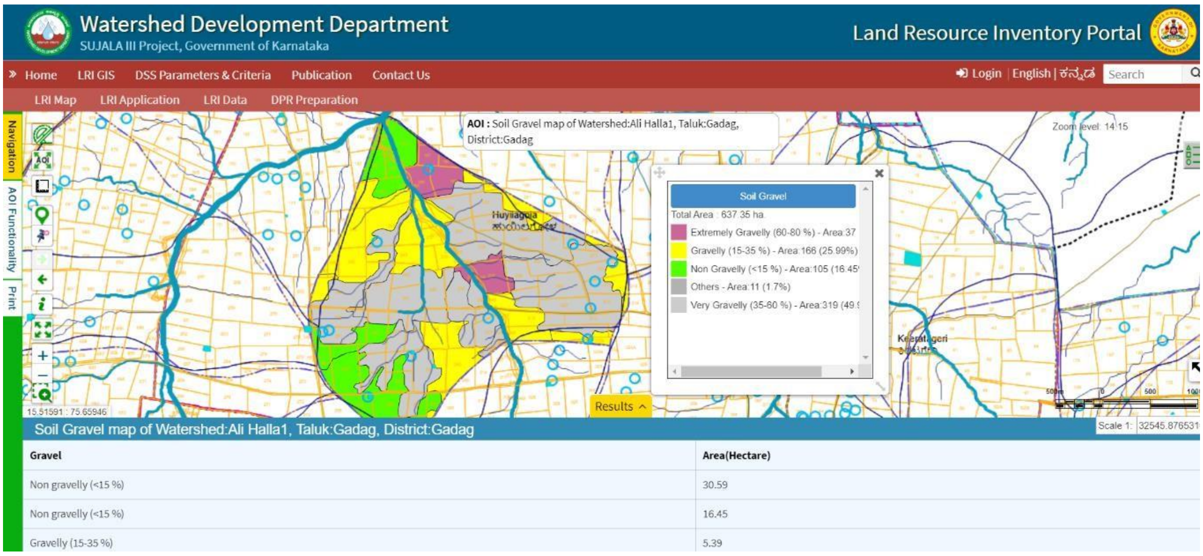
LRI Digital Library is centralized database comprising various thematic maps pertaining to natural resource and project component required for Decision Support System. This is hosted at Karnataka State Data Center which is being equipped with modern IT infrastructure enabling data sharing and collaboration. The data base also includes Land Resource Inventory data at micro watershed level (about 500 ha.) which have been prepared in collaboration with its partners (University of Agricultural Sciences, Bangalore, Raichur, Dharwad, Shivamogga and National Bureau of Soil Survey and Land-use Planning, Karnataka State Remote Sensing Application Centre, Karnataka State Natural Disaster Management Centre, Bangalore and Indian Institute of Science). More than 2000 micro watersheds have been already covered and atlases are ready which is providing parcel wise data like physical properties of soil, nutrient content in the soil, Land-use & Land-cover and also crop suitability for the different soil management units which is embedded in the portal.

The user can view weather, market prices on real time basis and, select the area of his interest and get the required data/map/information from the Portal. Apart from this, there is a log in facility for the farmers and other users, through which the farmer can register himself and access a host of benefits including advisories on crop selection, fertilizer requirement, pest and disease and their remedial measures, selection of farm ponds, crop water requirement, irrigation scheduling, market prices, weather advisory etc. Further, the user can select any area of his interest, view and generate base maps, thematic maps, query, upload, download, print, report generation, DPR preparation and others. The Portal also houses various non-spatial datasets like weather and climatic data, demography, land use, sources of irrigation etc. from census, farmer particulars from Bhoomi, package of practices for major crops, location of market yards, storage facilities, FPOs and other information.



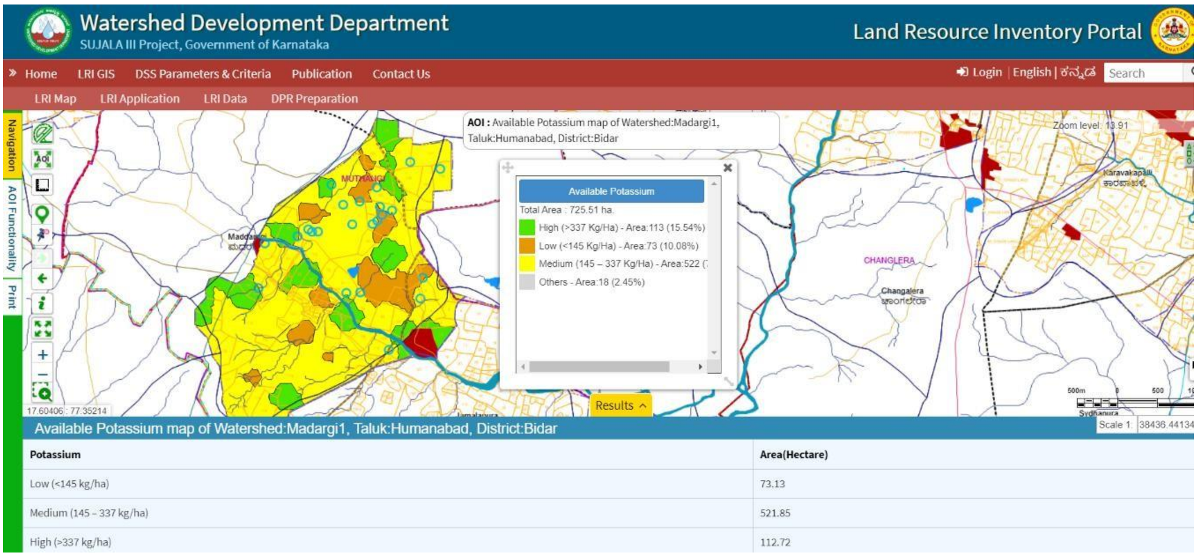
Home page of the LRI Portal

Generation of thematic maps: From the LRI database migrated and stored in the Portal, thematic maps on the constraints, potentials, status of soil nutrients, suitability for various crops and other land uses, hydrological parameters, and various other themes can be generated with the help of the interactive menu provided. The user can select the area and the theme of his interest from the menu to generate the required map which he can either view, save or print or even generate a report of the area. For example, the thematic map on gravel shows the amount, nature, and distribution of the gravel present in the soils of Ali Halla 1 micro watershed.



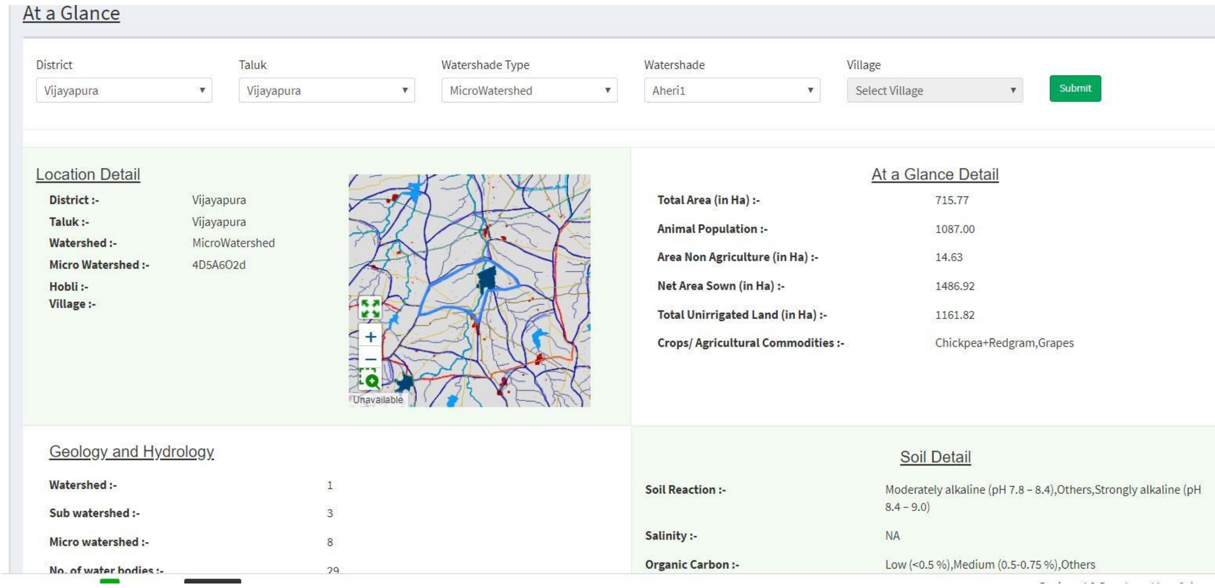
Soil gravel content in Ali Halla 1 micro watershed, Gadag Taluk

Similarly, the user can generate maps on erosion, slope, soil texture, soil depth, soil moisture, macro and micronutrients, suitability for various crops etc. from the Portal. The map on the status of the available potassium in the soils of Mandargi-1 watershed, shows that it is high in about 15 per cent of the area, medium in about 60 per cent of the area and low in only 10 per cent of the area. Similar maps on the status of organic carbon, macro and micronutrients present in the soil can be generated for any area covered by LRI in the state.



Distribution of available Potassium in Mandargi-1 watershed, Humanabad Taluk

Apart from the above, the User Dashboards-provide users with the view of all the activities performed/to be performed by the user in the system. For example, the Watershed Commissioner can see the list of all the micro-watersheds with summary of work progress/DPR implementation etc., on the Dashboard. The Dashboard for Farmers will show the details of the farm, crop/crops under cultivation, weather forecast, suitability for various crops, nutrient status, and fertilizer requirement for the crop/crops, nearest APMC yards and prices of the commodities sold, and programs and other services available for his area.



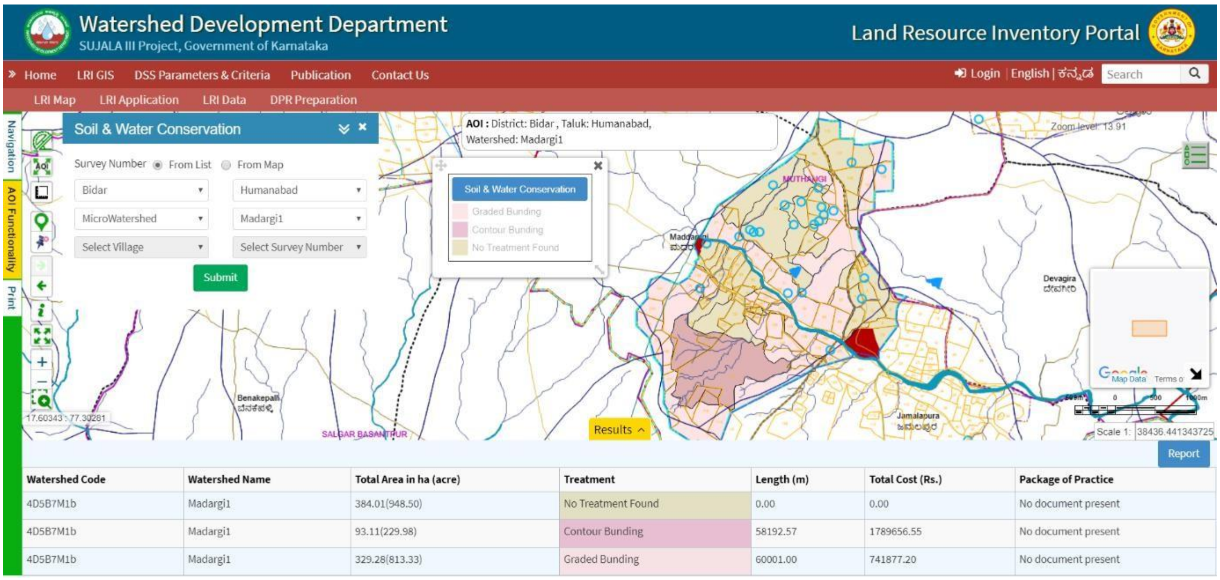
Dashboard for Department Users

Role of Decision Support System (DSS) in Program convergence

The DSS is developed by integrating LRI data and data compiled from other sources with criteria, models and algorithms developed under this project. The DSS development is critical for the successful implementation of various schemes by line departments and for empowering farmers and other stakeholders in the state. As a part of Sujala III Project, nine Decision Support Systems are developed to facilitate the departments to take up key interventions and to provide advisories to the farmers and other stakeholders as indicated below.

