University of Agricultural Sciences, Bangalore

LRI Driven Watershed Management: A Scientific Pathway to Resilience

Prakash N. B., Nagaraja N., Dasog G. S.

November, 2025

WATERSHED MANAGEMENT
UAS BANGALORE
Promote science based approach in watershed management

Reference Book for the Training Programs organized under REWARD Program

Printed: November 2025

Authors

Prakash N. B.	:	Special Officer, CoE-WM
Nagaraja N.	:	Consultant (Training & Capacity Building), CoE-WM
Dasog G. S.	:	Consultant (LRI), CoE-WM

Contributing team of CoE-WM for the Book

#	*Topic*		*Name*
1.	Land Resource Inventory	:	Dr. Divyashree K S
2.	Hydrological Assessments	:	Dr. Lakshminarayana S V
3.	Digital Library and Portal	:	Dr. Virupaksha H S
4.	Decision Support Systems	:	Dr. Virupaksha H S Dr. Divyashree K S Dr. Lakshminarayana S V Dr. Pruthviraj N
5.	DPR Generation, Validation, and Approval	:	Dr. Virupaksha H S
6.	Soil Nutrient Management	:	Dr. Divyashree K S
7.	Micro Watershed level Agro-met Advisories	:	Dr. Lingaraj Huggi Dr. Premalatha K Ms. Soundarya H L
8.	Editing and Layout	:	Ms. Kavya B N
9.	Graphics	:	Ms. Ayesha Begum

ISBN: 978-81-990914-3-6

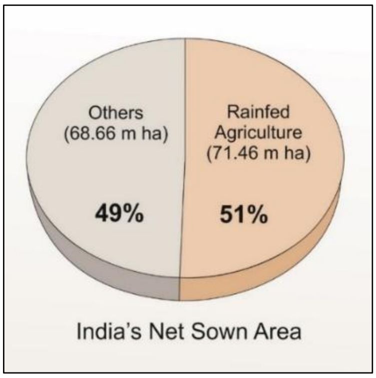
Published by Dr. Prakash N. B., Special Officer, Centre of Excellence on Watershed Management, University of Agricultural Sciences, Bangalore

CONTENTS

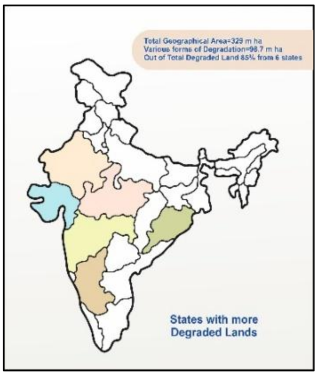
1. An Overview of REWARD Program

A. Watershed Development and its importance

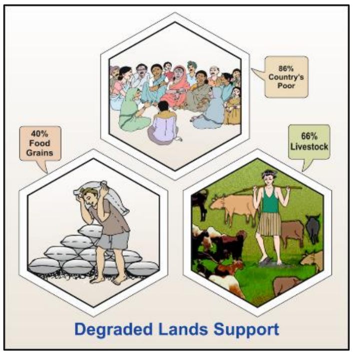
1. India ranks first globally in area and value of production from rainfed agriculture. It occupies about 51 per cent of country's net sown area of 140.13m ha. Out of the total geographic area of 329 m. ha, more than 30 per cent is affected by various forms of land degradation and out of this, rainfed 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.



India's Net Sown Area



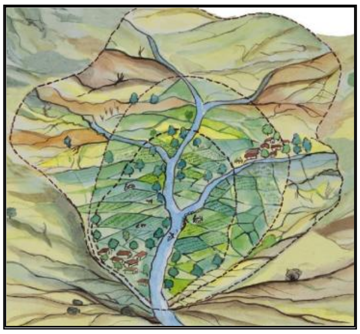
States with more Degraded Lands

2. 

Degraded Lands Support

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.

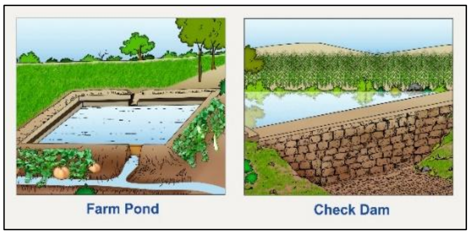
3. A watershed, is as an area in which all water flowing into it goes to a common outlet. All lands on earth are part of one watershed or the other. Watershed Development (WSD) is the preservation, renewal, and wise use of all natural resources, particularly those related to the land, the water, the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

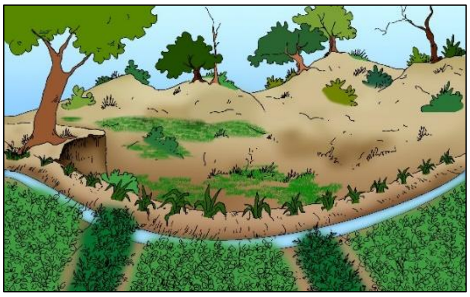


4. 
Preserving Rain Water in Conservation Measures

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.

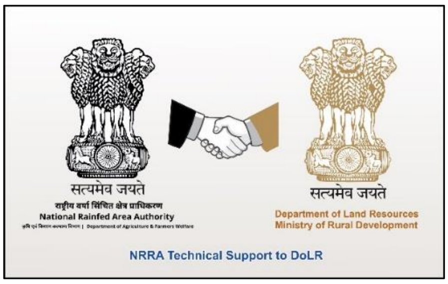
5. The objective of watershed development is maximizing the productivity and income per unit area, per unit time and per unit of water thereby improving the socio-economic status of the farmers. The objective of watershed development can be achieved through implementation of a series of systematic approaches, (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.





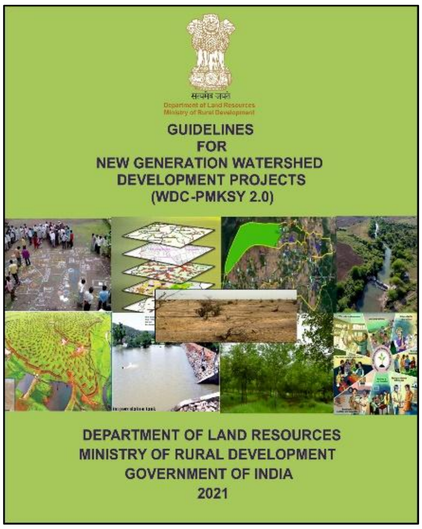
6.

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.

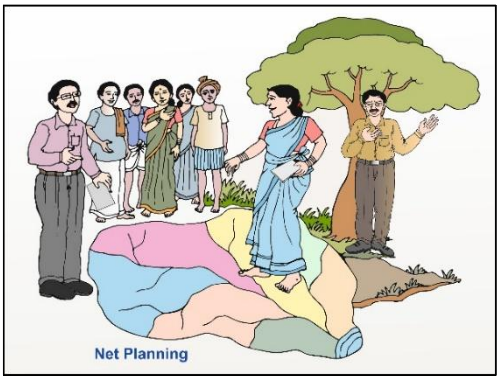


In 2006 National Rainfed Area Authority (NRAA) by the Planning Commission was established to provide technical support to Department of Land Resources (DoLR), GoI, and issued common guidelines for all watershed development programmes for the development of rainfed farming in India.

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.



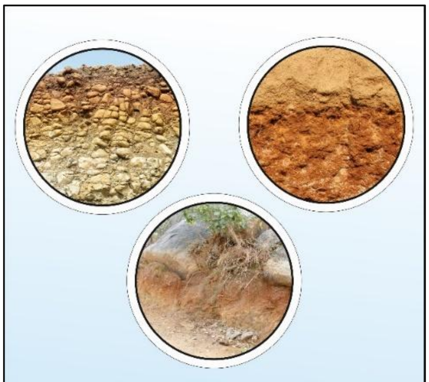
8.



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.



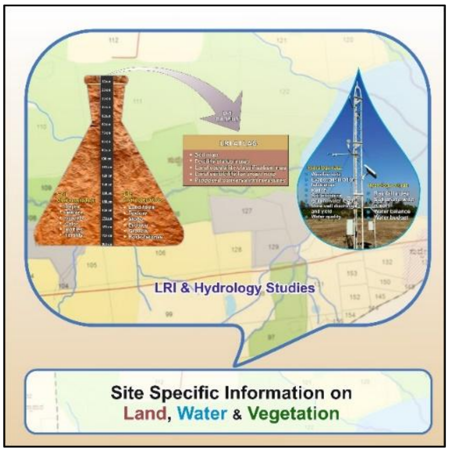
Nature & Extent of Variability in Soils

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

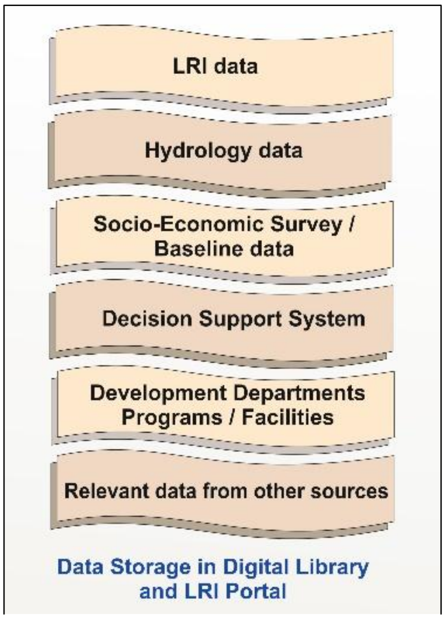
11. The uniqueness Sujala-3 project was adoption of more advanced scientific approaches for capturing the data on status of land, water, and other resources at cadastral level through land resource inventory (LRI) and hydrological assessments for preparation of scientific Detailed Project Reports (DPR) 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.

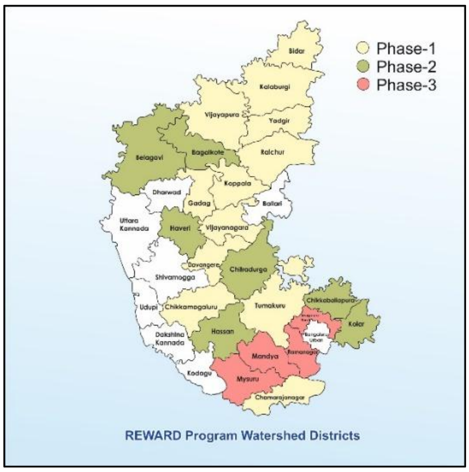
13. To carryout LRI and hydrological studies under Sujala-3 project, 15 scientific consortium partners were involved. Development of Decision Support System (DSS), to improve watershed planning, by integrating the data base generated with decision criteria, models and algorithms is one of the noteworthy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

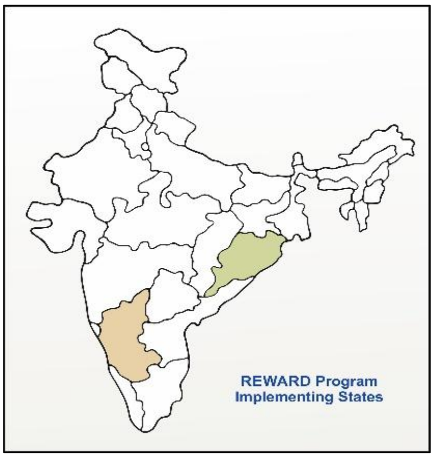


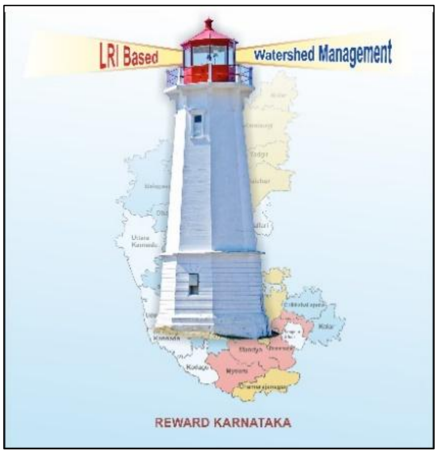
C. Emergence of REWARD program

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.

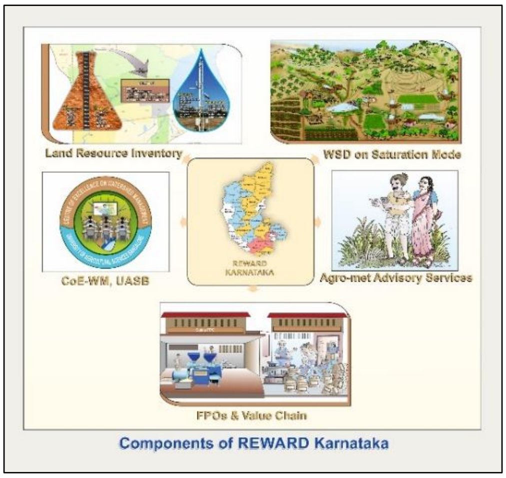


16. 



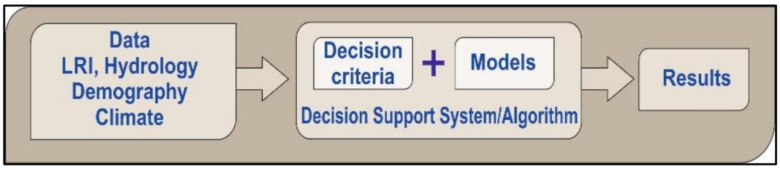
The REWARD-Rejuvenating Watersheds for Agricultural Resilience through Innovative Development program, will create a path for adoption of LRI (including hydrology) based scientific watershed management by all the States through WDC –PMKSY. Karnataka is identified as a light house partner to provide technical 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.