- DSS for Soil & Water conservation plan-to identify the type of structures, their design and estimate, for both arable and non-arable lands/areas
- DSS for Crop selection (Based on physical suitability and cost benefit ratio)
- DSS for delineating prime farmlands/arable and non-arable lands based
- DSS on crop based Nutrient Management and Soil Health
- DSS for estimating Surface runoff at farm/MWS/SWS levels
- DSS for designing Size and location of Farm ponds and Check dams
- DSS for estimating the Crop water requirement
- DSS for estimating Soil Water balance at MWS or higher levels
- DSS for Water budgeting

The DSS on **Soil & water conservation** helps to identify appropriate conservation structures for the arable and non-arable lands based on site-specific parcel level information available in the Digital Library. The user can select the area of his interest from the drop-down menu and run the DSS in the Portal to get the conservation map of the area along with the output showing the type of structures, cost of the main and side bunds with waste weir and conservation practices to be followed as indicated below for the Mandargi 1 watershed. The DSS can also be run for the selected survey number or parcel of land to get the type of structures to be constructed along with the cost and other details.



Conservation map of Mandargi-1 watershed

Similarly, the DSS on **Crop suitability** compares the bio physical characteristics of the land like the soil-site characteristics, climate etc., with the requirements of the crop and generates the suitability map. The suitability map will show the degree of suitability like highly, moderately, or marginally suitable or not suitable for the crop with their limitations and extent. The DSS model can also be run at the field or at any higher levels as per the needs of the users. This model is available for about 73 different crops that are under cultivation in the state at present.

The DSS on **Nutrient management** enables the farmer to choose the type, quantity and time of application of fertilizers to the selected crop based on the nutrient status of the soil. This model can be run at any levels from the farm, watershed or higher levels based on the availability of information. This helps to supply the required nutrients in a targeted manner and avoids misapplication of fertilizers, thereby reducing the cost of cultivation to the farmer. Similarly, the DSS on r**unoff, number of check dams, water balance and water Budgeting** is also available in the portal for the users to select and generate the outputs needed for any areas of interest.

The functionalities of the Mobile application are almost like that of the LRI Portal. It allows for registration and update of information, and provides information on weather and climate, soils, nutrient status, crops and package of practices, agro-climatic features, seeds, soil health, fertilizers, pest and diseases in crops and their remedial measures, commodity prices, various departmental schemes, suitability of crops, nutrient management, departmental applications, expert advisory etc.

Effectiveness of LRI Portal, DSS and Mobile apps on Convergence of programs

This Disruptive Technology Platform, established for science based site-specific interventions, has changed the way planning and implementation of many land-based programmes are carried out in the state.

- For example, due to the availability of site-specific LRI database on real time basis through the Portal, the interventions have become more focused, and farmer and youth oriented rather than remaining as a blanket or general type as was the case in earlier programmes,
- The watershed cycle is reduced to 3 to 4 years which used to take about 6 to 7 years earlier,
- Real time convergence of various programmes and budgetary allocations to line departments as per the requirement have become more realistic,
- More than anything, the time, capital and manpower use efficiency has increased significantly due to the application of this approach.

Apart from the above, many flagship programmes with huge allocation of funds can benefit immensely with the use of LRI information and Decision Support Systems available from the Portal in planning and implementation of their schemes which can save the scarce capital, improve the delivery and most importantly the efficiency of the interventions on a sustained manner than any time in the past.

Steps for accessing the LRI portal

To access the portal, go to

https://www.sujala3lri.karnataka.gov.in/

Select language,

English

To know the parameters and criteria considered,

Go to

"DSS Parameters and Criteria"

Select the required module out of 9 DSS to know its module description and flowchart employed

To get the publication made by WDD,

Go to "Publications"

Go to "Hydrology atlas"

Select required District, Taluk, Hobli and Village

Or

Uncheck Hobli to get the atlas by SWS/MWS wise and select the Watershed

Go to "LRI atlas"

Select required District, Taluk, Hobli and Village

To get the DPR published, go to

"Detail Project Report"

Similarly, one can also get the Technical manuals, User guides, Videos, Newsletters, Success stories and Glossary by selecting respective sections

For LRI card generation,

Go to "LRI card" (Left bottom end) in the home page

Select required district, taluk, hobli, village and survey number

For DPR generation,

Go to "LRI GIS"

Select "DPR preparation"

Select required district, taluk, watershed type and watershed

Select required themes to be included in the DPR and click Submit

To know the LRI of the specific survey number/SWS/MWS in brief

Go to "LRI GIS"

Select "LRI at a Glance"

Select required district, taluk, watershed type and watershed

Uncheck Watershed type to get the information by village and survey number wise

To access the nine DSS developed

Go to “LRI GIS”
Select “LRI Map”

To know the DSS by area of interest

Go to “Select”
Select “AOI”
Select required district, taluk, watershed type and watershed
Uncheck watershed type to get the information by village and survey number wise
Click “Submit”
Select “Area of Functionality” from Navigation pane
One can select any DSS out of nine for the selected area of interest
For printing the same, Click “Print” from navigation pane
Or
User can also draw the desired area on the map by clicking
“User AOI”

To get the maps of a MWS
Go to Map
Select required layers to be compiled in the map from “Layers”
Then select “Theme”
Select “AOI”
Select required district, taluk, watershed and theme
Click “Display/Print”
Or
User can also draw the desired area on the map by clicking
“User AOI”

To know the Individual DSS

Go to “LRI GIS”
Select “LRI Map”
Select “Decision Support System”

For Soil & Water Conservation

Click “Soil & Water Conservation”
User can select form the map by using point and polygon feature
Or
Select “From list”
Select required district, taluk, watershed type and watershed
Uncheck watershed type to get the information by village and survey number wise
Submit
Displays the result in a table showing the information such as watershed name, survey number, area in hectare as well as information related to treatment proposed, its length, cost for the main bund, cost for side bund, total cost and also cost of waste weir.

For Crop Selection

Click "Crop Selection"

User can select form the map by using point and polygon feature

Or

Select "From list"

Select required district, taluk, watershed type and watershed

Uncheck watershed type to get the information by village and survey number wise

Select Season, Crop type, Suitability type to be derived, Crop

Submit

Result displays the type of crop for the particular survey number/MWS, with season, suitability class, benefit ratio and the rank. system will also highlight the land parcel related to the selected survey number in GIS map

For Land Capability Classification

Click "Land Capability Classification"

User can select form the map by using point and polygon feature

Or

Select "From list"

Select required district, taluk, watershed type and watershed

Uncheck watershed type to get the information by village and survey number wise

Submit

Displays result in a table showing the information such as survey number, farmer name, area in hectare, land capability classification, limitation, arable/non arable.

For Nutrient Management

Click "Nutrient Management"

User can select form the map by using point and polygon feature

Or

Select "From list"

Select required district, taluk, village and survey number, season, crop and irrigation practice

Submit

Displays the result in a table showing the information such as survey number, farmer name, area in hectare, crop name, fertilizer required, total quantity in kg (a), basal dose kg (b), top dressing kg (c=a-b), total cost for fertilizer, action.

For Surface Runoff

Click "Surface Runoff"

User can select form the map by using point and polygon feature

Or

Select "From list"

Select required district, taluk, watershed type and watershed

Uncheck watershed type to get the information by village and survey number wise

Select method of Runoff calculation

For SCS curve number method, select required date
Submit

For Infiltration method, select required date, bund length manually or automated and per cent of vegetative cover
Submit

For Rational method, provide maximum length of flow, difference in elevation and intervention structures employed
Submit

For Size & Selection of Farm Ponds

Click "Size & Selection of Farm Ponds"
User can select form the map by using point and polygon feature
Or
Select "From list"
Select required district, taluk, village and survey number, per cent vegetative cover, bund length manually or automated
Submit

For Size & Selection of Check Dams

Click "Size & Selection of Check Dams"
Provide required district, taluk, MWS, storage capacity of check dams, per cent vegetative cover, bund length manually or automated
Submit

For Crop Water Requirement

Click "Crop Water Requirement"
User can select form the map by using point and polygon feature
Or
Select "From list"
Select required district, taluk, village and survey number, crop, total cropped area and date of sowing
Submit

For Soil Moisture Balance

Click "Soil Moisture Balance"
User can select form the map by using point and polygon feature
Or
Select "From list"
Select required district, taluk, village and survey number, crop, date of sowing, last date of irrigation with quantity (mm) and total cropped area
Submit

For Water Budgeting

Click “Water Budgeting”

User can select form the map by using point and polygon feature

Or

Select “From list”

Select required district, taluk, watershed, year

Provide information on water available in surface water bodies (m^3/year) and ground water recharge (m^3/year)

Select if there is any home cottage industry and provide water requirement for irrigation (m^3/year)

Select per cent vegetative cover and bund length manually or automated

Submit

To know the LRI Census Data

Go to “LRI GIS”

Select “LRI Map”

Select “Data”

Select “Census Data”

Select required District, Taluk, Watershed type and Watershed

Uncheck Watershed type to get the information by village wise

Select “Aggregate”

Submit

To get the report on individual nutrient for a MWS

Go to “LRI GIS”

Select “LRI Map”

Select “Custom report”

Select fertility parameter required

Select required District, Taluk, Watershed and fertility rating

Click “Execute”

5. Decision Support Systems (DSSs)

DSS on Delineation of arable and non-arable land

Land capability assessment is done to find out the general capability of the resources of an area for agricultural crops, forestry and other uses. In this assessment, the mapping units occurring in an area are grouped according to their limitations they pose for cultivation, the risk of damage if they are used for the identified use, and the way they respond to management interventions. Normally the criteria used in grouping the units do not take into consideration any major and costly reclamation measures or conservation techniques that change the slope, depth or characteristics of the soils. This system is not aimed to find out the suitability of the land resources for specific uses or crops. Though the classification was evolved originally to help the soil conservation efforts, but now this system can be used for identifying priority areas, which requires immediate attention and development within a watershed or project areas.

The capability grouping is based on the inherent soil characteristics, external land features and environmental factors that limit the use of the land for different purposes (I.A.R.I., 1971 and Soil Survey Division Staff, 1993). The following land and soil characteristics are used to group the land resources identified in an area into various classes, subclasses and units.

- Soil characteristics: Soil depth, texture, gravelliness, soil reaction, water holding capacity, calcareousness, salinity/ alkalinity etc.
- Land features: Slope, erosion, rock outcrops and drainage.
- Climate: Rainfall distribution and length of growing period.

In the capability system, mapping units are generally grouped at three levels – capability class, subclass and unit. Depending on the level of available information, grouping can be done at any one of the above levels. If the information available for an area is of general nature, then the classification can be done only up to class or subclass level and if it is detailed and site-specific then the classification can be done up to the unit level, which is an equivalent of a management unit for the survey area. Since site-specific and comprehensive database is generated through the Land Resource Inventory for all the watersheds in the project districts, the land resources can be grouped into various land capability units for each watershed area.

Structure of the classification

Capability classes, the broadest groups, are designated by roman numerals I to VIII. The numerals indicate progressively greater limitations and narrow choices for practical use. The classes I to IV are arable lands and classes V to VIII are non-arable lands. The eight classes used in the classification are:

Class I	The mapping units have few or very few limitations that restrict their use
Class II	Mapping units have moderate limitations that reduce the choice of the crops or that require moderate conservation practices
Class III	Mapping units have severe limitations that reduce the choice of the crops or that require special conservation practice, or both
Class IV	Mapping units have very severe limitations that reduce the choice of the crops or that require very careful management, or both.
Class V	Soils in the mapping units are not likely to erode, but they have other limitations, impractical to remove that limit their use
Class VI	The land area has severe limitations that make them generally unsuitable for cultivation
Class VII	The land area has very severe limitations that make them unsuitable for cultivation
Class VIII	Soils and miscellaneous areas have limitations that nearly preclude their use for any commercial crop production

Capability subclasses are formed based on the dominant limitations observed within the capability class. They are designated by adding a lower-case letter like **e, w, s, or c,** to the class numeral. For example, in subclass IVe, the letter ‘e’ shows that the main hazard in class IV land is the risk of erosion. Similarly, the symbol ‘w’ indicates drainage or wetness as a limitation for plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); the symbol ‘s’ indicates shallow depth, calcareousness, salinity and sodicity or gravelly nature of soil as limitations and ‘c’ indicates climate or rainfall with short growing period as a limitation for plant growth.

The land capability subclasses have been divided into land capability units based on the kinds of limitations present. Ten land capability subclass units are used in grouping the resources of an area, which are indicated below with their symbols

(0) Stony or rocky
(1) Erosion hazard (slope, erosion)
(2) Coarse textures (sand, loamy sand, sandy loam)
(3) Fine texture (cracking clay, silty clay)
(4) Slowly permeable sub soils
(5) Coarse underlying material
(6) Salinity or alkali
(7) Stagnation, overflow, high groundwater
(8) Soil depth
(9) Fertility problems

Capability units have almost similar soil and other land characteristics that influence the use of the land resources at the field level. Accordingly, each capability unit is expected to respond uniformly to a given level management. (Note: Under Sujala III project, land capability assessment is done only up to land capability subclass and not up to land capability unit levels)

By following the Land capability classification system, the phases mapped, or the map units identified at the watershed level can be grouped into various land capability classes, sub classes and land capability units. The various parameters to be considered and their ratings to be used in grouping the land parcels/areas into land capability units are given in the table below.
Source:

1. United States Department of Agriculture (USDA), 2012, Soil Survey Manual, Handbook No:18, USDA, USA.
2. Natarajan, A., and Dipak Sarkar, 2010, Field guide for soil survey, National Bureau of Soil Survey and Land Use Planning (NBSSLUP), ICAR, Nagpur, India.
3. IARI (1971) Soil Survey Manual, IARI, New Delhi

Parameters and their ratings to be used for land capability units/classes

Climate, soil and site parameters/features affecting LCC		**Land capability ratings**							
		Suitable for Agriculture				**Suitable for forestry, silvipasture, wildlife etc.**			
		I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Climate	Humid with well distributed rainfall	√							
	Humid with occasional dry spells		√						
	Sub humid- yields frequently reduced by droughts		√						
	Semi-arid			√					
	Arid				√				
Slope	**Red soils**								
	A (<1%)	√							
	B (1-3%)		√						
	C (3-5%)		√						
	D (5-10%)			√					
	E&F (10-25%)				√				
	G, H&I (25>50%)						√		

	Black soils								
	A (<1%)	√							
	B (1-3%)		√						
	C (3-5%)			√					
	D (5-10%)				√				
Erosion	Slight (e_1)	√							
	Moderate (e_2)		√						
	Severe (e_3)			√					
	Very Severe (e_4)				√				
Drainage	Excessive						√		
	Well drained	√							
	Mod.WD		√						
	Imperfect			√					
	Poor				√				
	Very Poor					√			
Soil depth	> 100 cm	√							
	50 –100 cm		√						
	25-50 cm			√					
	10-25 cm				√				
	< 10 cm						√		
Texture	sl, scl, cl, loam, silty clay loam	√							
	sandy clay, silty clay		√						
	clay			√					
	loamy sand				√				
	sand						√		
Gravels	< 15 %	√							
	15-35 %		√						
	35-60 %			√					
	> 60 %				√				
Rockout crops (%)	<2		√						
	2-10			√					
	10-50				√				
	50-90						√		
	>90								√
Salinity	<2	√							

EC	2-4		√						
	4-8			√					
	8-16				√				
pH	Favorable Reaction (6.5-7.5)	√							
	Unfavourable reaction (easy to modify) (5.5-6.5 & 7.5-8.5)		√						
	Unfavourable reaction (difficult to modify) (4.5-5.54 & 8.5-9.5)			√					
	Unfavourable reaction (exceedingly difficult to modify) (<4.5 & >9.5)				√				
Permeability	Very slow			√					
	Slow		√						
	Mod. slow	√							
	rapid			√					
	Very rapid							√	

DSS on Selection of crops as per the suitability to land

The land resources are finite and under stress due to the increased demand for food, fiber, fodder etc. from growing population. The population growth is leading to unfavorable man to land ratio. In India, per capita cultivable land holding has been declining from 0.48 ha in 1951 to 0.16 ha in 1991 and it is likely to decline further to 0.11 ha in 2025 and less than 0.09 ha in 2050 (NAAS, 2009). Although, the food production has increased from 52 m tons in 1950's to almost 311 m tons in 2020-21 (GOI, 2022), this increase has been largely as a result of expansion in cultivated and irrigated area and high chemical (fertilizer) inputs. The significant growth of agriculture has been at the cost of decline in soil quality and risk of soil degradation. We are now facing the serious threat of ensuring sustainability in our production systems. In many of the so-called first green revolution areas, a whole range of second-generation problems are posing serious challenges to the sustainable agricultural production. About 57 per cent of soils are under different kinds of degradation and these are getting further deteriorated with risk of jeopardizing our food security (Sehgal and Abrol, 1994). In addition to this, many issues concerning environmental sustainability, carrying capacity of our land resources, etc., are also cropping up and adversely affecting soil and human health. These problems demand a systematic appraisal of our soil and climatic resources to recast and implement an effective and appropriate land use plan at local level. Soil survey interpretation and land evaluation precede land use planning. Standard survey information can be interpreted for several purposes like suitability for agriculture through technical classification of soils, hydrological groupings, suitability for sewage disposal, trafficability, building construction, etc.

Land evaluation is the process of estimating the potential of land for alternative kinds of use. These uses can be productive such as i) arable farming, ii) livestock production, iii) forestry or other uses such as, a) catchment protection, b) recreation, c) tourism, d) wild life conservation. It involves interpretation of surveys, climate, soils, and vegetation and other aspects of land with the requirements of alternative land use.

Land evaluation procedures

The land evaluation activities undertaken and the order in which the work is done depend on the type of approach adopted, whether parallel or two-stage.

The main activities in a land evaluation are as follows:

- Initial consultations, concerned with the objectives of the evaluation and the data and assumptions on which it is to be based
- Description of the kinds of land use to be considered, and establishment of their requirements
- Description of land mapping units, and derivation of land qualities
- Comparison of kinds of land use with the types of land present
- Economic and social analysis
- Land suitability classification (qualitative or quantitative)
- Presentation of the results of the evaluation

It is important to note that there is an element of iteration, or a cyclic element, in the procedures. Although the various activities are here of necessity described successively, there is in fact a considerable amount of revision to early stages consequent upon findings at later periods. Interim findings might, for example, lead to reconsideration of the kinds of land use to which evaluation is to refer, or to changes in boundaries of the area evaluated.

Data set requirements for land evaluation

The land units and their homogeneity form the basic requirement for proper land evaluation. The land units selected for land evaluation have no scale limitation. The information on the land units is generated through different kinds of soil surveys.

The land characters and land qualities considered in defining the land units are as under:

Land characters: Land characteristics used in land evaluation are measurable properties of the physical environment directly related to land use and are available from the soil survey. These characteristics are

Bio-physical characteristics: factors like topography (t)-slope length and gradient; wetness (w)- drainage and flooding

Physical soil characteristics: Texture, soil depth and intensity of acid sulphate layer and gypsum or kankar layer

Fertility characteristics (f): Cation exchange capacity of the clay as an expression of weathering stage, base saturation and organic matter content

Salinity and alkalinity (n): Salinity status and alkalinity status

Climatic database: Factors such as temperature, potential evaporation, the temporal and spatial variability of rainfall, specific to an area are considered as database for estimation of growing period.

There are a number of other important properties, which co-vary with changes in the property; however, these properties are of great value in interpreting the various uses. Soil classification systems very much rely extensively on quantitative composition of soils and these compositions are selected on their assumed importance in understanding the genesis of the soil.

Land qualities: It is a complex attribute of land which acts in a distinct manner, its influence on the suitability of land for a specific kind of use. They may be positive or negative. They are in fact practical consequences of land characteristics. They could be segregated in to two groups: FAO (1976) suggests three comprehensive land qualities:

Internal qualities: Water holding capacity; oxygen availability; availability of foot hold to roots; tolerance to iron induced chlorosis; nutrient availability; resistance to structural degradation of top soil; absence of salinity and alkalinity.

External qualities: Correct temperature regime; resistance against erosion; ability for layout of farm plan and workability.

Land Evaluation Approaches

Land evaluation is the ranking of soil units on the basis of their capabilities (under given circumstances including levels of management and socio-economic conditions) to provide highest returns per unit area and conserving the natural resources for future use (Van Wambeke and Rossiter, 1987). Several systems of land evaluation have been recognized (Storie, 1954; Requier *et al*., 1970; Sys, 1985; Sehgal *et al*., 1980). There are both qualitative and quantitative approaches in vogue.

A. Qualitative evaluation

i) Land Capability Classification (Klingbiel & Montgomery, 1961).
ii) Land Irrigability Classification (Soil Survey Staff, 1951; USBR, 1953).
iii) Fertility Capability Classification
iv) Crop Suitability Classification (FAO, 1976; Sys, 1985; Sys *et al*. 1993)
v) Prime Land Classification (Ramamurthy *et al*., 2012)

B. Quantitative evaluation

i) Soil index rating (Shome and Raychaudhari, 1960; Storie, 1978)
ii) Actual and potential productivity (Riquier *et al*., 1970)
iii) Soil suitability classification- statistical approach (Sehgal *et al*., 1989)
iv) Land use planning and analysis system (LUPAS) (Laborte *et al*., 2002):
v) Land suitability assessment by parametric approach (Rabia and Terribile, 2013)
vi) Land suitability by fuzzy AHP and TOPSIS methods (Mukhtar Elaalem *et al*., 2010)
vii) Land suitability by integrated AHP and GIS method (Ramamurthy *et al*., 2020)

Land Suitability Evaluation

Each plant species requires specific soil-site conditions for its optimum growth. The land suitability assessment provides the suitability or otherwise of the various land resources occurring in an area for major crops grown. This helps to find out specifically the suitability of the land resources like soil, water, weather, climate and other resources and the type of constraints that affect the yield and productivity of the selected crop.

This assessment is based on the model proposed by the FAO (1976 and 1983) for land evaluation and suggested the classification of land in different categories: Orders, Classes, Sub-classes and

Units. The soil-site characteristics are expressed in terms of degree of limitation (0, 1, 2, 3 or 4); the limitation of 2 is considered critical at which the expected yield declined significantly and the cultivation is considered marginally economical. The final soil-site evaluation/suitability is based on the number and degree of limitation (s). Modern approaches involve simulation model predicting yield as a measure of suitability. Although very well refined, yet these approaches are largely based on local experience of farmers or of the researchers.

Land evaluation involves the assessment of land and soils for their potential for different uses involving matching the land qualities and requirements for the land use. For rationalizing land use, soil-site suitability for different crops need to be determined to suggest the models for guiding the farming community to grow most suitable crop(s), depending on the suitability/capability of each soil unit mapped.

The adaptability of crops in one or the other area is the interaction between existing edaphic conditions and fitness of the cultivar under these conditions. Although, lot of data on crop production through experimentation have been generated by the SAU's and Crop Research Institutes, yet it has not been correlated with sufficient data base on the soil-site conditions in order to work out soil-site suitability models for optimizing land use in the country.

In the land evaluation, there are four steps namely (i) characterization of existing soil, climatic and land use conditions (ii) development of soil site criteria or crop requirements (iii) matching of crop requirements with existing soil and climatic conditions and (iv) choosing of the best fit among the crops and the selecting the same as the alternative crop strategy.

Among the above four steps, the formulation of the soil site criteria to meet the crop requirements forms a vital and important step. For the development of crop requirements, one has to do either experimentation at each well characterized growing environment or take the help of published literature. Naidu *et al*. (2006) have compiled the soil-site requirement of major crops of India by reviewing published literature and consulting crop specific researcher teams.

Matching of crop requirements consists of comparing existing climate, soil and physiographic conditions with the soil-site criteria with respect to individual crop. On the basis of the degree and the number of limitations identified, the suitability class is established, *viz*., highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable land (N1 & N2) for specific kind of land use. Land suitability subclasses are divided into land suitability units based on specific management requirements. The ratings used for defining each class are based on the number and degree of limitations present. The S1 classes correspond to areas, which have a yield potential above 80% of the maximal attainable harvest within the climatic region of the area. This figure drops to 60% and 40% for classes S2, and S3, respectively.

Simple limitation method: In assigning the overall suitability class to any area, the limitation approach or law of the minimum is followed. According to this approach, even if all other factors are favorable for the crop and only one factor is likely to be a limitation, then that factor is given precedence in assigning the suitability class. The suitability classes and sub-classes are directly assigned to land units based on suitability criteria. A brief description of the orders, classes and subclasses used in the suitability assessment of major crops is given below:

Order S (Suitable)

Class S1	:	(Highly suitable) Land unit having no limitation for sustainable use or with not more than three slight limitations.
Class S2	:	(Moderately suitable) Land with more than three slight limitations but with not more than three moderate limitations.
Class S3	:	(Marginally suitable) Land with more than three moderate limitations but with not more than two severe limitations.