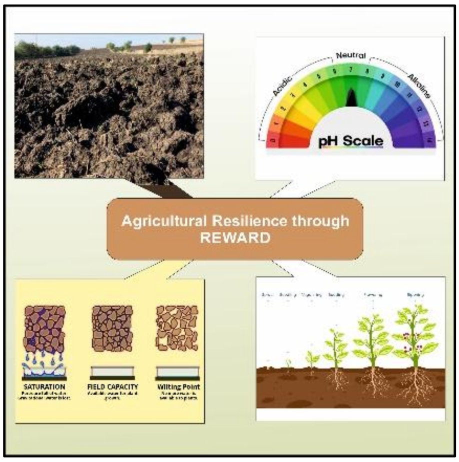


Components of REWARD Karnataka

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

SLNA
Chairperson:
Commissioner WDD

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

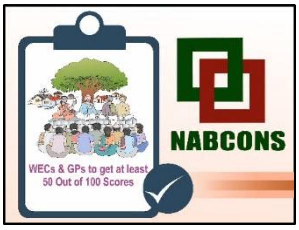
f. WCs and GPs: Program Implementing Agency shall support WC and GPs to actively participate in the implementation of Program, including operation and maintenance, reporting.

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.

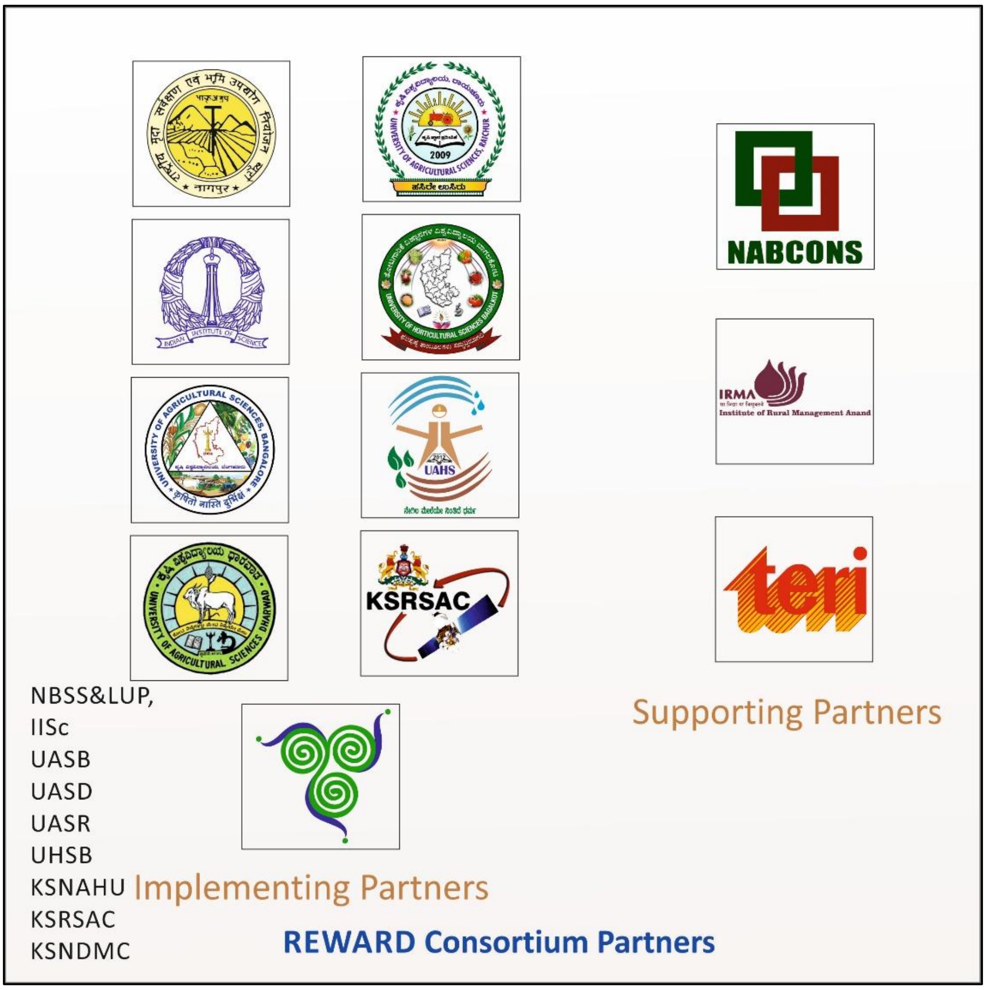
According to the third indicator, 27000 farmers to adopt and practice resilient agriculture technologies.

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 Resource Inventory for Watershed Planning

It is well established that the factors and processes influencing land degradation, productivity, and long-term sustainability are highly site and location specific. Effective restoration and management therefore, demand detailed site-specific land resource information. Such data is currently lacking for a large part of the country.

Given that land resources are inherently variable and differ from one field to another within the same landscape, the generation of precise, location-specific information on soil characteristics, water availability, topography, land use, and related advisories becomes essential. Such information forms the foundation for effective planning and implementation of development programs across agriculture, horticulture, watershed development, forestry, irrigation, and other sectors.

The site-specific information can be obtained by conducting Land Resource Inventory. 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 provides a diagnostic report for taking up appropriate soil and water conservation measures, reclamation of physically/chemically degraded lands/soils, improved crop production and diversification for enhanced productivity and profits and to take up livelihood support activities for the communities.

The LRI parameters considered for assessment are geology, soil depth, soil texture, soil gravelliness, soil colour, slope, erosion, drainage and flooding, soil structure, available water capacity, land capability classification.

The fertility parameters assessed as part of LRI are Organic carbon, EC, pH, Macronutrients (N, P, K), Secondary nutrients (Ca, Mg, S), Micronutrients (Fe, Mn, Zn, B, Cu). For LRI and hydrological assessments, the map inputs required from the remote sensing application centre include (a) physiography and geology map of watershed, (b) sub-watershed boundary, (c) micro watershed boundary, (d) village boundary, (e) drainages, waterbodies, roads, railways, habitation, (f) cadastral map (survey no plots - 1:7920 scale), (g) grids (points) at 320 m interval for collection of soil samples, (h) two-meter contour lines overlaid on satellite imagery, (i) satellite imagery (False Colour Composite) 5 m resolution. Serial numbers b to h are to be overlaid on satellite imagery.

The LRI has to be carried out by conducting a series of activities in a sequential order. These activities can be grouped under three phases namely pre-field activities, field and post field activities.

Under pre field activity phase, most important activity is preparation of base map which is a derived from integration and interpretation of cadastral map and satellite imagery. In the process of LRI assessment, selection and use of appropriate base map is critical for the generation of required data. The cadastral map is the source which can provide all the needed information. The cadastral map provides information on the field boundaries with survey numbers, location of tanks, streams, wells, habitations and other permanent features of an area.

Delineation of land forms like hills, uplands, valleys, salt affected areas etc. is the base for LRI work and it is also called as image interpretation. For delineation of various landform features accurately, and to know their extent, high resolution remote sensing data products like Worldview has to be used. Two-meter contour intervals are extracted using Digital Elevation Model (DEM) and the same is overlaid on imagery improves the accuracy of the landform delineation and description at the field level.

In the field activities phase, first and foremost action is field traversing for checking the variations in rock types, landforms, soil site characters etc. in the field from the base map and correcting accordingly. The second order action under field activity phase is well inventory and preparation of maps in respect of land use and land cover, existing conservation and water harvesting structures. Third order actions within the field activities phase are collection of soil samples from grid points for fertility analysis, studying soil profiles and site characteristics, collection of samples from master profiles, grouping similar areas based on soil characteristics into mapping units.

The post field activities include finalization of soil map with descriptive legend followed by analysis of soil samples, processing of field data into land capability and suitability groups.
The next order activities among post field activities include preparation of conservation plan, crops suitability plan and various thematic maps based on collected and processed data through the GIS platform.

Concurrently, in addition to field level data, meteorological data, demographic, socio-economic and farmers' details will also be captured and used appropriately. After completion of pre field, field and post field activities, the LRI output is presented in the form of LRI atlas for each micro watershed and the same is uploaded to the digital library/portal for its use for generation of DPR.

LRI Atlas

The LRI atlas will provide bundle of details relating to a micro-watershed. Firstly, it provides general description of the micro watershed and cadastral maps as well as satellite imagery. Secondly, the LRI atlas will have maps to highlight physiography and geology of the micro watershed, current land use, location of wells and existing conservation structures. Thirdly, atlas depicts the extent of slope, erosion, texture, drainage, gravelliness etc. as part of the site characteristics of the micro watershed.

Fourthly, the LRI atlas will have another important map that is soil phase map. Soil phase means, the soils with same/ similar characteristics will be grouped in to one unit which is also called as soil mapping unit. Soil phases are alpha numerically coded to explain the soil series, texture, slope, erosion, gravelliness, stoniness and rockiness. If a soil phase is coded as **BNKaB1g1St1 R2** first three alphabets **BNK** indicate the soil series, next alphabet **a** indicate texture(sand), next alphabet **B** indicate the slope (1-3%), next numeral **1**indicate erosion(slight), next alpha-numeral **g1**indicate gravelliness (15-35%), next alpha-numeral **St1** indicate stoniness (0.01to 0.1%), alpha numeral **R2** indicate rockiness (10-25%). Utility of soil phase map is to simplify the process of selecting the conservation measures and crops. For example, 500 ha micro watershed area may have 20 soil phases. So, one soil phase will have several survey numbers. If a conservation measure is suggested to a soil phase, it will be the same for all the survey numbers in the micro watershed. Similarly, the crop suitability plan.

Fifthly, he LRI atlas will also have maps indicating the land capability classes and soil phase wise proposed conservation and crop plans. Sixthly, the soil fertility maps presented in the LRI atlas indicate the status of macro and micro nutrients, pH, EC and OC to optimize the application of nutrients and to improve the soil properties.

The description of conducting LRI is presented in Annexure-1.

3. Hydrological Assessments for Watershed Management

Hydrology is the study that focuses on distribution and movement of water across the earth's surface and subsurface. Agro-hydrological study includes 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, its type, amount and distribution of vegetation cover determine what proportion of the rainfall re-evaporates. Vegetation, soil conditions and topography determine how much water infiltrates in to the soil, how much runs off the land's surface and where it goes.

Knowledge of the hydrological environment is necessary to determine the possible opportunities to create optimal soil moisture conditions, and how to exploit those opportunities. Integration of hydrological variables with land resource inventory is essential for developing robust comprehensive watershed management plans. The hydrology data required for the watershed area include rainfall, evapotranspiration, infiltration, runoff, soil moisture, ground water levels, recharge and draft, bore well discharge, yield etc.

In the perspective of watershed planning and management, the supply and demand side status of water need to be estimated. Rainfall and irrigation are on the supply side, and water utilization (storage, cropping intensity etc.) is on the demand side. Out of the total quantity of water received from rain or supplied as irrigation, it is required to estimate the extent of losses due to evapotranspiration and runoff, and storage in the soil as soil moisture and ground water recharge. These estimations have to be done through appropriate methods and models.

The water balance, which considers the total water received or supplied, losses, and storage, forms the basis for determining appropriate conservation and harvesting measures for a watershed. The water demand side status will indicate allocation of water harvested and stored in various structures for different purposes like crops production, livestock and domestic purposes in a watershed. It is also called as water budgeting.

The approaches in assessing rainfall, evapotranspiration, runoff, soil moisture and ground water storage for a given watershed are given as part of hydrological assessments for watershed planning and management.

Rainfall Measurement

Rainfall is the amount of rain that falls in a place during a particular period. Rainfall is also defined as precipitation in liquid form. The most common rainfall measurement is the total rainfall depth during a given period, expressed in millimeters (mm). Karnataka State Natural Disaster Management Centre (KSNDMC), which is a consortium partner in the REWARD program, has designed and installed a dense network of solar powered, GPRS enabled Telemetric Rain Gauge and Weather Stations.

In all the Gram Panchayaths of the State, Telemetric Rain Gauge Stations (6505 Nos.) and in all the *Hoblis* (a *Hobli* is an administrative cluster of adjoining villages grouped together for revenue and administrative purposes. It functions as an intermediate unit between the taluk/ block and the individual villages. Four to six *Hoblis* constitute a taluk.), Telemetric Weather Stations (935 Nos.) have been installed.

The near-real time data received at central server, located at Master Control Facility, KSNDMC campus, at every 15 minutes from all the stations is analyzed and scientific reports prepared through auto-mode by using web-enabled application and the same are disseminated to the scientific consortium partners (SAUs and NBSS & LUP) in the REWARD program.

In addition to KSNDMC rain gauge and weather stations, under REWARD program, in each project District, one model micro watershed representing the district in respect of agro-hydrological aspects is selected and required equipment are installed for assessment of various parameters related to hydrological studies. Further, 10 m tall Micrometeorological Tower which is also called as Agro-Met Stations (AMS) is a unique facility created in each model micro watershed to capture valuable hydrological data.

AMS provides data on rainfall, relative humidity, air temperature, wind speed and direction, atmospheric pressure, net radiation, diffuse radiation, soil heat flux and soil temperature. From AMS, data on various parameters are measured at 5 minutes' intervals and averaged for 30 minutes. The data for every half hour is stored in a data logger and also transmitted through a "yagi antenna" to pre-determined server. Averaged time series (means the period considered for assessment) rainfall data received from KSNDMC and AMS from model micro watersheds, will be compiled for a catchment with lowest possible frequency and longest possible record.

Based on the rainfall data received, the rainfall indices (which depicts the deviation from the annual averages of the selected period) for the catchment will be prepared for different crop seasons namely, *Kharif, Rabi* and Summer as well as annually. *Kharif* rainfall index will be prepared for the period from June to September for *Kharif* crop season for a particular calendar year and the corresponding time series. Similarly, *Rabi* rainfall index will be prepared for the period from October to January for *Rabi* crop season, summer rainfall index for the period from February to May and annual rainfall index is prepared by aggregating the available daily (and sub-daily, as the case may be) rainfall over the calendar year for the period of record.