Order N (Not Suitable)

Class N1	:	(Currently not suitable) Land with severe or very severe limitations that may be overcome in time but cannot be corrected with existing knowledge at current acceptable cost
Class N2	:	(Permanently not suitable) Land having limitations that will be very difficult to correct and use

There are no sub-classes within the suitability class S1. Classes S2, S3 and N1 are divided into subclasses based on the specific limitations encountered in an area for the selected land use. The specific limitations that are likely to affect crop production at the watershed or village level are indicated below with their symbols to be used.

Erratic rainfall and its distribution and short growing period	c
Erosion hazard (Slope and erosion)	e
Soil depth (rooting conditions)	d
Soil texture (lighter or heavy texture)	t
Coarse fragments (gravelliness or stoniness)	g
Soil fertility constraints, calcareousness, sodicity hazard, salinity problem etc.	n
Drainage problem	w
Moisture availability	m
calcareousness	z
Topography	l

Limitations are indicated in lower case letters after the suitability class symbol. For example, marginally suitable land with low rainfall or short growing period as a limitation is designated as S3c. Normally two and sometimes three limitations are included at subclass level. Land suitability units are indicated by the Arabic numbers after the limitation symbol.
Based on the suitability classification, land resources of any watershed or area can be evaluated to find out their suitability for various crops, like cereals and millets, oil seeds, pulses, commercial crops like cotton, sugarcane, spices and horticultural crops. The assessment can be done for the existing crops that are under cultivation at present or for some of the promising crops and varieties from other places before they are recommended for cultivation in the area.

The process involved in the crop suitability assessment is elaborated below.

- Selection of the crop and the survey number or land parcel to be assessed for suitability evaluation
- Finalisation of suitability criteria for the crop or crops to be assessed. The criteria table developed for each crop will show the soil-site and other land characteristics on one side and the range of values assigned to each of the land characteristics for different suitability classes like Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), Currently Not Suitable (N1) and Not Suitable (N2) on the other side
- Run the system to match the crop suitability criteria with LRI, Hydrology and other resource information pertaining to the farm/survey number stored in the system
- After the matching process, the system displays the degree of suitability for the crop with constraints if any as subscripts after considering the following criteria/logic
- Law of Minimum/Limitation approach in assigning the degree of suitability
- Internal prioritization among crops with same rank
- Displaying the suitable crops (on prioritization basis) with all limiting factors as sub-script
- Based on the soil, site, climate and other datasets, the system calculates the number of S1s, S2s and S3s against the parameters provided with each crop matrix. Then the crop is placed into a suitability class/category based on the law of minimum as illustrated below.

Example:

Sorghum: 4S1 + 3S2 + 4S3 ~ will be placed in to S3 (Internal prioritization based on the Law of Minimum approach)

Maize: 1S1 + 10S2 + 0S3 ~ will be placed in to S2 (Internal prioritization based on the Law of Minimum approach)

Red gram: 15S1 + 0S2 + 0S3 ~ will be placed in to S1 (Since there is no limitation for the crop)
Maize S2, Groundnut S2-Selection of the most suitable crop among the two will be based on B:C Ratio as the score for both crops are same.

Benefit cost ratio: is decided based on standard cost of cultivation, yield and dynamic market prices. The standard cost of cultivation for any crop is available with the Department of Agriculture. Market prices can be obtained from Agmarketnet web API. Using the above the B:C Ratio can be calculated as (Yield X Market Price) / Cost of Cultivation.
The Crop suitability choices arrived for an area need to be shared to the concerned agricultural office/stakeholders and vetted before the same is recommended to the farmer. This assessment can help greatly in identifying the best suited areas and the areas having limitations in the watershed area. Similar assessments can be made for other areas and for other crops for the same area.

Exercise - 1

Crop wise soil characteristics for deciding suitability of crops

Description		***Ragi***	***Redgram***	***Mango***	***Areca***
Depth (cm)					
Very shallow	<25	Nr	Nr	Nr	N
Shallow	25-50	S3r	Nr	Nr	N
Moderately shallow	50-75	S2r	S3r	Nr	S3r
Moderately deep	75-100	S1	S2r	S3r	S2r
Deep	100-150	S1	S1	S2r	S1
Very deep	>150	S1	S1	S1	S1
Gravels (%)					
g0	<15	S1	S1	S1	S1
g1	15-35	S2g	S2g	S2g	S2g
g2	35-60	S3g	S3g	S3g	S3g
g3	60-80	Ng	Ng	Ng	Ng
Slope (%)					
A	0-1	S1	S1	S1	S1
B	1-3	S1	S1	S1	S1
C	3-5	S2l	S2l	S2l	S2l
D	5-10	S3l	S3l	S3l	S3l
E	>10	Nl	Nl	Nl	Nl
Texture					
Loamy sand (b)	ls	S3t	S3t	Nt	S3t
Sandy loam (c)	sl	S1	S2t	S2t	S2t
Sandy clay loam (h)	scl	S1	S2t	S1	S1
Clay loam (f)	cl	S1	S2t	S1	S1
Sandy clay (i)	sc	S1	S1	S1	S1
Clay Red (m)	c	S1	S1	S1	S2t
Clay Black (m)	c	S3t	S2t	S3t	S3t
Drainage					
Well		S1	S1	S1	S1
Moderately well		S1	S2w	S2w	S2w
Poorly		S3w	S3w	S3w	Nw
Very poorly		Nw	Nw	Nw	Nw

Considering the above crop suitability criteria, for the given soil phases indicate suitability of Ragi, Redgram, Areca and Mango as S1/S2/S3/N

Soil Phase	***Characters***					***r***	***t***	***g***	***l***	***w***	***Suitability class***
	Depth	***SSG***	***SST***	***Slope***	***Drainage***	***Depth***	***Texture***	***Gravels***	***Slope***	***Drainage***	
Ragi											
TDHhB1	50-75	0	sc	1-3%	mod. well						
APHiA1St1	<25	33	sl	0-1%	well						
CKMiC1g1	75-100	0	ls	3-5%	poor						
Redgram											
KMHiB1g1	100-150	23	c(r)	1-3%	well						
BPRiB1	25-50	32	scl	1-3%	poor						
JDGcA1	50-75	8	sc	0-1%	mod. well						
Arecanut											
GLRiD1	100-150	40	c(r)	5-10%	well						
NDLhC1	>150	50	s	3-5%	well						
BDKcB1	25-50	14	c(b)	1-3%	very poor						
Mango											
RTRiB2g1	25-50	10	c(b)	1-3%	well						
TSDiA1	75-100	17	scl	0-1%	poor						
TDGiC1	>150	37	s	3-5%	well						

DSS on Nutrient management as per the fertility status of soil

The importance of soil fertility and plant nutrition to the health and survival of all life cannot be understated. As human population continue to increase, human disturbance of the earth's ecosystem to produce food and fiber will place greater demand on soils to supply essential nutrients. The practice of intensive cropping with hybrid varieties for boosting food production in India caused nutrient depletion in soil, consequently macro and micro nutrient deficiencies are reported in soils of India. If we do not improve and/or sustain the productive capacity of our soils, we cannot continue to support the food and fiber demand of our growing population. Maize is gaining importance as a commercial food grain crop in Karnataka. High fertilizer responsiveness together with preference for cultivation under irrigation, maize crop is known to remove nutrients exhaustively. It is therefore important to monitor the nutrients status of soil from time to time with a view to monitor the soil health.

In the recent past, concept of watershed based holistic development has emerged as one of the potential approaches in rainfed areas, which can lead to higher productivity and sustainability in agriculture. Hence, assessing the fertility status and nutrient mapping of soils is needed to identify extent of nutrient deficient area for site specific recommendations. Micronutrient deficiency in soil has become wide spread in recent years and has resulted in low crop yields, more so after the introduction of high yielding crop varieties coupled with the use of high analysis fertilizer and increased cropping intensity. The information regarding the status of available micronutrients and nutrient mapping of soils is needed to realize the concept of watershed approach successfully.

Many of the soils in different ecosystems are fragile and miss management can rapidly lose whatever capability they have for sustained productivity. If we do not improve and/or sustain the productivity capacity of our fragile soils, we cannot continue to support the food and fiber demand of our growing population. Therefore, it is critical that we increase our understanding of the soil nutrient status and relationships in the soil-plant atmosphere continuum that control nutrient availability.

Hence, geo-referenced information on the location, extent, quality of land display of spatial data is a must for advisory purposes. Geographic information system (GIS) is a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world. Geographic information system (GIS) can be used in producing a soil fertility map of an area, which will help in formulating site specific balanced fertilizer recommendation and to understand the status of soil fertility spatially and temporally. This is an important technique for formulating site-specific recommendation of nutrients.

Available Nutrients mapping

Surface (0-20/30 cm) soil samples are to be drawn in grid sampling from the area at 320-meter grid intervals. Soil samples are to be processed and analyzed for the soil fertility parameters like organic carbon, nitrogen, phosphorous, potassium, calcium, magnesium, Sulphur, copper, iron, zinc, manganese and boron by standard analytical techniques. Thematic maps are to be prepared for the analysis data using GIS tools.

Inputs data required for the DSS: GIS layers of all soil fertility parameters, crop wise NPK fertilizer and micro nutrient recommendations, criteria for adjusting the fertilizer recommendations, information of the farmer and location details of the farmer's field.

Soil fertility criteria for adjusting the recommended fertilizer doses for macro nutrient application (NPK)

Nutrient	*Very Low*	*Low*	*Medium*	*High*	*Very High*
Nitrogen	Recommended dose x 1.67	Recommended dose x 1.33	Recommended dose x 1.00	Recommended dose x 0.67	Recommended dose x 0.33
P_2O_5					
K_2O					

Note: For example, if the recommended dose of N for irrigated maize is 150 kgs/ha and if the nutrient content of the soil is very low, then we need to add 250 kg/ha (150 x 1.67), for low 200 kgs/ha (150 x1.33), for medium 150 kgs/ha (150 x 1.0), for high 100 kgs/ha (150 x 0.67; 2/3 general recommendation as per POP) and for very high 50 kgs/ha (150 x 0.33; 1/3 general recommendation as per POP). Similarly, for phosphorus and potassium, the fertilizer requirements are calculated using the above formula.

Step by Step Process

Step	*Description*
1	Read farmers information (Contact number, land parcel, crop sown, area, ACZ, dry or irrigated)
2	Read soil fertility status with respect to land parcel from LRI information
3	Select nutrient recommendation from selected crop
4	Adjust nutrient recommendation with respect to soil fertility status
5	Read nutrient content in fertilizers
6	Estimate amount of fertilizer required for the crop
7	Estimate the dose at different stages of plant growth (Basal dos and top dressing)
8	Send the advisory to the farmer-dosage of fertilizer and cost at different stages of growth along with package of practices to be followed
9	Based on the nutrient status of the soil in the watershed/sub watershed area estimate the amount of fertilizers required for the area.

Apart from the display of the nutrient status maps, the amount of nutrients required for the Micro watershed/sub watershed area can be estimated and shown as an output as per the requirement.

Exercise - 2

Nutrient Management Plan

Based on soil nutrient status as in LRI card, calculate the actual quantities of fertilizer required per acre of area

Group	***Soil fertility status Available nutrient kg/ha***			***Crops***	***Fertilizer adjustments***
	N	***P2O5***	***K2O***		
1	VL	L	VL	Maize, Tomato	Calculate quantity of fertilizers to adjust the nutrient requirement of the crop: Combination of 1. Straight fertilizers and 2. DAP++
2	L	L	VH	Redgram, Potato	
3	L	M	H	Groundnut, Carrot	
4	VL	VL	VL	Cotton, Chrysanthemum	
5	VL	VL	VL	Tomato, Redgram	
6	H	M	VL	Potato, Carrot	

ಬೆಳೆಗಳಿಗೆ ಶಿಫಾರಸ್ಸು ಮಾಡಿರುವ ಪೋಷಕಾಂಶಗಳು

ಬೆಳೆ	ಸಾ	ರಂ	ಪೊ	ಸತು	ಇತರೆ
ಹೈಬ್ರಿಡ್ ಜೋಳ					
ನೀರಾವರಿ	60	30	15	–	–
ಮಳೆಯಾಶ್ರಿತ	40	20	10		
ಹಿಂಗಾರಿ ಜೋಳ	20	10	0	–	–
ಮುಸುಕಿನ ಜೋಳ					
ನೀರಾವರಿ	60	30	16	4	–
ಮಳೆಯಾಶ್ರಿತ	40	20	10	4	–
ರಾಗಿ					
ನೀರಾವರಿ	40	20	20	5	4 ಕಿ.ಗ್ರಾಂ ಬೋರಾಕ್ಸ್
ಮಳೆಯಾಶ್ರಿತ	20	16	15	–	
ನವಣೆ	16	16	0	–	–
ಹಾರಕ	8	8	0	–	–
ಸಾಮೆ	8	8	0	–	–
ತೊಗರಿ	10	20	10	6	8 ಕಿ.ಗ್ರಾಂ ಗಂಧಕ
ಹೆಸರು	10	20	20	–	–
ಉದ್ದು	10	20	10	–	–
ಹಲಸಂದೆ	10	20	10	–	–
ಕಡಲೆ					
ನೀರಾವರಿ	10	20	20	–	–
ಮಳೆಯಾಶ್ರಿತ	5	10	10		
ಅವರೆ	10	20	10	–	–
ಹುರುಳಿ	10	15	10	–	–
ಶೇಂಗಾ					
ನೀರಾವರಿ	10	30	15	4	4 ಕಿ.ಗ್ರಾಂ ಬೋರಾಕ್ಸ್ 500 ಕಿ.ಗ್ರಾಂ/ಹೆ ಜಿಪ್ಸಂ
ಮಳೆಯಾಶ್ರಿತ	10	20	10		
ಸೂರ್ಯಕಾಂತಿ					
ನೀರಾವರಿ	36	36	25	4	6 ಕಿ.ಗ್ರಾಂ ಬೋರಾಕ್ಸ್
ಮಳೆಯಾಶ್ರಿತ	15	20	15		
ಎಳ್ಳು	15	10	10	–	–
ಹರಳು	15	15	10	–	–
ಹತ್ತಿ	60	30	30	–	–
ಕಬ್ಬು	100	40	50	–	–

ತರಕಾರಿ ಮತ್ತು ಹೂವಿನ ಬೆಳೆಗಳು (ಕಿ.ಗ್ರಾಂ/ಎಕರೆಗೆ)	**ಸಾ**	**ರಂ**	**ಪೊ**
ಟೊಮ್ಯಾಟೋ	100	100	100
ಬದನೆ	50	40	20
ಆಲೂಗಡ್ಡೆ	50	40	50
ಮೆಣಸಿನಕಾಯಿ	40	20	20
ಎಲೆಕೋಸು	60	40	50
ಹೂಕೋಸು	60	40	50
ಗೆಡ್ಡೆಕೋಸು	60	40	50
ಸೌತೇಕಾಯಿ	24	20	32
ಹೀರೇಕಾಯಿ	20	20	20
ಕಲ್ಲಂಗಡಿ	40	30	40
ಕರಬೂಜ	40	30	20
ಬೆಂಡೆ	50	30	25
ತಿಂಗಳ ಹುರುಳಿಕಾಯಿ	25	40	30
ತರಕಾರಿ ಅಲಸಂದೆ	10	30	24
ಅವರೆಕಾಯಿ	10	20	10
ಚವಳಿಕಾಯಿ	10	30	24
ನುಗ್ಗೆ	20	50	12
ಮೂಲಂಗಿ	20	40	20
ಕ್ಯಾರೇಟ್	20	20	20
ಬೀಟ್‌ರೂಟ್	30	40	24
ಕೊತ್ತಂಬರಿ	14	14	24
ಕರಿಬೇವು (ಗ್ರಾಂ/ಗಿಡಕ್ಕೆ)			
ಒಂದನೇ ವರ್ಷ	50	25	25
ಎರಡನೇ ವರ್ಷ	150	37	37
ಮೂರನೇ ವರ್ಷ	300	50	50
ಗುಲಾಬಿ (ಗ್ರಾಂ/ಗಿಡಕ್ಕೆ)	10	10	15
ಮಲ್ಲಿಗೆ (ಗ್ರಾಂ/ಗಿಡಕ್ಕೆ)			
1–2 ವರ್ಷ	30	60	60
3–5 ವರ್ಷ	60	120	120
5 ವರ್ಷಗಳ ನಂತರ	120	240	240
ಸೇವಂತಿಗೆ	40	60	40
ಚೆಂಡುಹೂವು	90	24	24
ಕನಕಾಂಬರ	40	24	24
ಅರಿಶಿಣ	60	50	100
ಶುಂಠಿ	40	20	20

ವಿವಿಧ ರಸಗೊಬ್ಬರಗಳಲ್ಲಿ ಪೋಷಕಾಂಶಗಳ ಪ್ರಮಾಣ

ರಸಗೊಬ್ಬರಗಳು	ಪೋಷಕಾಂಶಗಳ ಪ್ರಮಾಣ
ಯೂರಿಯಾ	46% ಸಾರಜನಕ
ಅಮೋನಿಯಂ ಸಲ್ಫೇಟ್	20.6% ಸಾರಜನಕ, 24% ಗಂಧಕ
ಕ್ಯಾಲ್ಸಿಯಂ ಅಮೋನಿಯಂ ನೈಟ್ರೇಟ್	25% ಸಾರಜನಕ, 8.1% ಸುಣ್ಣ
ಸಿಂಗಲ್ ಸೂಪರ್ ಫಾಸ್ಫೇಟ್	16% ರಂಜಕ, 12% ಗಂಧಕ, 20%ಸುಣ್ಣ
ಮ್ಯೂರೆಟ್ ಆಫ್ ಪೊಟ್ಯಾಷ್	58–60% ಪೊಟ್ಯಾಷಿಯಂ
ಸಲ್ಫೇಟ್ ಆಫ್ ಪೊಟ್ಯಾಷ್	48–5%0 ಪೊಟ್ಯಾಷಿಯಂ 18% ಗಂಧಕ
ಡಿ.ಎ.ಪಿ	18% ಸಾರಜನಕ 46% ರಂಜಕ
ಮೆಗ್ನೀಷಿಯಂ ಸಲ್ಫೇಟ್	9.6% ಮೆಗ್ನೀಷಿಯಂ 13% ಗಂಧಕ
ಸತುವಿನ ಸಲ್ಫೇಟ್	21% ಸತು, 11% ಗಂಧಕ
ಕಬ್ಬಿಣದ ಸಲ್ಫೇಟ್	18.5% ಕಬ್ಬಿಣ
ಮ್ಯಾಂಗನೀಸ್ ಸಲ್ಫೇಟ್	33% ಮ್ಯಾಂಗನೀಸ್
ತಾಮ್ರದ ಸಲ್ಫೇಟ್	24% ತಾಮ್ರ
ಬೊರಾಕ್ಸ್	10.5% ಬೋರಾನ್
ಅಮೋನಿಯಂ ಮಾಲಿಬ್ಡೇಟ್	54% ಮಾಲಿಬ್ಡಿನಂ
ಜಿಪ್ಸಂ	13–18% ಗಂಧಕ 22% ಸುಣ್ಣ
ಕೃಷಿ ಸುಣ್ಣ	33% ಸುಣ್ಣ
ಡೋಲೋಮೈಟ್	21% ಸುಣ್ಣ 13.9% ಮೆಗ್ನೀಷಿಯಂ
ಕ್ಯಾಲ್ಸಿಯಂ ನೈಟ್ರೇಟ್	19% ಸುಣ್ಣ
ಶಿಲಾರಂಜಕ	33% ಸುಣ್ಣ

DSS on Estimation of surface runoff

When rainfall occurs in excess of absorption by soil, it causes runoff which increases with time and length of slope. Runoff is influenced by multiple factors like intensity and duration of rainfall, initial abstraction, existing land use, slope gradient and length, rate of infiltration, percolation rate, presence of hard substratum, antecedent moisture, management practices and other factors. Runoff is a critical factor in deciding the type of conservation needed, number and location of water harvesting and recharge structures, formulation of appropriate cropping pattern and crop selection and the water balance and water availability at the watershed scale.

Some important runoff estimation models that are in use are SCS Curve Number method, which is an empirical method of estimating excess precipitation, Constant infiltration-based method in which saturated soil conductivity is used as infiltration rate; Horton equation, which is based on mathematical equation; SAC-SMA (Sacramento Soil Moisture Accounting) which attempts to mimic physical constraints of water movement in a natural system, many other models and Rational method (Ramser's method).

Under this DSS, along with the SCS Curve Number and Rational methods, Runoff model developed based on LRI database (Infiltration) and precipitation available from KSNMDC is included to estimate the amount of runoff that can be expected to occur at different levels in a watershed area.

SCS Curve Number method

Input parameter required for runoff estimation under SCS Curve Number method

Required input	Master table/map	Derived data	Remark
Land use/ cropping pattern	Land use/ cropping system- from land use maps		Data from the land use map generated by LRI, or using remote sensing
Soil texture	Management unit wise (soil phase) texture data	Characterization of soil in four hydrological groups- not done under LRI	
Infiltration rate	Soil phase wise infiltration rate		
Land slope	Soil phase wise Slope		
Curve numbers		Curve numbers for different combinations of Land cover/use classes and soil hydrological groups	
Rainfall	Daily rainfall data	Daily rainfall, 5-day antecedent rainfall	

Step-by-step processes for runoff estimation under SCS Curve Number method

Steps	Description
1	Read **Soil phase** wise Land use-land cover/use classes
2	Read Soil phase wise soil hydrological groups
3	Decide curve number for each Soil phase based on land cover/use class and soil hydrologic group (AMC-II)
4	Check 5-day antecedent rainfall with AMC condition AMC- I: Lowest runoff potential. The soils are dry enough for satisfactory cultivation (rainfall < 35 mm) AMC- II: Average condition (rainfall between 35 to 52.5 mm) AMC- III: Highest runoff potential. The area is practically saturated from antecedent rains (rainfall > 52.5 mm)
5	Select multiplication factor to Convert Curve Number for AMC II to AMC I or III
6	Adjust the curve number using AMC factor
7	Estimate the potential maximum soil moisture retention after runoff begins and initial abstraction factor using adjusted curve number
8	Estimate runoff using daily rainfall, the potential maximum soil moisture retention after runoff begins and initial abstraction
9	Display runoff at different levels from survey number, management unit, MWS, SWS and higher levels

Note: Display of results at SWS and higher levels is not possible at present due to the change in land use at each survey number. It will be available from all the three methods from survey number and soil unit levels at present. From infiltration method, results can be provided at any levels as per the requirement.

Master table of curve numbers based on land cover/use and hydrologic soil groups

Land cover	Hydrologic soil groups*			
	A	B	C	D
Forest	30	43	60	63
Cropped area (Good crop, Fair crop, Poor crop)	71	77	84	86
Fallow	77	86	91	94
Settlement	75	85	90	91
Uncultivable				
Water body	0	0	0	0

Multiplication factor for converting AMC II to AMC I or III

Curve Number (AMC II)	Factors to Convert Curve Number for AMC II to AMC I or III	
	AMC I (dry)	AMC III (wet)
10	0.4	2.22
20	0.45	1.85
30	0.5	1.67
40	0.55	1.5
50	0.62	1.4
60	0.67	1.3
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1	1

Rational method (Ramser's method)

The return period, also known as recurrence interval or frequency is defined as the period of years during which a rainstorm of a given duration and intensity is expected to occur. This method is used to design water harvesting structures, except farm ponds, at the watershed and higher levels. Recommended return period or rainfall frequency for various types of structures is given in Table 5.

Recurrence interval for different conservation structures

Type of structure	Frequency of occurrence (years)
Storage and diversion dams having permanent spillways	50-100
Earth fill storage dams having natural spillways.	25-50
Stock water dam (Nala bund, Check dam, Percolation tank & Vented dam)	25
Small permanent masonry gully control structure and silt retention structure (Ravine reclamation structure)	10
Bunds, Water ways, Farm ponds & Diversion channel.	10

Two methods are used for estimating peak rate of runoff, namely Ramser's or Rational method. The most widely used method is the Rational method and is the oldest, simplest, and possibly the most consistent one in its ability to adapt to new concepts and developments in conservation programmes.

Rational Formula Q = CIA/360,
Where,

'Q' is peak rate of runoff (Cubic meters per second)
'C' is runoff coefficient (Table 6.6)
'A' is area of catchment (hectares)
'I' is intensity of rainfall for the design frequency and for duration equal to time of concentration of the watershed/catchment. (mm/hr.). Highest rainfall intensity of a day observed in about 10 years' time period or whatever years data is available from KSNDMC.

The runoff coefficient, C is a dimensionless quantity giving the ratio of peak runoff rate to the rainfall intensity. It is influenced by the soil type, topography, and land use. If there is homogeneous condition only one value of C will be valid. If there is heterogeneous condition, weighted value of C should be calculated using the formula:

$C_w = A_1C_I + A_2\,C_2 + \ldots\ldots A_n\,C_n/A$

Where, A is the total area of the watershed, C_1, C_2, …., Cn are the coefficients of runoff for the different homogeneous areas of size A_1, A_2 ….. A_n ha respectively.