Evapotranspiration measurement

Evapotranspiration is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants. It is estimated by FAO 56 Penman–Monteith equation (1998). Two types of evapotranspiration namely potential and actual evapotranspiration are estimated and used in the hydrological assessments. The estimations are expressed in milli meters (mm) per day.

Potential evapotranspiration (PET) is the amount of evaporation from soils and transpiration by 15 cm tall actively growing vegetation like grass that would occur under unlimited soil moisture conditions.

Actual evapotranspiration (AET) is the amount of water that evaporates from the surface and is transpired by plants under existing soil moisture conditions. Under REWARD program, evapotranspiration is estimated using the measurements from the 10 m tall micrometeorological tower or Agro-Met Station (AMS)

Annual total AET is computed for the watershed area for different years and also the averages for each of the calendar month. Further, month wise comparison of AET and Rainfall is done to understand the water balance at the catchment scale.

The Budyko Curve drawn to understand water-energy balance at the catchment level considering the precipitation, potential and actual evapotranspiration. On the X axis dryness index (PET/P) and on the Y axis, evaporative index (AET/P) are plotted. With increasing values of dryness index, the catchment's climatic condition becomes warmer and drier. With increasing values of evaporative index, the catchment's hydrological condition becomes drier which means less runoff. In the Budyko curve, water limited implies dry conditions. That is, AET is limited by the amount of water that is available (No/ less runoff). Energy limited implies wet condition. That is, AET is limited by the amount of thermal energy that is available (runoff occurs).

Soil moisture Measurement

Soil moisture is the water content in the soil, a key variable in controlling the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration. Three types of soil moisture measurements are done in REWARD program namely, surface soil moisture, profile soil moisture and continuous surface and root zone 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 as surface soil moisture to reach the root zone. Hence, surface soil moisture will provide some insight into the root zone soil moisture.

Surface soil moisture is a useful variable to predict the hydrological cycle over land and other applications especially in agronomy and drought management. Surface soil moisture is measured using HydraGo sensor at several plots in a micro watershed concurrent with Sentinel-1 and RISAT-1A remote sensed image at 7- 10 days' frequency. The surface soil moisture is being measured for the three major purposes namely calibration/validation of SAR satellite data, calibration of STICS crop model and to validate the radiometer satellite data.

Continuous soil moisture monitoring helps in irrigation scheduling, calibration and validation of satellite soil moisture products and in predicting drought. Both surface and root zone soil moisture are measured continuously at 15 min interval and soil temperature through sensors at 6 different depths (5cm, 15 cm, 30 cm, 50cm, 70cm, 90cm) by Stevens Hydra Probe

Groundwater measurement

Groundwater use in agriculture has grown exponentially leading to faster depletion than aquifer recharge. Therefore, understanding the basic processes about groundwater as well as the factors that affects its quantity and quality is of vital importance in managing this resource.

The groundwater level data is an important variable in the hydrological budget that is estimation of recharge from rainfall or other sources in micro-watersheds. Time series data of groundwater level is useful in understanding the usage patterns of groundwater for irrigation.

This data is also useful in assessing aquifer recharge in micro-catchments. The data on groundwater quantity and quality are captured at regular intervals to test for various parameters. Groundwater gauge is used for assessing the groundwater levels at selected bore wells at 15 days to 1-month interval. In addition to that, Automatic water level recorders are installed to monitor groundwater level continuously in selected bore well at 15 minutes interval. A groundwater level sensing probe with a graduated tape is used for bore wells fitted with submersible pumps and in narrow tubes and piezometers

Runoff measurement

Runoff is that part of the water cycle that flows over land as surface water instead of being absorbed in to groundwater or evaporation. 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 (infiltration), 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, selection of appropriate crop and cropping pattern, water balance and water availability at the watershed scale.

The important runoff estimation models that are in use are SCS Curve Number method and Rational method which is also called as Ramser's method. In REWARD program, infiltration method is used which is developed based on LRI database. Three types of parameters used for estimation of runoff.

Firstly, rainfall related information like 15 min interval data, peak intensity, duration and possible runoff causing events. Secondly, soil related parameters like area of different mapping units in the micro-watershed, texture, slope, depth and infiltration rate. Thirdly, parameters related to existing conditions like, maximum length of bund, design runoff depth, water spread area and runoff retained.

Mapping unit wise runoff is estimated considering the area of the mapping unit, soil texture, peak intensity (mm/hour), average intensity (mm/hour), constant infiltration rate (mm/hour), duration of rainfall hours, design runoff depth (mm), water spread area, runoff retained (mm) and number of possible events.

Infiltration rate is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will occur. Soil phase wise rate of infiltration is measured using double ring infiltrometer. After the calculations, mapping unit wise estimates on runoff available with the existing conditions and runoff available after execution of suggested interventions are computed.

Finally, the micro watershed wise runoff distribution will be presented. It will have details on annual rainfall, runoff available with existing conditions, runoff available after execution of suggested interventions, runoff excess available for harvesting by constructing suitable structures and runoff allowed as environmental flow at the outlet. All measurements are expressed in mm. For environmental flow 30 per cent of total runoff available will be considered.

Hydrology Atlas

After analysis of hydrology data, it is interpreted and presented in the hydrology atlas for its application in watershed planning and management. The hydrology atlas firstly will provide information on rainfall index for the watershed. Based on the annual average rainfall data received from the nearest rain gauge station, the years of deficit and excess rains received during the decade are presented. The rainfall index is also presented for Kharif, Rabi and Summer crop seasons to understand the years of deficit or excess during the crop seasons.

Secondly, the hydrology atlas will present details on evapotranspiration. The comparisons of average actual evapotranspiration (AET) with average rainfall for a particular period is presented. If the average AET is more than the average rainfall, the inference is that runoff cannot occur in the watershed. The comparisons are made for different months of the year as well as for different crop seasons. Further, evapotranspiration index map is also presented in the atlas. The Budyko curve depicted in the atlas will help to understand the energy limited catchments (MWS) indicating occurrence of runoff, where PET is less than the precipitation ($PET/P < 1$) and water limited catchments where there is no occurrence of runoff, where PET is more than the precipitation ($PET/P>1$).

Thirdly, the atlas will have soil moisture maps. Soil moisture maps are prepared for different crop seasons of different years. From the maps, soil moisture behaviour for different crop seasons can be understood to carryout agricultural operations in the catchments.

Fourthly, the atlas will have groundwater status graph. The graph indicates the groundwater level trends for different months of the years under consideration.

Fifthly, the atlas will provide the details on water budget for the catchment. The information on rainfall for the year under consideration, actual evapotranspiration, soil moisture storage, ground water recharge and runoff are presented. Further, water budget table indicate out of the total runoff available with existing conditions, how much can be harvested in-situ with appropriate soil and water conservation measures, how much to be allowed as environmental flow at the outlet (normally it is 30% of the available runoff) and finally, how much runoff is in excess for harvesting for construction of water storage structures.

Sixthly, the atlas will have two types of runoff maps. One presents the runoff with existing conditions and the other one runoff with effective interventions. The runoff values are given mapping unit / soil phase wise for the sub watershed.

The description of hydrological assessments is given in Annexure-2.

4. Decision Support Systems for Selection of WSD Interventions

The scientific data (LRI and hydrology) generation is of not much use to the watershed implementing personnel unless it is converted into usable form for planning and implementation of their program. That is possible through development of decision support system.

The decision support system (DSS) is a computerized expert interactive information system, integrated in a Geographic Information System (GIS) environment, to support decision-making in watershed planning and management. To develop decision support system, important requirement is finalization of decision criteria, models, algorithms, and guidelines for selection of appropriate interventions for comprehensive watershed development/ management. Important decision criteria for selection of soil conservation interventions are, slope, erosion, gravels, soil texture, soil depth and rainfall.

The decision criteria for selection of water harvesting structures are harvestable runoff from the soil phase and catchment, weather, rainfall, infiltration, ET, Kc values, length of growing period (LGP), land cover etc.

The decision criteria for selection of crops are land capability classification, slope, drainage, surface texture, gravel content, depth, salinity, sodicity, LGP etc.

The decision criteria for nutrient and soil health management are status of macro and micro nutrients, CEC, pH, EC etc. After development of decision criteria, models, algorithms etc. it is important to test them thoroughly and validated before they are rolled out for use. The developed decision criteria, models, algorithms etc., are to be integrated with the scientific data for getting output on appropriate measures for comprehensive watershed planning. Under Sujala-3 project, nine decision support systems (DSSs) were developed and the same are refined and used in REWARD program.

Out of nine DSSs, four are developed based on the inputs from LRI namely soil and water conservation, crop selection, delineating arable and non-arable lands, crop based nutrient management and soil health. Other five DSSs were developed taking inputs from hydrological assessments namely, estimating surface runoff, designing size of farm ponds and check dams, estimating the crop water requirement, estimating soil water balance and water budgeting. The DSS can be accessed for each survey number, soil phase of a micro watershed, village, micro watershed and sub watershed as per the need.

1. DSS on Soil and Water Conservation Measures

The sustainability of soil and water resources, particularly of the vast rainfed tracts of the state, depends on the effectiveness of the conservation measures planned and executed at the field level. The availability of cadastral level soil, water, weather, hydrology, land use, cropping pattern etc., generated through LRI helps to design appropriate conservation measures required at the field/watershed level. The conservation plan is prepared by matching the site- specific constraints and potentials of the area with different type of conservation measures and selecting the appropriate one based on the criteria available. The criteria for different type of structures are developed by various agencies (SAU’s, WDD, ICAR, ICRISAT and others) over a period through field trials at different locations. The development of DSS for Soil and Water Conservation based on the above criteria enables the user/department to generate the conservation map of any watershed including the budget requirement and inter bund conservation practices to be followed in a fraction of a time.

The major interventions followed for soil and water conservation at the field level are bunding, terracing and trenching. The criteria for selecting the type of treatment to be used depends on the amount of rainfall, type of landform, soils, land use etc. The treatment for arable lands will be different from the non-arable lands. Similarly, the treatment for black soils will be different than the red and lateritic soils observed in the state.

The watershed area is divided in to three zones or reaches namely, upper reach, middle reach and lower reach based on the locality within the watershed area. For the purpose of execution of soil and water conservation measures and production systems, watershed is divided in to arable land, non-arable land and drainage lines. The type of soil and water conservation measures differ for different types of lands and locations. The DSS used in the REWARD program attempts to provide decision on the suitable structures for all types of lands and locations in the watershed. For a given soil texture, slope, erosion, gravels, soil depth and rainfall, a particular conservation measure is suggested as per the decision criteria.

An example of selecting soil conservation treatment based on LRI and hydrology data

To select treatment for arable black soil based on decision rules for a soil phase CKMcB1g0 first, detail the characteristics of soil phase: c is sandy loam surface texture, B is slope which is 1-3%, 1 is erosion which is slight; gravel percentage, g0 gravel is less than 15%, rainfall less than 750 mm, soil depth is 50- 100cm. For the soil phase CKMcB1g0, as per the decision criteria, the suggested soil conservation measure is either contour bund or trench cum bund.

After selection of measure, decide about vertical and horizontal intervals based on decision rules. It is VI = 0.6 m and HI = 39 m. Cross section is calculated taking in to account base width + top width divided by two and multiplied by height. In this case, base width=2.1m; top width=0.3m; height= 0.6m as per the decision rules. Accordingly, the cross section is 0.72 m^2.

Next is to estimate length of bunding per hectare which is calculated using formula bund length (m)= 10000 x S/ (VI x 100) where S is slope (1-3%), VI is vertical interval (0.6 m). According to this example, the bund length will be 333 m. After estimation of length of the bund, the length of side bund should be calculated. As per the decision rules, length of side bund will be 10 per cent of the main bund. Therefore, it will be 33.33 m.

Next step is estimating the cost of conservation measure. To estimate the cost, the unit costs are worked out based on prevailing schedule of rates. As per 2018 schedule of rates, the unit cost for main bund is Rs.42.49/m, for side bund Rs 31.17/m, for waste weir it is Rs. 5.22/ running meter of main bund and cost of sowing seeds on the bund Rs. 0.28 /m.

Based on the specification of the conservation structure and unit costs for the earlier example it will be Rs. 17,035. Out of which, for main bund it is Rs 14,163.2, side bund is 1,038.9, waste weir is 1740, and sowing seeds it is Rs 93.33.

The Watershed Development Department, GoK, has restricted the bund length to 200 m for red soils and 250 m for black soils. If these criteria are applied, the total bunding cost will be Rs12,776/ for black soils. The software is developed as part of the decision support system considering the decision criteria as explained for one structure, corresponding flow charts, algorithms and integrated with LRI and hydrology data and this is made available in the portal. For all possible conservation measures DSS is developed as per the procedure explained earlier.

The details of decision criteria and support requirements are provided in Annexure-3.

2. DSS for Land Suitability for Crops Selection

The DSS for land suitability for crops selection will guide the implementing personnel of watershed program or extension functionaries of line departments and farmers on the suitability of crops for each parcel of land in the micro watershed. The process followed in developing DSS on land suitability for crops selection is, specific requirements of a crop are compared with the characteristics of land and suitability of the area for the crop is arrived at based on matching. If the land characteristics of an area match with requirements of the selected crop, then area is considered as suitable for crop, otherwise it is grouped as not suitable for the crop.