'C' Values for use in Rational formula

Land Use & Slope (%)	**Soil Texture**		
	Sandy loam	**Clay & Silt Loam**	**Clay**
1. Cultivated Land			
0-5	0.30	0.50	0.60
5-10	0.40	0.60	0.70
10-33	0.52	0.72	0.82
2. Pastureland			
0-5	0.10	0.30	0.40
5-10	0.16	0.36	0.55
10-33	0.22	0.42	0.60
3. Forest Land			
0-5	0.10	0.30	0.40
5-10	0.25	0.35	0.50
10-33	0.30	0.50	0.60

Rainfall Intensity

Available rainfall intensity is used for calculation of the intensity for a given duration of a particular recurrence interval is considered. Wherever rainfall intensity data are not available calculation of the intensity for a given duration of a particular recurrence interval involves the following steps

For Slope = $(\Delta H / L) * 100$ in %

$\Delta H = \text{Slope} * L/100$

Where, ΔH is difference in elevation in meters
L is maximum length of the flow in meters

Rainfall intensity – duration – return period relationship & Empirical constants

Meteorological Station	Agro-climatic Zone	K_1	a	b	n
1. Bangalore	1. Southern Dry zone 2. Eastern Dry Zone	6.275	0.1262	0.5	1.1280
2.Hyderabad	3. Northern Dry Zone 4. North eastern Dry Zone 5. Central Dry Zone	5.250	0.1354	0.5	1.0295
3. Mangalore	6. Coastal Zone	6.744	0.1395	0.5	0.9374
4.Other Zones	7. Southern transition Zone 8. Northern transition Zone 9. North eastern transition Zone 10. Hilly Zone	6.311	0.1523	0.5	0.9465

Infiltration Method

This is a new pilot, developed to estimate runoff based on LRI information generated for the watershed areas under Sujala III project. The sequence of activities is described below.

- A query will be executed to find the Cadastral ID on basis of Selected Village, Taluk, District, and Survey Number from CADASTRAL table.
- Get the Soil texture, Slope, Landform (Black, Red / lateritic) from the Parcel characteristics table for the respective cadastral ID.
- A query will be executed to find current Land use for the selected survey number.
- A query will be executed on Master Infiltration Rate to get constant infiltration rate depending Soil Texture and Land use.
- Calculate the Rainfall Peak Intensity (mm/hr)
    - Calculate rainfall = Rainfall at end of storm – Rainfall at start of storm
    - Intensity = Calculated rainfall / Duration of storm in hrs.
    - If each of the Intensity >= 20 then consider it, else ignore the value
    - Average intensity should be calculated based on average of the interval selected. (Eg: if it is 20-30, the average intensity is 25, if it is 50-60, the average intensity is 55 and so on.

1. Average intensity should be calculated based on average of the interval selected. (Ex: if it is 20-30, the average intensity is 25, if it is 50-60, the average intensity is 55 and so on.
2. If Rainfall has occurred with a storm from 8am to 10am, then consider 8am to 8.30am rainfall and add it to 8.30 to 10am rainfall. This storm will be considered for next day runoff.
3. Depending upon the Soil Texture, Slope and Vegetative Cover, Constant Infiltration rate (mm/hr) is selected from the table mentioned below. User has to select the vegetative cover from the below mentioned percentage (%) and as per the user selection the application will select the infiltration rate according to the Soil texture and Slope (mA, mB, mC, mD, mE and so on) in the selected survey no. (These are values as per the suggestion obtained from Dr. Sathish Kumar, UASR).

For Black soil (i.e. 5 clay bounds)

Soil code	mA	mB	mC	mD	mE
Vegetative cover					
0-20%	9	8.5	8	7.5	7
20-40%	10	9.5	9	8.5	8
40-60%	11	10.5	10	9.5	9
60-80%	12	11.5	11	10.5	10
80-100%	13	12.5	12	11.5	11

For Red/Laterite (i.e. 7 Sand bounds)

Soil code	mA	mB	mC	mD	mE
Vegetative cover					
0-20%	20	19	18	17	16
20-40%	22	21	20	19	18
40-60%	24	23	22	21	20
60-80%	26	25	24	23	22
80-100%	28	27	26	25	24

4. If Slope and Soil Texture are not available, Infiltration rate is considered as 8 for clay bound and 13 for red and lateritic soils.
5. If the selected survey number has different slopes or soil type, then Weighted Average of Infiltration Rate will be considered for the further calculations.
6. **Net instantaneous runoff** is estimated by subtracting Infiltration rate due to Slope and Vegetation (mm/hr) from Average Rainfall Intensity (mm/hr).
   Net Instantaneous Runoff Rate = (Average Rainfall Intensity) – (Infiltration rate)
7. By multiplying Net Instantaneous Runoff Rate with Possible Duration of Rainfall, Impact Factor and Number of Possible Events, Design Runoff Depth (mm) (Rd) is estimated (potential runoff).
8. Impact factor is considered as 1.
9. An input is asked to the User to enter the length of the bunding structure (m) if it is present in the selected survey no. or from the conservation maps generated for the area.
10. Anticipated Water Spread Area (m^2) is calculated as 1/2*10m*0.3m=0.75
11. Design Runoff Retained (Rr) (mm) is calculated by multiplying Minimum Length of the Bund (m) and Anticipated Water Spread Area (m^2).
    Design Runoff Retained = (min length of the bund) * (Anticipated Water Spread Area) / 10
12. If Design Runoff Depth is greater than Design Runoff Retained, Design Runoff Excess (RE) (mm) is calculated as "Design Runoff Depth – Design Runoff Retained", else it is equal to "0".
    If Rd > Rr,
    Design Runoff Excess = Design Runoff Depth – Design Runoff Retained Else,
    Design Runoff Excess = 0

13. Number of possible events is taken up for the whole day between the considered range i.e. if the Rainfall intensity value falls in any of the intervals (say 40-50, 50-60, 60-70 and so on up to 190-200), those no. of rainfall intensity within that interval need to be counted. For eg: if the Rainfall Intensity is 55mm/hr, 40 mm/hr, 32 mm/hr, 57 mm/hr, 89 mm/hr, 59 mm/hr and so on, then 55, 57 and 59 fall into 50-60 interval class and the no. of possible events in this class is 3. In 40-50 interval class, no. of possible events is 1 and in 80 to 90 interval class, no. of possible event is 1. 32 will not be considered, as it is less than 40mm. Anything above 200 will be considered in 190-200 interval class.
14. Design runoff excess is termed as Runoff excess after bunding.
15. Total Runoff Excess after Bunding (mm) will be the runoff excess after bunding for the corresponding land parcel area. This will be the final output of total runoff for the selected survey no. in the result table.
    - Display the result in a table showing the information such as Survey No, Farmer Name, Area in Hectare, Interval, Runoff (mm).
    - Display the Farm owner details based on the data fetched for cadastral from result grid view through web service integration with Bhoomi.

Note: Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyze DSS results based on these temporary changes.

DSS on Designing size of farm ponds

Farm ponds: Farm ponds are manmade ponds constructed for storing rainwater which could be used during scarce season to ensure lifesaving irrigation for the uninterrupted physiological activities of the crops. Farm ponds are constructed by excavating the soil, by depositing the soil on the bunds. These ponds may be lined with impermeable membrane such as HDPE sheet to avoid infiltration of water into soil. However, unlined ponds are more suitable for groundwater recharge. The excavated ponds are generally made in relatively level regions across waterways, small gullies or to one side of them. They are preferably located in areas with impervious substratum. These ponds should be as deep as possible within the limitations of workability and pumping conditions

Calculating cost of Farm Ponds based on Cubic meter rate (Amount in Rs. /m^3)

South Zone		***North Zone***		***North Zone (Shimoga & Chithradurga)***		***North East Zone***	
Clayey/ black soil	*Loamy /red soil*	*Clayey/ black soil*	*Loamy/ red soil*	*Clayey/ black soil*	*Loamy /red soil*	*Clayey/ black soil*	*Loamy/ red soil*
172	**164**	**186**	**179**	**173**	**164**	**183**	**206**
Districts		**Districts**		**Districts**		**Districts**	
Kodagu		Dharwad		Shimoga		Bellary	
Udupi		Gadag		Chithradurga		Raichur	
South Canara		Haveri				Koppal	
Hassan		Belagavi				Kalburgi	
Chickmagalore		Uttara kannada				Yadgir	
Mysore		Bijapur				Bidar	
Mandya		Bagalakote					
Chamaraja nagara		Davanagere					
Ramanagaram							
Tumkur							
Chickballapur							
Bangalore(u)							
Bangalore®							
Kolar							
1) Without smoothening of segments 2) costing as per WDD schedule of rate- 2018-19							

The application decides the farm pond size based on following steps Slide Slope Consideration:

For Black Soil: 1.5:1

For Red Soil: 1:1

Depth needs to be considered as 3 m.

Top Width = √ (Runoff Volume/3) + 4.5 for Black soil

Top Width = √ (Runoff Volume/3) + 3 for Red Soil

Bottom Width = √ (Runoff Volume/3) - 4.5 for Black soil
Bottom Width = √ (Runoff Volume/3) - 3 for Red Soil

Top Area = Top Width * Top Length

Since its square Top width = Top Length

Bottom Area = Bottom Width * Bottom Length

Since its square Bottom width = bottom Length

Volume = (Top Area + Bottom Area)/2 * Depth

Example:

Depth of Farm Pond : 3 m
70% Surface Runoff : 1500 m3
Soil Type : Black Soil, Slide Slope consider as 1.5:1

Top Width = √ (1500/3) + 4.5 = 26.8608 (Round off the Top width to = 27 m)
Top Area = Top Width X Top Length = 27 * 27 = 729 m^2
Bottom Width = √ (1500/3) - 4.5 = 17.8608 (Round off the Bottom width to = 18 m)
Bottom Area = Bottom Width X Bottom Length = 18 * 18 = 324 m^2
Volume of Farm Pond = (Top Area + Bottom Area) / 2 * Depth

= (729 + 324)/2) * 3 = 1579.5 m^3

The Farm Pond Size will be = 27 X 27 X 3

- Further, the application will check for the Storage Capacity (m^3) by considering the 70% Runoff for the purpose of harvesting (from DSS 5.2 – Infiltration method)
- Depending on the standard rates of farm pond construction, cost of construction (rupees) is estimated
- Total Surface runoff (mm/year) is displayed in the final output table along with the farm pond size and the cost of construction. Display the Farm owner details based on the data fetched for cadastral from Bhoomi data
- Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyze DSS results based on these temporary changes

Survey Number	Excess Runoff (m^3)	Net Runoff (m^3)	Farm Pond Size	Volume of Farm Pond (m^3)	Cost of Construction	Action
123	2142.86	1500	27 X 27 X 3	1579.5	271674	Custom

Note: For peak intensity, consider the highest peak event average for the storage capacity of the farm pond.

DSS on Estimation of crop water requirement

The amount of water that needs to be supplied to the cropped field is defined as crop water requirement or Crop Evapotranspiration (ETc). Crop water requirement is estimated using FAO 56 method. The common approach to calculate ETc is to estimate a reference crop Evapotranspiration (ETo) using weather variables from nearby weather station and multiplying it by an appropriate crop coefficient (Kc). Inputs required for estimating the crop water requirement and steps for estimating the crop water requirement are given below.

Inputs required for estimating Crop Water requirement

Inputs	Input parameter	Master table	Note
Location information	Geo-coordinates, land area	Micro-watersheds, management units, parcel numbers,	
Weather	Maximum, Minimum Temperature, Relative humidity, solar radiation or sunshine hours, wind speed, etc.	Estimate Potential evapotranspiration at daily scale	ETo will be estimated using weather parameters
Crop management details	Crop grown, date of sowing, crop duration	Farmers data, FAO data on crop duration	Length of crop growth stages to be prepared for each crop separately from package of practices publication
Crop growth parameters	Crop coefficient and root growth function at different stages	FAO, NBSS&LUP, NWDA data on crop coefficients; Literature from root growth	Kc values to be compiled for different crops and for root growth characteristics like very shallow, shallow, medium, deep and very deep

Steps involved in the estimation of Crop Water requirements

S. No	Description of the steps involved
1	Define land use class/ cropping system and its management details- Input from users-survey number, crop, date of sowing etc
2	Estimate day after sowing
3	Estimate crop coefficient based on days after sowing and crop growth parameters
4	Estimate potential evapotranspiration requirement using measured weather parameters on daily time scale

5	Estimate crop water requirement using crop coefficient and potential evapotranspiration (Multiply crop coefficient with PET)
6	Display crop-wise water requirement **at parcel level**. (Aggregate crop water requirement at soil unit, MWS and SWS levels based on the crop cultivated)
7	Display crop-wise water requirement to the farmer/other stakeholders

Note: Only parcel level output is possible due to the changes in the land use, which varies from parcel to parcel in the watershed area.

Crop coefficient (Kc) values compiled for major crops (FAO, 1998)

	Crop	*Initial stage Kc*	*Midseason Kc*	*End season Kc*	*Remarks*
All Small Vegetables		0.7	1.05	0.95	
1	Cabbage		1.05	0.95	
2	Cauliflower		1.05	0.95	
3	Carrots		1.05	0.95	
4	Lettuce		1.00	0.95	
5	Garlic		1.00	0.70	
6	Onions		1.05	0.75	
7	Radish		0.90	0.85	
8	Spinach		1.00	0.95	
9	Broccoli		1.05	0.95	
Vegetables	All Solanaceous crops	0.6	1.15	0.80	
1	Tomato		1.15	0.70-0.90	
2	Egg Plant		1.05	0.90	
3	Capsicum (bell)		1.05	0.90	
Vegetables	All Cucumber family crops	0.5	1.00	0.80	
1	Cucumber	0.6	1.00	0.75	
2	Pumpkin		1.00	0.80	
3	Watermelon	0.4	1.00	0.75	
4	Sweet Melons		1.05	0.75	
5					
Tuber crops	All tuber crops	0.5	1.10	0.95	
1	Cassava	0.3	0.80	0.30	
2	Potato		1.15	0.75	
3	Sweet Potato		1.15	0.65	
4	Turnip		1.15	0.95	

	Crop	*Initial stage Kc*	*Midseason Kc*	*End season Kc*	*Remarks*
Legumes	All Legumes	0.4	1.15	0.55	
1	Green Gram & Cowpeas		1.05	0.60 (Harvested fresh)	
2	Green Gram & Cowpeas		1.05	0.35 (Harvested dry)	
3	Groundnut		1.15	0.60	
4	Chickpea		1.00	0.35	
5	Soybeans		1.15	0.50	
6	Beans (green)	0.5	1.05	0.90	
Fibre Crops		0.35			
	Cotton		1.15-1.20	0 0.70-0.50	
Oilseeds	All oilseeds	0.35	1.15	0.35	
1	Castor		1.15	0.55	
2	Rapeseed		1.0-1.15	0.35	
3	Safflower		1.0-1.15	0.25	
4	Sesame		1.10	0.25	
5	Sunflower		1.0-1.15	0.35	
Cereals	All cereal crops	0.3	1.15	0.4	
1	Maize		1.20	0.60	
2	Sorghum-grain		1.00-1.10	0.55	
3	Rice	1.05	1.20	0.90-0.60	
4	Millet		1.00	0.30	
5	Bajra				
Sugarcane		0.40	1.25	0.75	
Banana	1st year 2nd year	0.50 1.00	1.10 1.20	1.00 1.10	
Grapes–Table or Raisin		0.30	0.85	0.45	
Pineapp le	with grass cover	0.50	0.50	0.50	
Citrus	70% canopy 50% canopy	0.75 0.80	0.70 0.80	0.75 0.80	

Exercise - 3

Estimation of crop water requirement

Steps in estimation of crop water requirement

#	**Description of the steps involved**
1	Define land use class/ cropping system and its management details
2	Estimate day after sowing
3	Estimate crop coefficient based on days after sowing and crop growth parameters
4	Estimate potential evapotranspiration requirement using measured weather parameters on daily time scale
5	Estimate crop water requirement using crop coefficient and potential evapotranspiration (Multiply crop coefficient with PET)
6	Display crop-wise water requirement at parcel level. (Aggregate crop water requirement at soil unit, MWS and SWS levels based on the crop cultivated)
7	Display crop-wise water requirement to the farmer/other stakeholders

Calculate the crop water requirement for the following crops in one soil phase
Place: Hodekallu micro watershed in Tumkur Taluk
Daily average PET during south-west monsoon is 4.33
Daily average PET during north-east monsoon is 4.49
Refer above table for crop coefficient (Kc) values compiled for major crops (FAO, 1998)

Crop	Area (ha)	Initial Stage			Mid-Season			End-Season			*Total water requirement ha mm*
		Kc value	Duration (days)	Water Requirement ha mm	Kc value	Duration (days)	Water requirement ha mm	Kc value	Duration (days)	Water requirement ha mm	
Maize	7										
Groundnut	10										
Sorghum	14										
Soyabean	3										
Sunflower	9										
Cotton	12										

6. LRI based Fertilizer Application

Need for LRI based fertilizer application: Land Resource Inventory (LRI) provides site and crop specific fertilizer recommendations based on the fertility status of the soils, but still, most of the farmers follow blanket recommendation. This has led to either over or sub optimal application of fertilizers in most of the situations, thereby increasing the input costs and reducing the profit margin or may result in lower yields. This can be avoided if the fertilizer applications are made based on the LRI recommendations. Therefore, aligning soil fertility status with nutrient requirement of crops assumes greater importance. The extension functionaries of the State Department of Agriculture especially those who are working in Raitha Samparka Kendras have to influence fertilizer purchase decisions of farmers to align them to the soil fertility status to avoid inappropriate use and overuse of chemical fertilizers.

Adjustment of recommended dose of fertilizer based on soil nutrient status

Soil analysis provides a detailed picture of the available nutrients in your soil. This helps identify deficiencies before they become a problem. Based on the soil analysis results, one can choose fertilizers that provide the specific nutrients to the crops need, avoiding unnecessary application of other elements which promotes a more sustainable approach to crop management. By optimizing nutrient use, one can minimize environmental impact and improve soil health in the long run. By prioritizing soil analysis and addressing nutrient deficiencies, a strong foundation for healthy plant growth, maximize yields, and minimize losses from other stresses can be achieved.

The table provided below shows how to adjust the recommended dose of fertilizer (RDF) of any crop based on the soil nutrient status for Nitrogen (N), Phosphorus (P_2O_5), and Potassium (K_2O).

Nutrient	***Very low***	***Low***	***Medium***	***High***	***Very high***
	kg ha^{-1}				
Available N	<140	140 to 280	281 to 560	561 to 700	>700
Available P_2O_5	<11.45	11.45 to 22.9	22.91 to 57.25	57.26 to 91.6	>91.60
Available K_2O	<72.3	72.3 to 144.6	144.7 to 337.4	337.5 to 674.8	>674.8
Correction/ Adjustment	**RDF x 1.67**	**RDF x 1.33**	**RDF x 1.00**	**RDF x 0.67**	**RDF x 0.33**

Based on the above table provided, the following example can be used for a maize crop having RDF 60:30:15 kg/acre of NPK if the soil fertility status is very low, low and medium respectively:

If the soil nutrient status is Very Low

Fertilizers in kg per acre

Nitrogen - **60** (RDF) x 1.67 = 100	Urea: 217	Urea: 175
Phosphate - **30** (RDF) x 1.67 = 50	SSP: 313	DAP: 109
Potash - **15** (RDF) x 1.67 = 25	MOP: 42	MOP: 42

If the soil nutrient status is Medium

Fertilizers in kg per acre

Nitrogen - **60** (RDF) x 1.00 = 60	Urea: 130	Urea: 105
Phosphate - **30** (RDF) x 1.00 = 30	SSP: 188	DAP: 65
Potash - **15** (RDF) x 1.00 = 15	MOP: 25	MOP: 25

If the soil nutrient status is Very High

Fertilizers in kg per acre

Nitrogen - **60** (RDF) x 0.33 = 20	Urea: 44	Urea: 35
Phosphate - **30** (RDF) x 0.33 = 10	SSP: 63	DAP: 22
Potash - **15** (RDF) x 0.33 = 5	MOP: 08	MOP: 08

Land Resource Inventory (LRI) Card interpretation

What is LRI card?

Land resource inventory card is a printed document given to a farmer for each of his land holdings. It provides information about the soil's health condition based on soil physical and chemical properties. It helps farmers assess the quality of their farm soil and improve its productivity in the long run.

Based on these parameters, the LRI card provides recommendations on fertilizer use and other soil management practices. It also evaluates the changes in soil health that occur due to land management practices.

Land resource inventory card contains the following information:

1. Farmers general information
    - Name
    - Gender
    - Micro watershed name
    - Adress
    - Soil sampling year
    - Survey/ Hissa No.
    - Area in (Acre/ gunta)
    - Annual rainfall (mm)
2. Details of land surface and soil properties
    - Soil depth
    - Soil texture
    - Soil gravelliness (%)
    - Soil slope (%)
    - Soil erosion
    - Land capability classes
    - Soil water holding capacity
    - Soil and water conservation plan
    - Traditional soil name
3. Soil test results: pH, Electrical conductivity, Organic carbon, Available nitrogen, Available Phosphorus, Available potassium, Sulphur, iron, manganese, zinc, copper and boron
4. Secondary and micronutrients recommendations for deficient soils
5. Soil nutrient classification for very low, low, medium, high and very high soils
6. Suggested crop plan (Highly suitable, moderately suitable, marginally suitable and not suitable) based on land resource information

How to use Land Resource Inventory Card

1) **Depth :** Shallow soils are to be used for growing short duration & shallow rooted crops. Digging deep/bigger than recommended size pits & filling with good quality loamy soils from outside for planting Horticultural crops suggested.
2) **Texture :** Clayey soils are to be moderated by adding sandy soils or weathered parent material. Quantity of material to be added depends on the local crops requirements. For sandy soil addition of tank silt or black clayey soils provides better soil air-water relationship environment.
3) **Gravelliness :** Addition of tank silt or black clayey soils to increase soil volume is better. This helps in increasing soil available water & nutrient holding capacity.
4) **Slope :** By following appropriate suggested conservation measures like trench cum bunding, graded bunding, strengthening of existing bunds or sowing crops across the slope, better management of lands can be achieved. Bunds Strengthening has to be done every year.
5) **Soil Erosion :** Reducing the slope by appropriate bunding, levelling, planting across the slope, growing cover crops & mulching are suggested.
6) **Available Water Capacity:** By addition of organic matter, in-situ moisture conservation, addition of clayey materials to sandy soils shall help to improve the AWC to some extent.
7) **Soil and Water Conservation Plan:** The recommended soil and water conservation and drainage line treatment plans are to be followed. Proper maintenance is most essential.
8) Always apply recommended level of FYM/compost before crop sowing.
9) There is no need of adding amendment (lime of gypsum) if the Soil pH is neutral (pH6.5-7.5)
10) Application of required quantity of burnt lime is recommended if the soil pH is <6.5. Repeat the soil test after two years and correct based on the soil pH values.
11) In Sodic soils (pH >8.5) apply recommended dose of Gypsum & drain out the excess salts with good quality irrigation water.
12) Apply 25 percent extra RDF if the soil is low in major nutrients and reduce 25 percent from RDF if the soil has high NPK content. For example if the soil is deficient in nitrogen, application o-f 125kg RDF nitrogen is recommended in place of 100 kg N. The same needs to be followed for P & K also.
13) Incorporation of bio-fertilizers like Rhizobium, Azotobacter, Azospirillum, Phosphate Solubilizing Bacteria and Mycorrhiza will enhance availability of major & micro nutrients to the plants & also reduces the cost of cultivation.
While applying, soil moisture condition should be good.
14) It is recommended to go for soil test at every 2 years interval.

For More Informations Please refer Sujala Website **(Sujala3lri.karnataka.gov.in)**

Farmers Helpline Centeres: Agricultural Problems-1800-425-3553,Varuna Mitra-92433 45433, Horticulture Helpline--1800-4257910 and Krishi marata vahini-1800-425-1552

Govt. of Karnataka

THE WORLD BANK

ICAR-NBSS&LUP

ICAR

REWARD

Watershed Development Department Kaveri Bhavana, Bengalore-560 009
And
ICAR - National Bureau of Soil Survey and Land Use Planning, Regional centre, Hebbal, Bangalore -560 024
Contact: E-Mail: nbssgis@gmail.com

Land Resource Inventory Card

Farmer's Name	D Sugunamma
Gender: Male/Female	Female
Microwatershed Name	Kamatampalli (4C3D7v01)
Address	Agutamadike Village Bagepalli Taluk, Chikkaballapura District
Soil sampling year	2023
Survey/Hissa No	46/3
Area in (Acre/Gunta)	1.6
Annual Rainfall (mm)	835
***Note: Survey Number total area**	

Details Of Land Surface And Soil Properties	
Soil Depth	Shallow (25-50 cm)
Soil Texture	Loamy sand
Soil Gravelliness (%)	Very gravelly (35-60 %)
Soil Slope (%)	Gently sloping (3-5%)
Soil Erosion	Severe Erosion
Land Capability Classes	Moderately good cultivable lands with erosion and soil limitations
Soil Water Holding Capacity	Very low (<50 mm/m)
Soil & Water Conservation Plan	Trench cum bunding
Traditional Soil Name	Shallow Red gravelly Loamy soil

Laboratory Name and Address: National Bureau of Soil Survey and Land Use Planning, Regional centre,Hebbal, Bangalore -560 024.