The site-specific land resources database generated through LRI helps to establish the suitability of the resources to any selected crop for the area in an objective manner. The land suitability classification for crops is divided in to four categories, namely orders, classes, subclasses and units. At the order level, the mapping units are grouped into suitable(S) or not suitable(N) based on kinds of suitability for the selected land use. The orders are divided in to classes based on the degrees of suitability as S1, S2, S3 and N1 and N2 for non-suitability.

S1 is considered as highly suitable and land unit having no limitation for sustainable use. S2 is considered as moderately suitable and land unit not having more than three moderate limitations. S3 is considered as marginally suitable and land unit having more than three moderate limitations but not more than two severe limitations.

N1 is considered as currently not suitable due to severe limitations, that may be overcome in time. N2 is considered as permanently not suitable due to the constraints which cannot be corrected.

The classes are further divided in to subclasses based on kinds of limitations. The 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 decision criteria considered for development of DSS on land suitability for crops selection are soil depth, gravel content, slope percentage, soil texture and soil drainage. The additional criteria to be considered are, soil reaction, salinity, sodicity and length of growing period.

An example: Pigeon pea crop suitability to a soil phase JDGcA1 is explained as follows: soil depth is 50- 75 cm (S3), gravel content 8% (S1), soil texture-sandy clay (S1), slope -0-1% (S1), drainage-moderately well (S2). The inference for the exercise is pigeon pea is marginally suitable to this soil phase as it has rooting limitation due to lesser soil depth and suitability class is abbreviated as S3r considering Liebig's Law of the Minimum.

The details of decision criteria and support requirements are provided in Annexure-4.

3. DSS on Delineation of Arable and Non-Arable lands

Delineation of watershed area in to arable and non-arable land is essential to select appropriate conservation and crop production systems within the watershed. The capability grouping is based on inherent soil characteristics, external land features and environmental factors that limit the use of land for different purposes. Based on soil characteristics, land features and climatic factors, the area in the watershed is classified as arable and non-arable land. The soil characteristics include soil depth, texture, gravelliness, soil reaction, water holding capacity, calcareousness, salinity/ alkalinity etc. The land features include slope, erosion, rock outcrops and drainage. The climate factors include rainfall distribution and length of growing period.

The capability classes 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 mapping units falling under Class-I will have few or very few limitations that restrict their use. The Class-II mapping units will have moderate limitations that reduce the choice of the crops or that require moderate conservation practices. Class-III mapping units will 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 prevent their use for any commercial crop production.

Further, capability subclasses are formed based on the dominant limitations observed within the capability class. Sub classes 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. The symbol ‘w’ indicates drainage or wetness as a limitation for plant growth. The symbol ‘s’ indicates shallow depth, calcareousness, salinity and sodicity or gravelly nature of soil as limitations The symbol ‘c’ indicates climate or rainfall with short growing period as a limitation for plant growth.

Classification of the soil phase KBTmB3g1 is explained as follows: slope is2, erosion is 3, drainage is 2, soil depth is 1, soil texture is 3, gravelliness is 2. This soil phase is classified as IIIes as per Liebig’s Law of the Minimum.

The details of decision criteria and support requirements are provided in Annexure-5.

4. DSS on Crop based Nutrient Management

Based on LRI information, soil fertility status of each land parcel is classified as very low, low, medium, high and very high in the fertility maps. The limits fixed for classifying soils as very low for major nutrients, the available N to be less than 140kg/ha; P2O5 to be less than 11.45 kg/ha; and available K2O to be less than 72.3 kg/ha. When the fertility status for major nutrients is very low, the adjustment to be done by multiplying recommended dose of fertilizers for a specific crop with 1.67.

The limits fixed for classifying soils as low for major nutrients, the available N to be in the range of 140-280kg/ha; P2O5 to be between11.45-22.90 kg/ha; and available K2O to be between 72.3-144.60 kg/ha. When the fertility status for major nutrients is low, the adjustment to be done by multiplying recommended dose of fertilizers for a specific crop with 1.33.

The limits fixed for classifying soils as medium for major nutrients, the available N to be in the range of 281-560 kg/ha; P2O5 to be between 22.91 & 57.25 kg/ha; and available K2O to be between 144.70 & 337.40 kg/ha 72. When the fertility status for major nutrients is medium, there is no adjustment required. It is application of recommended dose of fertilizers for a specific crop.

The limits fixed for classifying soils as high for major nutrients, the available N to be in the range of 561-700 kg/ha; P2O5 to be between 57.26 & 91.60 kg/ha; and available K2O to be between 337.5 & 674.80 kg/ha. When the fertility status for major nutrients is high, the adjustment to be done by multiplying recommended dose of fertilizers for a specific crop with 0.67.

The limits fixed for classifying soils as very high for major nutrients, the available N to be more than 700 kg/ha; P2O5 to be more than 91.60 kg/ha; and available K2O to be more than 674.8 kg/ha. When the fertility status for major nutrients is very high, the adjustment to be done by multiplying recommended dose of fertilizers for a specific crop with 0.33

Similarly, the critical limits for micro nutrients are indicated. Based on the micro nutrient status of the soil phase, the micro nutrient fertilizers' recommendations are made.

The fertilizers both straight and complex which are commonly used by the farmers are included in the DSS to automatically calculate the quantities of fertilizers for a specific crop based on the nutrient status of a soil phase.

The cost of fertilizers is also integrated in to the system to estimate the cost of recommended doses of fertilizers for a crop to choose relatively cheaper combination and also to know the total amount required for nutrient management.

The details of decision criteria and support requirements are provided in Annexure-6.

5. DSS on Estimating Surface Runoff

Runoff is a critical factor in deciding the type and size of water harvesting and recharge structures needed, their number and location, formulation of appropriate cropping pattern and crops selection. The runoff estimation is done by (a) SCS curve number method, (b) rational method, (c) infiltration method. Under REWARD program, infiltration method is considered as important because of its strengths in accurate assessment of the runoff.

While accessing DSS on estimation of runoff through infiltration method, the information on extent of vegetative cover to be mentioned by the user. The assessments indicate runoff available with existing conditions, runoff available with proposed conservation measures. The assessments also indicate runoff excess available for harvesting by construction of new water harvesting structures. The assessments further indicate quantity of runoff to be allowed as environmental flow at the outlet.

An example of runoff estimation for a sub-watershed which has received annual rainfall of 806.00 mm during 2014 as described in hydrology atlas is illustrated for better clarity.

Out of the total rainfall, the runoff availability with existing conditions was estimated as 154.10 mm. The runoff available after execution of appropriate conservation interventions is 68.20 mm. The available runoff to be allowed as environmental flow at the outlet is 20.46 mm which is 30% of the runoff available after execution of conservation structures (68.20 mm). Therefore, runoff available for harvesting in new water storage structures is 47.74 mm. To calculate actual quantities of runoff, it should be multiplied with the catchment area.

The details of decision criteria and support requirements are provided in Annexure-7.

6. DSS for designing Size of Farm ponds and Check dams

Farm Pond

The farm ponds are manmade ponds normally constructed in the arable lands owned by the farmers. Farm ponds are constructed by excavating the soil, by depositing the soil on the bunds. These 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 imperious substratum. The ponds will be lined with impermeable membrane like HDPE sheet to avoid infiltration. Unlined ponds are suitable for groundwater recharge. These ponds are constructed for storing rain water to provide lifesaving irrigation to crop during water scarce conditions for uninterrupted physiological activities of crops. To decide the size of the farm pond, first should know the extent of catchment area or land parcel owned by farmer. Next step is to estimate the total quantity of potential runoff for that parcel/ catchment based on infiltration method which provides data on soil phase runoff. Based on the runoff available decide the size of the pond to capture the runoff quantity.

The water available for harvesting is estimated for the following conditions: soil type red, soil having catchment area of 1 ha and the runoff is 30 mm. The harvestable volume of water is 300 cubic meters.

The size of the pond is decided for red soils based on the following decision criteria. (a) side slope is 1:1, (b) depth is 3m, (c) top width will be square root of runoff volume divided by 3 plus 3, (d) bottom width will be square root of runoff volume divided by 3 minus 3, (e) top area is top width multiplied by top length, (f) bottom area is bottom width multiplied by bottom length, (g) total volume will be top area plus bottom area divided by 2 and multiplied by the depth

To store 300 cum of runoff, the size of the farm pond required is 13m x 13m x 3m. The cost of the farm pond is calculated considering the schedule of rates fixed for cubic meter

Check dams

Check dam is a stone masonry structure put up across the drainage line with catchment of 25 to 200 ha for harvesting runoff and to facilitate groundwater recharge. If net runoff (available for storage) is 850 cubic meters and above the check dams can be proposed. If the runoff is less than 850 cubic meters, there is no need to construct check dam and runoff can be allowed to run into the stream. Based on the quantity of net runoff available, number and storage capacity of the check dam to be decided.

To identify proper site, the information on length, width and depth of the stream/drainage line, nature of the substratum and amount of runoff should be available. At present, this information is not available from LRI/hydrology assessments.

Steps involved in construction of check dams are

1. Firstly, codification of drainage network based on the stream order number.
2. Secondly, demarcating the catchment of each order like first or second etc. of the drainage network using LRI maps.
3. Thirdly, estimate total quantity of potential runoff depth in mm for each stream order.
4. Fourthly, quantity of available total runoff considering the catchment area in ha of each order and potential runoff in mm.
5. Fifthly, aggregate the total runoff for all the stream orders in the watershed area.
6. Sixthly, from the total quantity of runoff, deduct the quantity of runoff likely to be retained in the proposed and existing conservation structures and farm ponds which will be about 50 per cent of the total runoff.
7. Seventhly, out of the total runoff available after deducting runoff retained in the proposed conservation measures, deduct 30 per cent for environmental flow to get the quantity of harvestable runoff.
8. Eighthly, based on the quantity of net harvestable runoff available, decide the numbers and size of the check dams.

The type and design of check dam to be decided based on the shape of the nala banks as per ground truth or with the help of DEM data wherever available and availability of the stones nearby. Cost of the structure is decided based on the cost for per cu m as per the prevailing rates in the districts. According 2018 cost norms, it ranges from Rs 464 to 601/ cu m.

The details of decision criteria and support requirements are provided in Annexure-8.

7. DSS on Crop Water Requirement

The amount of water that needs to be supplied to the cropped field is called as crop water requirement. It is estimated using FAO 56 method. To calculate crop water requirement (a) potential evapotranspiration (PET), (b) crop coefficient (Kc), (c) area of the crop are required. The crop coefficients values have to be estimated based on the days after sowing and crop growth parameters. The crop coefficient values for major crops grown is compiled from FAO reports. The Kc values are indicated for different stages of the crops like initial stage, mid-season and end season. The PET is estimated using measured weather parameters on daily time scale.

Considering these parameters, the crop water requirement is calculated by multiplying Kc value with PET, duration and area.

An example of water requirement of maize during *Kharif* season for 5 ha area is estimated considering crop duration as 120 days and the step-by-step estimation follows.

1. The Kc values are to be obtained from FAO report, the Kc values for maize is 0.3 during initial stages, at mid-season it will be 1.20 and at the end season it will be 0.60
2. The PET value is also obtained from FAO report. During south-west monsoon season, the PET will be 4.33/ day around Bangalore.
3. The maize crop water requirement is estimated by multiplying crop area with duration, Kc values and PET for different seasons and aggregated for all the seasons. The total duration of the maize in this example is divided as initial stage 30 days, mid-season 60 days and end season 30 days.
4. The total water requirement is 2143.35 ha mm. one ha mm will be 100 cubic meters. During the initial stages it is 194.85 ha mm, during mid-season it is 1558.8 ha mm and it is 389.7ha mm towards the end season.
5. The total water requirement for all the crops grown in the village/ watershed area is calculated to quantify the water required for agriculture.

The details of decision criteria and support requirements are provided in Annexure-9.

8. DSS on Water Balance

Soil Water (Moisture) is a fundamental hydrological variable affecting physical, chemical and biological properties of soils and in turn impacts the growth and yield of crops. It is influenced by the amount of rainfall, topography, land use, type of soil, substratum and management practices followed in an area.

Estimation of the amount of water present in the soil on real time basis will help to take up appropriate contingency measures needed to overcome the stress period wherever possible. Soil Water (Moisture) balance equation at land parcel scale is defined as the change in soil moisture storage =Rainfall + Irrigation - Surface runoff - Evapotranspiration - Deep percolation.

The parameters used for estimation of soil water (moisture) balance are information on soil, weather, crop management and crop growth parameters. Among the soil data base, field capacity, permanent wilting point, soil depth, infiltration rate is to be obtained from LRI data. Among weather parameters, rainfall, max and min temp, relative humidity, wind speed and solar radiation are considered. Crop management details include date of sowing, crop duration. Among crop growth parameters, crop coefficient values and root growth function at different stages are to be used.

1. First step in estimating soil water/ moisture balance is defining the soil profile with information on water holding capacity, soil depth and other soil data base.
2. Next step is defining the land use class, cropping system and crop management practices followed.
3. Third step is, estimation of surface runoff on daily basis as per the procedure already described in the previous DSS on runoff estimation.
4. Fourth step is calculating crop water need (ETc) which is the amount of water needed to meet the water loss through evapotranspiration on daily time scale as per the procedure outlined in DSS on crop water requirement
5. Fifth step is calculating soil water balance by subtracting runoff from the rainfall obtained for that particular day. The soil water balance has to be calculated on daily basis for the entire crop period.
6. Sixth step is estimation of available moisture content in soil up to root zone depth. The root zone depths are classified as shallow root with depth ranging from 0.1 to 0.3 m, medium rot depth from 0.3 to 0.5 m and deep root depth from 0.5 to 0.9 m
7. Seventh step is estimation of soil water storage by subtracting crop water requirement from available moisture content up to root depth.

The procedure described from third step to seventh step to be repeated at daily scale for entire crop growth period to arrive at water balance at land parcel scale

The details of decision criteria and support requirements are provided in Annexure-10.

9. DSS on Water Budgeting

Water budgeting indicates the rate of change in the water stored or available in a watershed based on the demand and supply. Water budget helps to understand the surplus or deficit status of the watershed, and accordingly helps to design corrective/mitigation measures wherever there are a deficit and plan for the use of surplus water by increasing area under irrigation, livestock and livelihood activities to bring in additional and sustainable benefits to the society as a whole. Water budgeting is critical for the sustainable management of available water resources at field, watershed or any other scales.

The parameters considered for water budgeting are human population, livestock population, per capita water consumption for domestic and livestock use, surface runoff from infiltration method, existing water resource availability per year

1. Firstly, estimate the total water availability in the micro watershed based on measured capacities of surface water bodies and amount of water percolation in soil
2. Secondly, estimate water required for irrigation based on the crop water requirement and irrigation losses
3. Thirdly, estimate water requirement for household use and livestock purpose
4. Fourthly, estimate water available for irrigation by subtracting water required for human need plus livestock from total water available

The details of decision criteria and support requirements are provided in Annexure-11.

5. Digital Library and LRI/ Geo Portal for Accessing Information

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 Centre 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, Bagalkot, 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). For all the micro watersheds covered under Sujala-3 and the micro watersheds likely to be completed under REWARD, the atlases providing parcel wise data like physical properties of soil, nutrient content in the soil, Land-use and Land-cover and also crop suitability for the different soil management units and hydrology data are embedded in the library.

LRI/Geo Portal

This portal includes the Land Resource Inventory for Watershed Planning and Decision Support Systems, socio-economic survey data, development departments programs, relevant data from other sources required for watershed planning.

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, fertiliser 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.

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.

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.

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 fertiliser requirement for the crop/crops, nearest APMC yards and prices of the commodities sold, and programs and other services available for his area.

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 focussed, 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 required information in 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”

6. DPR Generation-Consolidation of all Activities for a Micro Watershed

A detailed project report (DPR) is the final blueprint of a project after which the implementation and operational process can occur. In REWARD program, more advanced scientific approaches (LRI and hydrological assessments) are followed in assessing the status of natural resources for management of a watershed compared to earlier programs. Further, development of LRI portal with decision support system, automate the preparation of the DPR. Hence, there will be considerable reduction in time required for preparation of DPR leading to shortening of watershed management cycle.

Pre-requisites for DPR preparation: The prerequisites for DPR preparation in REWARD program are completion of LRI and hydrology inventories, uploading the outcome of these inventories to portal, development of decision support system (DSS)-a computerized expert interactive information system, to decide on the most appropriate interventions that can be taken up for implementation based on the available information.

The outcomes of LRI and hydrology inventories are transformed in to atlases which contain (a) micro watershed wise cadastral maps, (b) current land use map, (c) soil, site & land use maps, (d) soil nutrient maps-macro & micro nutrients, (e) land capability maps, (f) ground water status maps, (g) existing well & cons. structure maps, (h) soil and water conservation plan maps, (i) drainage line treatment/WHS plans, (j) weather data-rainfall, RH, temperature, wind, ET, (k) hydrological data-runoff, soil moisture, ground water levels, (l) socio-economic data and reports, (m) package of practices, (o) crop suitability maps for cereals, oilseeds, pulses and horticulture crops.

Based on the stored data, the decision support systems are developed by integrating data with criteria, models and algorithms. The criteria tables include (a) selecting treatment for arable land, (b) selecting treatment for non-arable lands, (b) horizontal and vertical intervals for soil conservation treatments, (c) cross-section of soil conservation structures, (e) cost rate for conservation various structures, (f) land suitability for crops grown in the region, (g)soil fertility classes based on content of macro nutrients (kg/ha), (h) critical limits of micronutrients in soils, (i) crop wise fertilizer recommendation, (j) soil fertility for adjusting major nutrients recommendation. Regarding water harvesting structures, the information on runoff estimation and deciding type and number of structures and design criteria of structures are important to consider. Similarly, crop water requirement will be estimated considering (a) crop coefficient (Kc) values for major crops, (b) estimation of soil water (Moisture) balance and (c) water budgeting. The DSS serve as an important aid for planning, implementation and monitoring of watershed program and all agriculture related activities by concerned development departments.

Phases involved in preparation of DPR: The phases involved in the process of DPR preparation under REWARD are (a) pre- planning activities in the field, (b) DPR generation in the office, (c) community consultation and validation in the field and (d) compilation and approval of DPR. In each phase, several steps are involved and are detailed in the following paragraphs.

Phase-1: Pre- planning activities in the field

Following activities have to be completed in the pre-planning phase

1. Land Resource Inventory (LRI) data generated and available in the LRI portal for the selected sub-watersheds are finalized and approved
2. A manual/User Guide on Detailed Project Report (DPR) generation using LRI portal outputs is prepared
3. Field-Non-Government Organizations (FNGO)s are in place and trained at designated Training Centres
4. Baseline data of the selected watersheds is collected and uploaded into portal
5. Information, Education & Communication (IEC) materials are prepared and sequencing activities with time lines is finalized
6. Initial awareness activities are completed
7. Orientation for the Panchayat Raj Institution (PRI) members in local area is completed by Training Coordinator (TC)
8. Entry Point Activity (EPA) finalized and approved by Gram Sabha
9. Formation of Community Based Organizations (CBO), Watershed Executive Committees (WEC), Area Groups (AG) and Self-Help Groups (SHG)
10. Formation of Watershed Development Team (WDT) comprising of 15-20 members including FNGO staff and FPO representatives is identified and notified by PIA, DPR Preparation Team at PIA level WDT
11. Roles and responsibilities of all those institutions and teams involved in the project need to be specified
12. Training at Block/Taluk level on the processes of generation and validation of draft DPR and community consultation

Phase-2: DPR generation in the office

1. Download the table-top/ smart DPR from the LRI/geo portal. Detailed procedure to download DPR is given in Annexure-12.
2. Prepare survey number wise conservation plan: Refer draft conservation plan map generated by LRI partners, link the same with the farmer's details obtained from Bhoomi, software developed and available in the GoK website along with cost details (In case of non-availability of conservation plan in the portal, select conservation measures manually based on decision criteria LMU wise and then Survey No wise)
3. Prepare drainage line treatment, water harvesting structures, and other interventions needed like common land treatment, waste land treatment reclamation etc. based on the inputs provided in the LRI atlas, reports and digital library
4. (Select water harvesting structures based on decision criteria, water budgeting and water balance manually if the plan is not available in the portal)
5. Preparation of survey number wise crop plan by using the crop suitability maps generated for the area and linking the same with farmer's details
6. Include the package of practices to be followed during the entire duration of the crop selected (Decision criteria for selection of crops and nutrient management based on LRI output)
7. Similarly, prepare tentative plan for suitable horticultural crops, forestry, sericulture, animal husbandry and other interventions for the watershed area
8. Draft DPR generation - consolidation of all activities for a MWS and consolidated for SWS

Phase-3: Community consultation & validation

1. Draft DPR generated (MWS wise & consolidation for SWS)
2. AG wise treatment plan preparation for each MWS for transect walk
3. Dividing WDT into Sub-groups for community consultation and validation of DPR
4. Community consultation and validation of DPR by sub-groups
5. Ensuring Environment & Social Systems Assessment (ESSA) compliance
6. Compiling Area group wise treatment plan into MWS plan along with PRA exercise

Phase-4: Compilation and approval of SWS DPR

1. Approval of MWS plans at Gram Sabha
2. Compiling MWS wise plans into SW plans and submission to PIA office
3. Verification of the consolidated SW plan at PIA level and submission to District Level Technical Committee (DLTC)
4. Technical review by DLTC, placing before WCDC and WCDC to forward the DPR to PEC for approval
5. Forwarding approved DPR to PIA for implementation

Steps in DPR preparation, validation & community consultation

1. Downloading/ generating Table top DPR from LRI portal with supporting information as described in **Annexure-12**.
2. Area Groups wise mini micro catchments wise crosschecking the suitability of proposed interventions with that of actual field conditions
3. Demystifying science to communities by explaining the scientific base in proposing the site and soil specific interventions during transects with area groups. A minimum deviation from the recommendations to satisfy the need of communities is allowed
4. Through PRA exercise finalization/ validation of activities for the Micro watershed
5. Consolidation of validated activities for the Micro Watershed
6. Presentation of finalized action plan in Gramasabha and seeking approval
7. Consolidation of MWS plans in to SWS plan

Download DPR from LRI portal

Contents of the DPR for Private lands

1. Sl. No.	17. Fruit ID	32. S2 Crops
2. MWS CODE	18. Soil Phase	33. Horti. Species 1
3. Hobli	19. SWC activity	34. No of Plants
4. G.P Name	20. Size / Section (in m2)	35. Per Plant Cost
5. Village	21. Actual field Size/Section (in m2)	36. Horti. Species1 total cost
6. Survey number		37. Horti. Species 2
7. Hissa	22. Actual RMT (in mtr)	38. No of Plants
8. Area: acre, gunta	23. Per RMT Cost	39. Per Plant Cost
9. Area: ha	24. No. of Waste Weir	40. Horti. Species 2 cost
10. Owner Name	25. Per WW cost	41. Total Hort Plants
11. Phone Number	26. WW Cost	42. Total Hort. Cost
12. Gender (M/F)	27. SWC Cost	43. Forestry
13. Caste-SC/ST/OBC/Min./Gen	28. Farm Pond size	44. No of Plants
14. Category (MF/SF/MEF/LF)	29. Farm pond cost	45. Per Plant Cost
15. Farmer code	30. S1 Crops	46. Forestry cost
16. AG Code	31. S3 crops	47. Total Beneficiary Cost

Community consultation

Need for community consultation

- The REWARD program aims in generating science based DPRs at planners' and implementers' level using LRI Data and Digital tools
- Lacks to address the basic principle of community participation, building community ownership and accountability mechanisms.
- Hence, the DPR developed through Digital tools needs to be demystified about the science involved in it to the communities as a Beneficiaries for their understanding, acceptance and adoption.
- To enhance ownership and sustainable Post Project Management

Community Consultation Process

- Using the MWS map, form AG groups – may be 5-10 AGs
- Bifurcate MWS plan AG wise in Excel format
- Carry the same during transect walk along with different thematic maps generated through LRI data
- Fix AG wise responsibility of mobilizing the farmers to FNGO staff
- Identify 2 to 3 Local Resource Persons for each MWS and take their help for transect walk and mobilization of community along with FNGO staff
- Prepare a AG wise schedule with date & time for each AG
- Give wide publicity through public announcements and pamphlet
- Identify a suitable place for community gathering and give a brief about tasks to be accomplished during the transect walk
- Arrange for coffee/ tea, snacks, lunch packets and water during transect walk
- Arrange for logistic support like vehicle, shamiyana, display boards etc.
- Discuss with the community on pros & cons and impact of the proposed activities on social and environment aspects and document the same. Further, also record if any modifications required by the community
- For common land treatment, opinion of the WEC and neighbor farmers should be recorded during transect walk
- After transect walk prioritize the interventions, each farmer should be aware of the investment to be made on his/her land and contribution to be paid, explain the cost sharing mechanism to beneficiary and take his consent
- Interact with the farmers and verify the local conditions specific to their lands and compare the extent of land holdings, its location in the watershed and site characteristics with LRI output and mark if any corrections/inclusions required
- Compare map of the land showing existing structures, land use, drainage lines etc., with actual observations and do necessary corrections
- Explain treatment plan generated by the LRI data to AG and note down the any concern/modification/ feedback of the farmers

Suggested Modifications / deletions Recording Format

1. Sl. No.
2. Soil Phase
3. Survey No./Nos.
4. Farmer name
5. Private Land (PL)/CPR
6. Recommended Intervention Suggested
7. Modification/Deletion

Precaution to be taken while recording the modifications or deletions

1. Suggested modifications should not lead to altering the entire plan
2. Concerted efforts to be made to convince the beneficiary about the plan prepared keeping in view of existing condition of the soil and topography
3. Ensure complying key recommendations of LRI and ESSA principles