Soil Test Results

Sl.no	Parameter	Test value	Unit	Rating
01	Soil reaction (pH)	5.5-6.0	-	Moderately acid
02	Electrical Conductivity (EC)	<2	dSm^{-1}	Non saline
03	Organic Carbon (OC)	0.25-0.5	%	Low
04	Available Nitrogen (N)	<140	Kg/ha	Very Low
05	Available phosphorus (P_2O5)	<11.5	Kg/ha	Very Low
06	Available Potassium (K2O)	<72	Kg/ha	Very Low
07	Available Sulphur (S)	10-20	P.P.M	Medium
08	Available Zinc (Zn)	<0.6	P.P.M	Deficient
09	Available Boron (B)	<0.5	P.P.M	Low
10	Available Iron (Fe)	>4.5	P.P.M	Sufficient
11	Available Manganese (Mn)	>1.0	P.P.M	Sufficient
12	Available Copper (Cu)	>0.2	P.P.M	Sufficient

Note: Fertility data obtained from 320 meters,and may not match the actual value.Properties indicated correspond to the maximum area covered in the survey number. For complete details please refer the LRI reports /atlases of the watershed area.

Colour Code: Dark Green : Very High Rating; Green:High Rating; Yellow:Medium Rating; Orange :Low Rating; Red : Very Low Rating

Secondary and Micronutrients Recommendation for Deficient Soil

Sl.no	Parameter	Fertilizer	
1	Sulphur (S)	Gypsum	Micronutrient fertilizers May be applied in consultation with scientists of KVK and RSK since the recommendation varies from crop to crop
2	Boran (B)	Borax	
3	Zinc(Zn)	Zinc Sulphate	
4	Iron(Fe)	Ferrous Sulphate	
5	Manganese(Mn)	Manganese Sulphate	
6	Copper(Cu)	Copper Sulphate	

Soil Nutrient Classification

Based on the soil test results the soil is classified as Low, Medium and High in the below table.

Nutrient	Very Low	Low	Medium	High	Very High
Organic Carbon (%)	<0.25	0.25-0.5	0.5-0.75	0.75-1.00	>1.00
Available Nitrogen (Kg/ha)	< 140	140-280	280-560	560-700	>700
Available phosphorus (Kg/ha)	< 11.5	11.5-23	23-57	57-91	>91
Available Potassium (Kg/ha)	< 72	72– 145	145-337	337-675	> 675
Available Sulphur (P.P.M)	-	<10	10-20	>20	-
Micronutrients		**Deficient**	**Sufficient**		
Available Zinc (P.P.M)	-	<0.6	>0.6	-	-
Available Iron (P.P.M)	-	<4.5	>4.5	-	-
Available Copper (P.P.M)	-	<0.2	>0.2	-	-
Available Manganese (P.P.M)	-	<1.0	>1.0	-	-
Micronutrient		**Low**	**Medium**	**High**	
Available Boron (P.P.M)	-	< 0.5	0.5 – 1.0	> 1.0	-

Suggested Crop Plan Based on Land Resource Information

Suitability	Suitable Crops	Limitations	Suggested Interventions
Highly suitable	-	-	Use of short duration varieties, Drought resistant crops, sowing across the slope. Land leveling without exposing parent material.
Moderately suitable	-	-	
Marginally suitable	Beetroot, Field Bean, Chrysanthemum, Marigold, Onion, Tomato, Brinjal , Cowpea, Groundnut, Maize, Carrot, Bheema Bamboo,Cauliflower,Ragi	Rooting conditions	
	Lowland Paddy	Rooting and Gravelliness conditions	
Not suitable	Guava, Mango, Papaya, Teak, Silver oak MalabarNeem ,Red gram, Sunflower	Rooting conditions	-

Note: Horticultural crops subjected to availability of good quality irrigation water

Issued Month & Year: November 2023

Benefits of LRI card

- The LRI card monitors soil type and quality and provides a report. Based on the report, farmers can wisely cultivate crops and boost their land's productivity and incomes in the long run.
- The LRI card provides a clear picture to farmers of which nutrients are lacking in their soils. It helps them know which fertilizers should be used and in what quantity.
- In the LRI card, the authorities observe the soil regularly and provide a report to the farmers once every three years. This ensures that farmers have up-to-date information about their soil's nature and other related aspects.
- Experts also provide recommendations about the nutrients and other measures to improve the soil's quality.

7. Inputs available from REWARD for planning DoA activities

1. MWS/Village wise cadastral maps
2. MWS/Village wise cartosat/QB imagery/World View
3. Current land use map
4. Site maps-slope, erosion, texture, drainage, salinity etc.
5. Soil maps-soil depth, texture, gravels etc.
6. Soil nutrient maps-macro and micro nutrients
7. Weather inputs-rainfall, RH, Temp., Wind, PET etc.
8. Hydrological data-runoff, soil moisture, GW status and availability
9. Ground water status maps
10. Land Capability maps
11. Soil and water conservation plan maps
12. Drainage line treatment/WHS plans
13. Crop suitability maps for cereals, pulses, oilseeds, etc.
14. Suitability maps for horticultural crops
15. Suitability maps for Sericulture
16. Suitability maps for forest tree species
17. Suitability maps for forage crops
18. Existing well and conservation structure maps
19. Package of Practices
20. LRI Reports and Atlas
21. LRI Cards
22. Hydrology Reports and Atlas
23. Digital Library
24. LRI Portal
25. DSS for: land capability classification, conservation and crop planning, nutrient management, runoff assessment, size of farm ponds/ check dams, crop water requirement, water balance and budgeting
26. Socio-economic data and reports

Application of LRI for planning and implementation of DoA programs

Datasets, Maps, Tools, DSS, etc., developed under REWARD program	*Soil Health*	*Crop improvement*	*Krishi Baghya*
MWS/Village wise cadastral maps	√	√	√
MWS/Village wise cartosat/QB imagery	√	√	√
Current land use map	√	√	
Site maps-slope, erosion, surface soil texture, drainage, salinity	√	√	√
Soil maps-soil depth texture, gravels etc.	√	√	√
Soil nutrient maps-macro and micro nutrients	√	√	√
Weather inputs-rainfall, RH, Temp., Wind, PET etc.		√	√
Hydrology data-runoff, soil moisture, GW status and availability	√	√	√
Socio-economic data and reports		√	
Package of Practices		√	√
Land Capability maps		√	
Ground water status maps		√	
Crop suitability maps for field crops	√	√	√
Suitability maps for horticultural crops	√	√	
Suitability maps for Sericulture	√	√	
Suitability maps for forest tree species		√	
Suitability maps for forage crops		√	
Existing well and conservation structure maps		√	√
Soil and water conservation plan maps		√	√
Drainage line treatment/WHS plans		√	√
LRI Reports and Atlas	√	√	√
LRI Cards	√	√	√
Hydrology Reports and Atlas	√	√	√
Digital Library	√	√	√
LRI Portal	√	√	√
DSS for Conservation, Crops, Nutrient mgmt, LCC, Runoff estimation, Location of FPs, Crop water, Soil Moisture, Water Balance & Budgeting	√	√	√
Mobile Applications	√	√	√

8. Convergence of programs of Line Departments with REWARD program

Convergence is the process that results in the achievement of common objectives through value addition, targeted and efficient use of financial and human resources. Coordinated planning and service delivery ensures timely inputs from multiple sources, simultaneously avoiding duplication and redundancies. The planning process drawing in from mutually agreed programmes, underlines clarity regarding targets, timeframes, shared responsibilities and monitoring parameters. Specific convergence initiatives could be of a complementary or supplementary nature, aimed at either more comprehensive treatment, adding productive value to assets created, ensuring sustainability or up-scaling successful initiatives.

Need for convergence

Convergence focuses on synergies required to move towards a more integrated delivery approach, using the comparative strengths of different partners to address the specific challenges of rainfed production and livelihood systems. Given that under the REWARD program site and location specific information through LRI and hydrological studies is available, it forms the basis for planning and implementation of programs of the departments related to land-based activities. The data are available in the LRI portal of the Watershed Development Department. Also, certain components of programs of various line departments can also be combined with the activities of REARD program. Therefore, the duplication can be avoided. The supplementary and complementary effect can be achieved through convergence.

Departments and integration of programs

Rural Development and Panchayat Raj (RDPR): is implementing Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) for land treatment especially earthworks such as farm and contour bunds, clearing drainage lines, preparing pits for plantation repair, renovation & restoration (RR&R), water resources (WR)- restore and augment storage capacities of water bodies. These activities can be integrated with the activities undertaken in the micro watersheds covered under REWARD program. On the other hand, while implementing activities under MGNREGA, the RDPR can make use of the huge data available in respect of status of soils, runoff volume etc.

Development Departments can use LRI data

Department of Agriculture is implementing the programmes like Krishi Bhagya, National Mission for Sustainable Agriculture (NMSA), National Food Security Mission (NFSM), Rastriya Krishi Vikas Yojana (RKVY), Pradanamantri Kissan Samman Nidhi, Organic farming, Millets promotion, etc. The production potential of crops from these programs can be improved by utilising data generated under the REWARD.

Department of Horticulture is implementing programs like National Horticulture Mission (NHM), Paramparagatha Krishi vikasa Yojane, PMKSY etc. The Department can use the LRI and hydrology data for deciding the crops suitability, nutrient management etc.

Forest Department (FD) Programme-treatment of ridge areas in the upper reaches-especially in the Reserve Forest areas, afforestation through the Green India Mission in common lands, farm bunds, etc. can be combined with REWARD and also the FD can make use of the data for implementation of their programs.

Animal Husbandry - Improved fodder availability through treatment of commons, agricultural residues and third fodder crop. Self Help Group (SHGs) and SHG federations can take up dairying as in Income generating option.

Critical levels for Convergence

The Project Empowered Committee (PEC) of REWARD chaired by the Development Commissioner cum Agriculture Production Commissioner with the Principal Secretaries and Commissioners/ Directors of all the Development Departments with Commissioner, Watershed Development Department will take the initiative to discuss convergence with other State Departments for both, Central and State schemes and issue necessary guidelines and instructions.

The Watershed Development Department which is the State Level Nodal Agency (SLNA) for watershed development will hold meetings with the State line Departments and decision makers to explore specific convergence potential and kick start the process.

At District and Project level, the Deputy Commissioner (DC), Chief Executive Officer (CEO) of Zilla Panchayath will take decisions for convergence. This key coordinating authority at the district level has an important decision-making role in bringing in convergence at the district level. Functional responsibilities of the line departments need to be clearly defined and included under the convergence process.

Watershed Cell Cum Data Centre (WCDC) on the strength of above instructions & in consultation with the concerned authority at the district level would facilitate linkages with relevant programmes of agriculture, horticulture, animal husbandry, rural development etc. with watershed development projects implemented under REWARD program for enhancement of productivity and livelihoods at the district level.

The Convergence potential and modalities would need to be clearly spelt out in the convergence and resultant matrix which would be an integral part of the Detailed Project Report (DPR)

Project Implementing Agencies (PIAs) and Watershed Development Teams (WDTs) would facilitate the implementation of important programmes through convergence of other Departments such as MGNREGA, NFSM, NHM, Ground Water Recharge, Green India etc. in the REWARD watershed areas on priority in collaboration with their field functionaries.

Format for convergence of DoA programs with REWARD

No.	***Activities identified for convergence***	***Mode of convergence***	***Expected outcomes***
1	Entry point activities		
2	Capacity building and training		
3	Works		
3.1	Soil and water conservation		
3.2	Groundwater recharge		
3.3	LRI card literacy		
3.4	Crops selection		
3.5	Nutrient management as per soil fertility status		
3.6	Agro-advisories		
4	Livelihood/ IGA		
5	Any other activity		

Exercise - 4

Format for convergence of REWARD program activities with DoA activities

Sl. No.	***Activities***	***Steps in convergence***	***Suggestions to take it forward***
1	Farm ponds under Krishi Bhagya		
2	Crops selection under various schemes		
3	Nutrient management as per fertility status		
4	Soil health improvement		