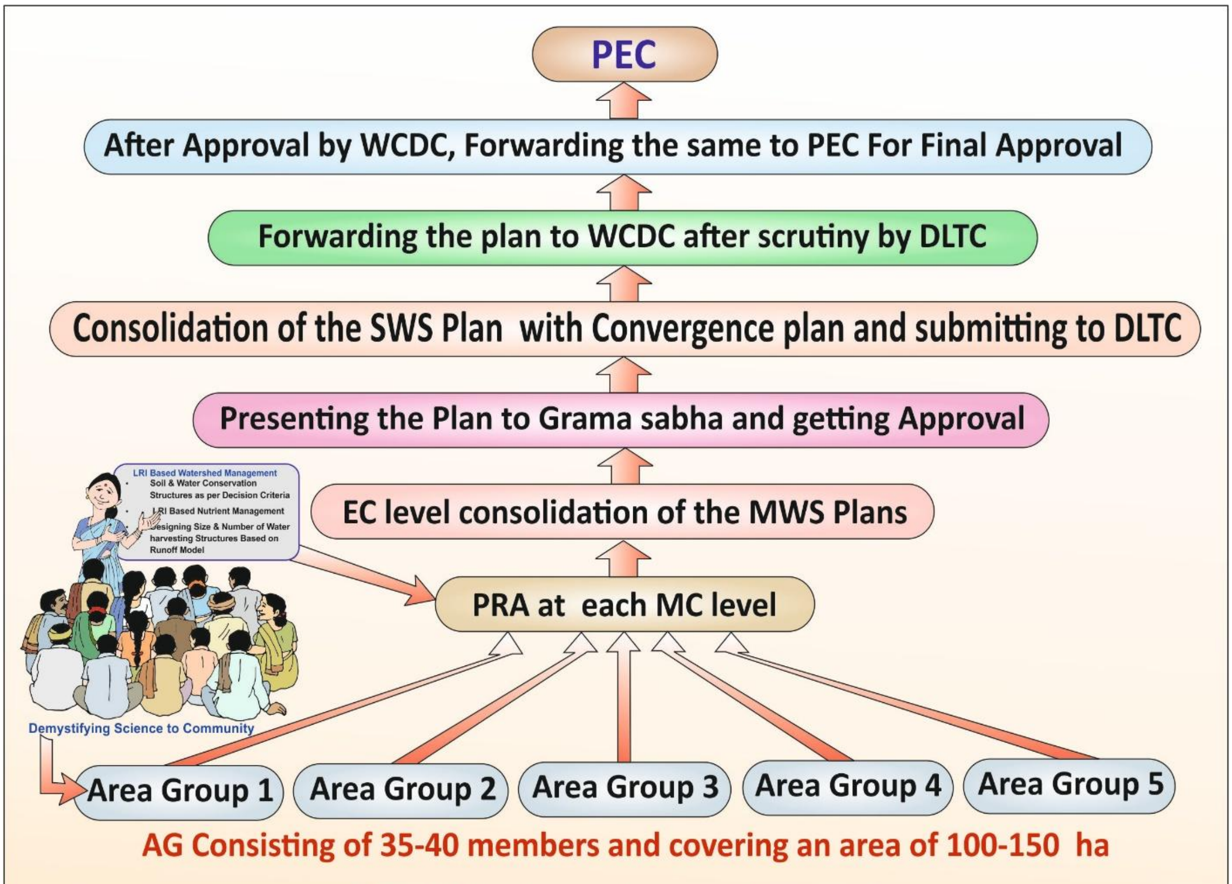
PRA exercises for cross verification and finalization

- For triangulation (Cross-verification) of information gathered during transect
- Seeking clarifications on any issue that might have arisen during transect
- Finalizing the activities to be taken in the watershed on individual and common lands
- Discussing implementation strategies, cost sharing aspects, labour availability for the works, etc.
- Carrying ESSA (Environment and Social Systems Assessment) to ensure that there are no adverse effect on environment and social system by implementing the proposed activities
- To include the suggestions/modifications required in the MWS plan and place before GS

Consolidation and approval protocols

- Include if any modifications suggested in the PRA and prepare revised MWS plans. Once the MWS plans are vetted in the PRA exercise, then generate farmer wise and survey number wise details in the form of net planning
- Convene a General Body/ Gram Sabha meeting of the WEC and present the overall MWS plans, budgets, contributions, mode of implementation (manual labour, machinery, contracts, etc.), common land and drainage line treatments, post management strategies, inter linkages between individual lands and common lands, etc.
- Present entire plan along with Budget before the General Body and get its approval. WDT, FNGO team and WEC committee members should play major role in getting the approval. Proceedings should be recorded with photo/video documentation
- After General Body approval, the plans are to be finalized by PIA along with a summary of SWS plan for technical scrutiny
- Taluk PIA office will verify component wise project allocations, unit costs, contribution and total budget allocation for all the MWS plans received from different WECs and prepare a component wise consolidated plan for the SWS and submit to DLTC headed by district JDA for technical scrutiny

- DLTC go through the individual MWS plans for technical feasibility and prepare a convergence plan wherever possible and recommend the same to WCDC headed by district Deputy Commissioner for approval
- WCDC will verify the consolidated SWS DPR as well as convergence plan and recommends to the Project Empowered Committee (PEC) for approval. Upon approval of the WCDC, district JDA will submit the same along with minutes of DLTC and WCDC to State PIA to place before PEC
- State PIA will submit the SWS DPRs before the PEC and upon approval forward to district JDA
- JDA will forward the approved DPRs to Taluk PIA and in turn to field staff, FNGO & WECs to take up implementation
- Funds will be transferred to WECs for work implementation



DPR Validation and approval protocols

7. LRI based Nutrient Management

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. Under the REWARD program, LRI cards have been distributed to each parcel of land and given to the concerned farmers with training on how to use information provided in the LRI card for nutrient management as per the soil fertility status and the crops under consideration. In this chapter details are presented for the benefit of Extension Staff to promote this approach.
Land Resource Inventory (LRI) Card interpretation

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.

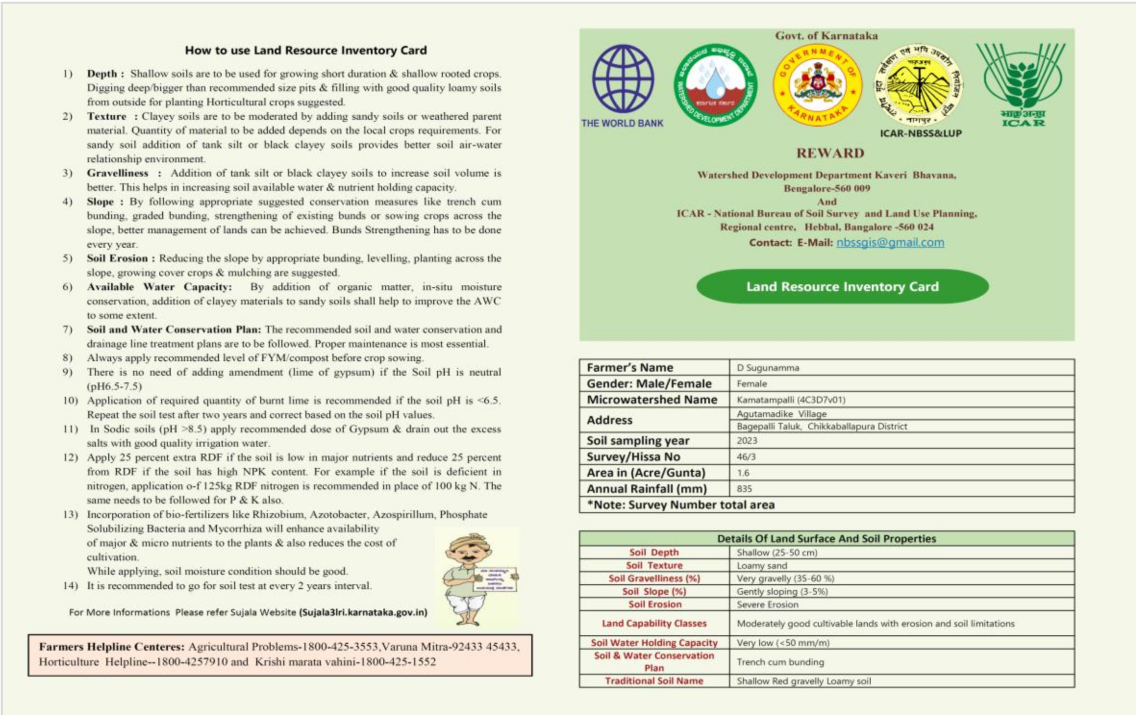
Land resource inventory card contains the following information:

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**	Micronutrient fertilizers May be applied in consultation with scientists of KVK and RSK since the recommendation varies from crop to crop
1	Sulphur (S)	Gypsum	
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.

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

8. Demystifying Science to the Communities

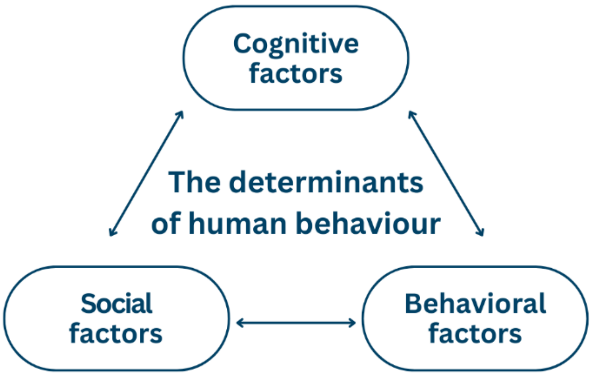
Science is the backbone for many of the decisions and policies that we make. The good thing about science is that it's true whether or not you believe in it. Innovative solutions from science and technology have profoundly improved people's quality of life, health, and economic advancement worldwide. We exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology. By its very nature, science is always true and yet it's in our interpretation of science where things get sticky. The technical jargons used makes it sometimes difficult to understand quickly. Science and communication reveal and connect the world to the unknown. Without building a bridge between these two fields, our world will be rife with misconceptions and false information about science-related solutions. Communicating science provides an excellent avenue for acceptance of innovations. Although, the current growth in scientific knowledge tailored toward solving problems of rural communities, the efforts to demystify science to these communities is yet take due share in extension educational activities of the development departments.

Under the REWARD program, more advanced scientific approaches are used in generation of location and site-specific information on the problems related to natural resource base and prospects for their restoration. It is not just enough to generate the factors and process affecting degradation of natural resources and approaches for their restoration, but it is also important to make the communities to understand the scientific tenor in application of science-based approaches in management of the natural resources by thoroughly understanding the cause-and-effect relationships. Therefore, demystifying scientific approaches to the communities who are the ultimate users and sustainers is very much important under REWARD program.

Approach to demystify science to communities

Demystifying science is nothing but, changing the behavior of person/s to accept and act on the scientific outcomes (evidence-based practice) to solve a problem instead of applying existing or traditional approaches. Therefore, for implementation of evidence-based practices, there is a need for behavioral change among the users on the suggested interventions. For example, through hydrology studies, estimating soil phase wise runoff from a given catchment is an evidence-based fact. To make the communities to accept the number and size of check dams in a drainage line based on the precise quantity of runoff from the catchment instead of a conventional approach is the behavioral change. Changing the behavior of communities on the evidence-based interventions is not that simple as identifying an evidence-based fact or generating scientific data.

Determinants of behavior: Individuals have a number of reasons for adopting or resisting behavior change. These barriers or facilitators are called behavioral "determinants. The factors which determine the behavior are grouped under three categories namely cognitive, behavioral and environmental. The cognitive factors include knowledge, expectations and attitudes, the behavioral factors include skills, practice and self-efficiency, and the environmental factors include social norms and access in community. Considering the determinants of behavior attempts should be made to change the behaviors.



Identifying behaviors of interest

Behavior change approach can be applied to any level may be from individuals to groups and from groups to organizations. In this approach, (a)diagnosis of behavior and (b)interventions required to change the behavior are important. While diagnosing behavior, it should be understood that who need to do what and how differently? as well as, what is preventing them from doing so? After the diagnosis, as an intervention help them to change what they do to promote implementation

a. What is the behavior (or series of linked behaviors) that you are trying to change? (Acceptance of science-based approaches in watershed planning)
b. Who performs the behavior(s)? (potential adopter: the farmer owning land in the micro watershed and watershed executive committee-WEC)
c. When and where does the potential adopter perform the behavior? (village or micro watershed level)
d. Are there obvious practical barriers to performing the behavior? (previous approach followed in watershed planning conflict with science-based approach)
e. Is the behavior usually performed in stressful circumstances? (Potential for acts of omission because of changed approach in planning)

Identifying whose behavior(s) need to change

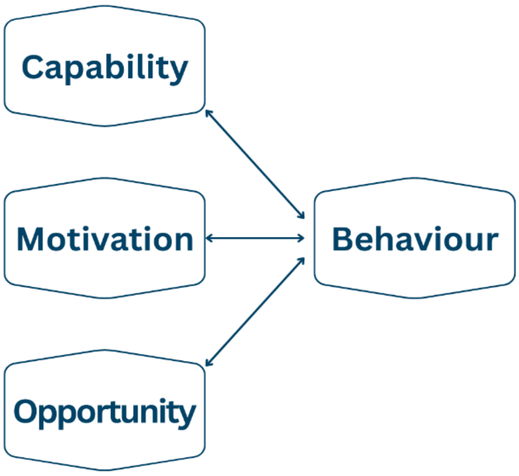
It is important to provide clarity regarding what to change and to specify target behaviors in terms of:

a. Actor performing the behavior (farmer/ WEC)
b. Action being performed (agreeing for the suggested measures based on LRI data)
c. Target at which the action is directed (validation of activities by the area groups considering the suggested activities in draft DPR)
d. Context in which action is performed (while planning for micro watershed)
e. Time during which the action is performed (the time frame jointly decided by the WEC and PIA)

Model of Behavioral Change:

In the process of changing the behavior of communities on scientific approaches, three components namely capability, opportunity, and motivation assume greater importance and these components interact to generate behavior.

Capability is the individual's psychological and physical capacity to engage in the activity concerned. It includes having the necessary knowledge and skills. Motivation is processes that energize and direct behavior, not just goals and conscious decision-making. It includes habitual processes, emotional responding, as well as analytical decision-making. Opportunity is all those factors that lie outside the individual that make the behavior possible or prompt it.



COMB model of behavioral change

The single-headed and double-headed arrows in the figure represent potential influence between components in the system. For example, opportunity can influence motivation as can capability; enacting a behavior can alter capability, motivation, and opportunity. A given intervention might change one or more components in the behavior system. The causal links within the system can work to reduce or amplify the effect of particular interventions by leading to changes elsewhere. While this is a model of behavior, it also provides a basis for designing interventions aimed at behavior change. Applying this to intervention design, the task would be to consider what the behavioral target would be, and what components of the behavior system would need to be changed to achieve that.

Capability can be achieved through imparting knowledge through educational activities, physical skill development through training which is the focus of training or potentially through enabling interventions such as medication, surgery or prostheses.

Motivation can be achieved through increasing knowledge and understanding, eliciting positive (or negative) feelings about behavioral target, associative learning that elicit positive (or negative) feelings and instincts relating to the behavioral target.

Opportunity can be achieved through by educating on the alternate approaches to improve or solve the problems over the existing approaches or relative advantages of all those alternatives compared to the existing ones.

Methods for changing the behavior or demystifying science

Some of the important methods that can be used by the field functionaries in demystifying science to communities are described below:

Demystifying Science to Community

1. **Education:** Increasing knowledge or understanding through discussions, use of print and electronic methods, interpreting the scientific outputs in a simple and understandable manner
   Example: Providing information on soil phase wise runoff available with the existing conditions and after execution of appropriate conservation measures
2. **Training:** Imparting skills on interpretation of thematic maps, selection of soil and moisture conservation measures based on decision criteria, selection of crops for different soil phases:
   Example: For a given quantity of runoff, deciding on number and size of check dams
3. **Persuasion:** Inducing positive feelings on the LRI based approaches for watershed planning and management. It may be important to identify and use progressive thinking people within the village to persuade others:
   Example: Comparison of Benefits between LRI based approaches and conventional approach in terms of expenditure, time saving, conservation of resources, productivity levels to be prepared and presented to key persons in the village and convince them

4. **Incentivization:** Rewarding for positive behavior on the introduced interventions. by complementing and recognizing the positive outcome. May be allocation of additional money for some important activities
   Example: Recognizing in a mega event and providing additional funds for some important activities
5. **Enablement:** Increasing means/reducing barriers to increase capability or opportunity. This may be possible through constant support from the PIA at various stages of project cycle
6. **Coercion:** Creating expectation of punishment by cost recoveries, if not complied with the scientific recommendations
   Example: Not providing budget from the project if the activities are deviated from approved DPR and if already implemented initiating recovery process from the supervisory staff
7. **Restriction:** Using rules to reduce the scope for deviation from the expected output. It should be compelling to adhere to the scientific recommendations in selection of interventions, crops etc.
   Example: if farmers do not cultivate crops as per the crop suitability criteria, such farmers will not get Government subsidy

Barriers for changing the behavior

Assessing the barriers or obstacles in changing the behavior is important to achieve success. Some of the common barriers are:

a. lack of ability in foreseeing the impact of/ advantages of introduced interventions specifically the anticipated impact
b. lack of immediate consequences of the introduced interventions
c. lack of environment or process support
d. social proof (difficulty in showing the proof / impact to the society)
e. lack of autonomy or ownership (sometimes the WEC or PIA may not be autonomous to take decisions)

9. Micro-Watershed Agro-Met Advisory Services (MWAAS)

Agro-met Advisory Services (AAS) are specialized services that provide weather-based agricultural advisories to farmers. These services integrate meteorological data with agricultural practices to offer actionable insights, enabling to make informed decisions regarding real time crop management. The core purpose of AAS is to enhance the resilience of agricultural systems by helping farmers adapt real time good agricultural practices based on weather variability and climate change. These services involve a multidisciplinary approach, combining knowledge from meteorology, agronomy, hydrology, plant protection and economics to offer timely and location-specific guidance on various agricultural activities.

Scope of AAS in rainfed agriculture

The scope of agro-met advisory services is broad, encompassing several critical aspects of agricultural management:

- The advisories encompassed with weather forecasting, provide short, medium, and long-range weather forecasts that help farmers plan agricultural activities like selection of crops & varieties, sowing, irrigation, nutrient, pest management, harvesting etc.
- Agro-met services offer tailored recommendations based on the type of crops being cultivated.
- By monitoring weather conditions that influence the proliferation of pests and diseases, agro-met services can provide early warnings, enabling farmers to take preventive measures.
- Agro-met advisory services play a vital role in managing climate risks by issuing early warnings for extreme weather events such as droughts, floods, and cyclones.
- These services often include decision support tools that help farmers assess the potential impact of weather conditions on their crops and make informed choices regarding agricultural practices. This enables farmers to optimize farm operations and thereby enhance productivity.

Importance in rainfed agriculture

Agriculture is highly dependent on weather and, weather variabilities have significant implications on crop production. Agro-Met advisory Services have emerged as an essential component of agricultural management, offering numerous benefits to farmers and the broader agricultural community, which are discussed hereunder.

- **Enhancing agricultural productivity through timely crop management:** AAS provide critical information that helps farmers optimize their agricultural practices. For instance, knowing the expected rainfall can guide farmers in deciding the appropriate crop, time for sowing, thereby ensuring better crop. Similarly, accurate temperature forecasts help in determining the timing of irrigation and the application of fertilizers, which can enhance crop yield.
- **Reducing weather-related crop losses:** Weather-related risks, such as droughts, floods and unseasonal rains pose significant challenges to Indian agriculture. AAS help to mitigate these risks by providing early warnings and advisories that allow farmers to take preventive measures. For example, if a forecast predicts heavy rainfall, farmers can delay harvesting to avoid crop damage. Similarly, in the event of a predicted

drought, farmers can adjust their irrigation schedules to conserve water. These proactive measures help reduce losses and ensure better outcomes for farmers.

- **Supporting sustainable agriculture:** Sustainable agriculture is crucial for ensuring long-term food security and environmental conservation. AAS promote sustainable practices by advising farmers on the optimal use of inputs such as water, fertilizers, and pesticides. By aligning agricultural activities with weather conditions, these services help minimize the environmental impact of farming, reduce resource wastage and promote the adoption of eco-friendly practices. This is particularly important in the context of climate change, where sustainable farming practices are necessary to adapt to changing weather patterns.
- **Empowering small and marginal farmers:** AAS empower these major farmers group (82%) by providing them with the knowledge and tools needed to make informed decisions based on weather conditions. Access to reliable weather information helps smallholders manage their resources more effectively, improve crop yield and enhance their resilience to climate variability and improve livelihoods.
- **Contributing to climate change adaptation:** Climate change poses a significant threat to Indian agriculture, with increasing temperatures, changing rainfall patterns and more frequent extreme weather events. AAS are vital for helping farmers adapt to these challenges. By providing information on weather trends and climate risks, these services enable farmers to adjust their practices to cope with changing conditions. This includes adopting drought-resistant crop varieties, altering planting schedules, and implementing water conservation measures. Agro-met services thus play a key role in building the resilience of Indian agriculture to climate change.

Components of Agro-Met Advisory Services

AAS developed for a region offer a diverse array of services aimed at helping farmers make informed decisions about their agricultural practices. These services are mainly targeted towards improvisation of crop productivity, managing climate risks, and enhancing the overall resilience of the agricultural sector.

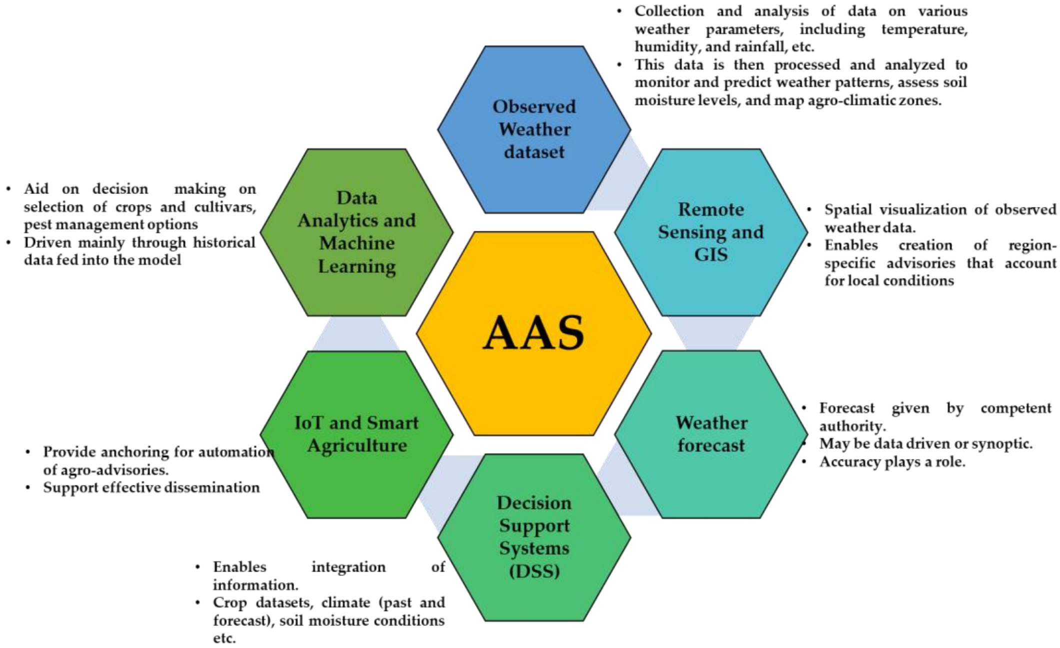
1. **Weather information (past and forecast):** The cornerstone of agro-met services is weather forecasting, which includes short-range (1-3 days), medium-range (4-10 days), and long-range (monthly and seasonal) forecasts. These forecasts provide critical information on temperature, rainfall, humidity, wind speed, and other weather parameters that directly influence agricultural activities.
2. **Crop-Specific Advisories:** AAS offer tailored advisories for specific crops, based on the weather forecasts and the crop's growth stage. These advisories include recommendations on the optimal timing for sowing, irrigation schedules, fertilizer application, pest and disease management.
3. **Pest and Disease Forecasting:** In recent years, pest and disease forecasting has become an integral part of AAS. By analysing weather conditions favourable for the outbreak of pest and diseases, these services provide early warnings to farmers. This allows them to take preventive measures, such as applying pesticides or adopting cultural practices to protect crops.
4. **Climate Risk Management:** AAS play a crucial role in managing climate risks by providing early warnings for extreme weather events such as droughts, floods, cyclones and heatwaves. These warnings enable farmers to take necessary

precautions, such as adjusting their cropping patterns, securing irrigation sources, or harvesting crops early to avoid damage.

5. **Decision Support Systems (DSS) for Farmers:** AAS are increasingly utilizing Decision Support Systems (DSS) that integrate weather data, crop models, and advisory tools. These systems provide farmers with actionable insights based on real-time weather information. DSS tools are often available through mobile apps and online platforms, making them accessible to a broad range of farmers.

Technologies and tools in agro-met advisory services

Usage of specific technology or tool in the AASs play critical role in the success and effectiveness. By leveraging advancements in meteorology, data analytics and communication technologies, these services provide timely and accurate weather-related information to farmers, helping them make informed decisions.



Technology and tools in agro-met advisory services

Micro-watershed level agro-met advisory services (MWAAS)

Karnataka with a second largest area under rainfed farming in India, faces challenges with respect to climate change induced weather aberrations specially the rainfall distribution, affecting sustainable production of crops and livelihood of rainfed farmers. In such situation, AAS play a vital role in day-to-day activities of farming based on realized and forecasted weather. In this view, the current MWAAS project is conceptualized to provide AAS at GP/ Micro-Watershed level based on medium and short-range weather forecast and LRI database involving State Agriculture Universities and KSNDMC. The project aims to reach 10 lakh ha. under REWARD program and to 28 lakh farmers in the state with the GP / micro-Watershed level weather forecast and advisory.

Scope of MWAAS in the state

- Timely dissemination of advisories based on weather forecast is key to achieve climate resilient agriculture at finer spatial scale i.e. at a level of micro-watersheds has not been considered yet, providing a huge scope for farmer centric advisories.
- Changed rainfall distribution both spatially and temporally resulted in increased frequency of weather extremes viz., drought or flood or both with in the same season. Several technologies of managing drought / flood are being evolved to minimize the crop losses need to be advocated to farmers.
- Location, soil and crop specific integrated AAS through IVRS, SMS and mobile App to the farmers enable them to take appropriate practices at farm level timely and to take the benefit of favourable weather and to minimize the adverse impact of unfavourable weather.
- These technologies are time and situation specific and should reach at right time. Agro-met advisories are the means for timely delivery of information.
- The success is being documented with increased production and economic status. The benefits can be further improved by downscaling the advisories to micro level and considering the bio-physical resources. Advisories at micro level considering the LRI data can help for bringing climate resilience at higher magnitude. Hence, the proposal is conceptualized.

Objectives

- Crop / cropping system recommendation based on LRI and extended range forecast for farmers at Micro-watershed level.
- Crop and soil specific real time contingent practices based on medium and short-range weather forecast.
- Advocating crop nutritional and plant protection schedule for the selected crop considering LRI data and forecasted weather.
- To develop Micro-Watershed Agro-met Advisory Services (MWAAS) dynamic / interactive app using LRI database and general climate.
- Impact assessment of MWAAS on crop performance, climate resilience and farmers income

Methodology

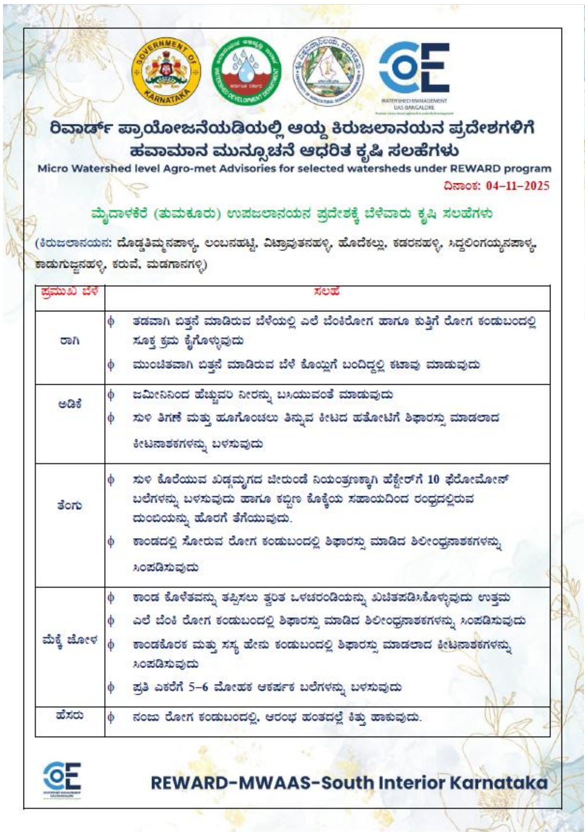
a. **Weather forecast**: Micro-watershed / GP / hobli level weather forecast is generated at KSNDMC in association with IMD / ISRO.
b. **LRI data bank including crops suitability**: WDD supports LRI data from digital library and the major crops of the domain
c. **Agro-Met Advisories**: SAU's prepare the agro-met advisories weekly twice (Tuesday and Friday) considering short / medium range weather forecast for the specified crops on real time basis. The advisories include soil and water conservation, tillage practices, crop and varietal selection, sowing, nutrient management, plant protection, after care, harvesting and post-harvest management practices.
d. **AAS Dissemination**: Agro-Met advisories are disseminated through IVRS (Varunamithra), SMS service, Interactive platform using apps etc by the KSNDMC

The advisories are given in 3 Phases

- **Phase I**: General advisories are initiated at micro-watershed level for major crops immediately
- **Phase II**: The advisories are customized to farmers scale with the mobile app
- **Phase III**: Automated AAS using models

Phase I: Issue of general advisories

As an inception, general advisories based on the crop and cropping systems information, past weather data and forecasted weather are initiated at micro-watershed level for major crops. The advisories are shared to LRI managers through WhatsApp and were in turn shared to farmers through groups created in each micro-watershed.



ರಿವಾರ್ಡ್ ಪ್ರಾಯೋಜನೆಯಡಿಯಲ್ಲಿ ಆಯ್ದ ಕಿರುಜಲಾನಯನ ಪ್ರದೇಶಗಳಿಗೆ
ಹವಾಮಾನ ಮುನ್ಸೂಚನೆ ಆಧರಿತ ಕೃಷಿ ಸಲಹೆಗಳು

Micro Watershed level Agro-met Advisories for selected watersheds under REWARD program

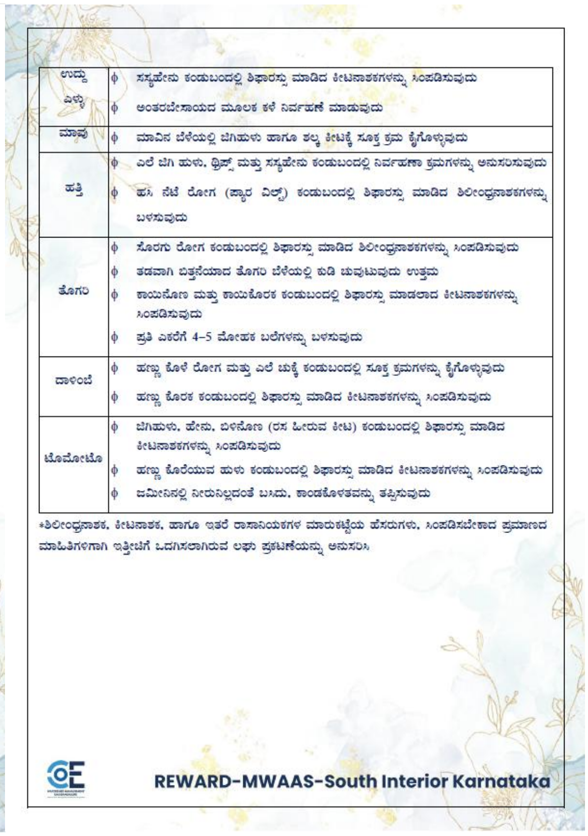
ದಿನಾಂಕ: 04-11-2025

ಮೈದಾಳಕೆರೆ (ತುಮಕೂರು) ಉಪಜಲಾನಯನ ಪ್ರದೇಶಕ್ಕೆ ಬೆಳೆವಾರು ಕೃಷಿ ಸಲಹೆಗಳು

(ಕಿರುಜಲಾನಯನ: ದೊಡ್ಡತಿಮ್ಮನಪಾಳ್ಯ, ಲಂಬನಹಟ್ಟಿ, ವಿಟ್ರಾವುತನಹಳ್ಳಿ, ಹೊದೆಕಲ್ಲು, ಕಡರನಹಳ್ಳಿ, ಸಿದ್ದಲಿಂಗಯ್ಯನಪಾಳ್ಯ, ಕಾಡುಗುಜ್ಜನಹಳ್ಳಿ, ಕರುವೆ, ಮಡಗಾನಗಳ್ಳಿ)

ಪ್ರಮುಖ ಬೆಳೆ	ಸಲಹೆ
ರಾಗಿ	ಕ ತಡವಾಗಿ ಬಿತ್ತನೆ ಮಾಡಿರುವ ಬೆಳೆಯಲ್ಲಿ ಎಲೆ ಬೆಂಕಿರೋಗ ಹಾಗೂ ಕುತ್ತಿಗೆ ರೋಗ ಕಂಡುಬಂದಲ್ಲಿ ಸೂಕ್ತ ಕ್ರಮ ಕೈಗೊಳ್ಳುವುದು ಕ ಮುಂಚಿತವಾಗಿ ಬಿತ್ತನೆ ಮಾಡಿರುವ ಬೆಳೆ ಕೊಯ್ಲಿಗೆ ಬಂದಿದ್ದಲ್ಲಿ ಕಟಾವು ಮಾಡುವುದು
ಅಡಿಕೆ	ಕ ಜಮೀನಿನಿಂದ ಹೆಚ್ಚುವರಿ ನೀರನ್ನು ಬಸಿಯುವಂತೆ ಮಾಡುವುದು ಕ ಸುಳಿ ತಿಗಣೆ ಮತ್ತು ಹೂಗೊಂಚಲು ತಿನ್ನುವ ಕೀಟದ ಹತೋಟಿಗೆ ಶಿಫಾರಸ್ಸು ಮಾಡಲಾದ ಕೀಟನಾಶಕಗಳನ್ನು ಬಳಸುವುದು
ತೆಂಗು	ಕ ಸುಳಿ ಕೊರೆಯುವ ಖಡ್ಗಮೃಗದ ಜೀರುಂಡೆ ನಿಯಂತ್ರಣಕ್ಕಾಗಿ ಹೆಕ್ಟೇರ್‌ಗೆ 10 ಫೆರೋಮೋನ್ ಬಲೆಗಳನ್ನು ಬಳಸುವುದು ಹಾಗೂ ಕಬ್ಬಿಣ ಕೊಕ್ಕೆಯ ಸಹಾಯದಿಂದ ರಂಧ್ರದಲ್ಲಿರುವ ದುಂಬಿಯನ್ನು ಹೊರಗೆ ತೆಗೆಯುವುದು. ಕ ಕಾಂಡದಲ್ಲಿ ಸೋರುವ ರೋಗ ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಶಿಲೀಂಧ್ರನಾಶಕಗಳನ್ನು ಸಿಂಪಡಿಸುವುದು
ಮೆಕ್ಕೆ ಜೋಳ	ಕ ಕಾಂಡ ಕೊಳೆತವನ್ನು ತಪ್ಪಿಸಲು ತ್ವರಿತ ಒಳಚರಂಡಿಯನ್ನು ಖಚಿತಪಡಿಸಿಕೊಳ್ಳುವುದು ಉತ್ತಮ ಕ ಎಲೆ ಬೆಂಕಿ ರೋಗ ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಶಿಲೀಂಧ್ರನಾಶಕಗಳನ್ನು ಸಿಂಪಡಿಸುವುದು ಕ ಕಾಂಡಕೊರಕ ಮತ್ತು ಸಸ್ಯ ಹೇನು ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಲಾದ ಕೀಟನಾಶಕಗಳನ್ನು ಸಿಂಪಡಿಸುವುದು ಕ ಪ್ರತಿ ಎಕರೆಗೆ 5-6 ಮೋಹಕ ಆಕರ್ಷಕ ಬಲೆಗಳನ್ನು ಬಳಸುವುದು
ಹೆಸರು	ಕ ನಂಜು ರೋಗ ಕಂಡುಬಂದಲ್ಲಿ, ಆರಂಭ ಹಂತದಲ್ಲೆ ಕಿತ್ತು ಹಾಕುವುದು.

REWARD-MWAAS-South Interior Karnataka



ಉದ್ದು ಎಳ್ಳು	ಕ ಸಸ್ಯಹೇನು ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಕೀಟನಾಶಕಗಳನ್ನು ಸಿಂಪಡಿಸುವುದು ಕ ಅಂತರಬೇಸಾಯದ ಮೂಲಕ ಕಳೆ ನಿರ್ವಹಣೆ ಮಾಡುವುದು
ಮಾವು	ಕ ಮಾವಿನ ಬೆಳೆಯಲ್ಲಿ ಜಿಗಿಹುಳು ಹಾಗೂ ಶಲ್ಕ ಕೀಟಕ್ಕೆ ಸೂಕ್ತ ಕ್ರಮ ಕೈಗೊಳ್ಳುವುದು
ಹತ್ತಿ	ಕ ಎಲೆ ಜಿಗಿ ಹುಳು, ಥ್ರಿಪ್ಸ್ ಮತ್ತು ಸಸ್ಯಹೇನು ಕಂಡುಬಂದಲ್ಲಿ ನಿರ್ವಹಣಾ ಕ್ರಮಗಳನ್ನು ಅನುಸರಿಸುವುದು ಕ ಹಸಿ ನೆಟೆ ರೋಗ (ಪ್ಯಾರ ವಿಲ್ಟ್) ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಶಿಲೀಂಧ್ರನಾಶಕಗಳನ್ನು ಬಳಸುವುದು
ತೊಗರಿ	ಕ ಸೊರಗು ರೋಗ ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಶಿಲೀಂಧ್ರನಾಶಕಗಳನ್ನು ಸಿಂಪಡಿಸುವುದು ಕ ತಡವಾಗಿ ಬಿತ್ತನೆಯಾದ ತೊಗರಿ ಬೆಳೆಯಲ್ಲಿ ಕುಡಿ ಚಿವುಟುವುದು ಉತ್ತಮ ಕ ಕಾಯಿನೊಣ ಮತ್ತು ಕಾಯಿಕೊರಕ ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಲಾದ ಕೀಟನಾಶಕಗಳನ್ನು ಸಿಂಪಡಿಸುವುದು ಕ ಪ್ರತಿ ಎಕರೆಗೆ 4-5 ಮೋಹಕ ಬಲೆಗಳನ್ನು ಬಳಸುವುದು
ದಾಳಿಂಬೆ	ಕ ಹಣ್ಣು ಕೊಳೆ ರೋಗ ಮತ್ತು ಎಲೆ ಚುಕ್ಕೆ ಕಂಡುಬಂದಲ್ಲಿ ಸೂಕ್ತ ಕ್ರಮಗಳನ್ನು ಕೈಗೊಳ್ಳುವುದು ಕ ಹಣ್ಣು ಕೊರಕ ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಕೀಟನಾಶಕಗಳನ್ನು ಸಿಂಪಡಿಸುವುದು
ಟೊಮೋಟೊ	ಕ ಜಿಗಿಹುಳು, ಹೇನು, ಬಿಳಿನೊಣ (ರಸ ಹೀರುವ ಕೀಟ) ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಕೀಟನಾಶಕಗಳನ್ನು ಸಿಂಪಡಿಸುವುದು ಕ ಹಣ್ಣು ಕೊರೆಯುವ ಹುಳು ಕಂಡುಬಂದಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಕೀಟನಾಶಕಗಳನ್ನು ಸಿಂಪಡಿಸುವುದು ಕ ಜಮೀನಿನಲ್ಲಿ ನೀರುನಿಲ್ಲದಂತೆ ಬಸಿದು, ಕಾಂಡಕೊಳತವನ್ನು ತಪ್ಪಿಸುವುದು

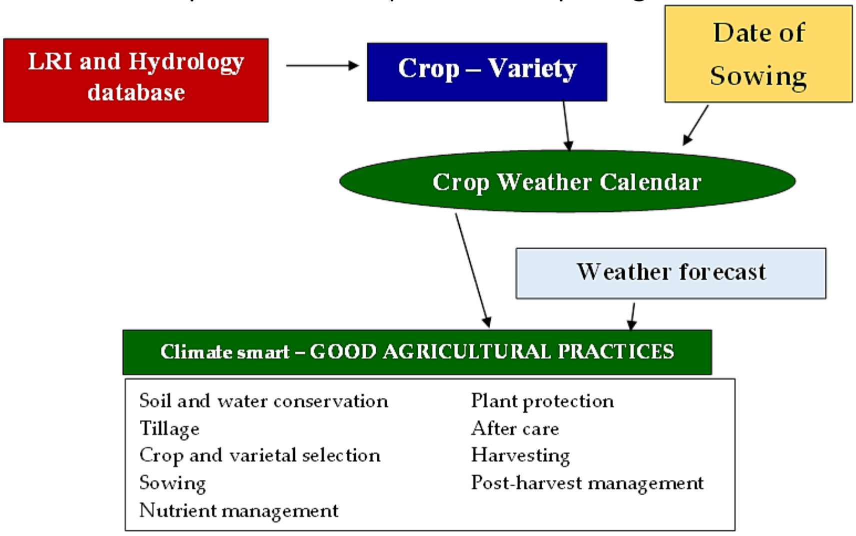
*ಶಿಲೀಂಧ್ರನಾಶಕ, ಕೀಟನಾಶಕ, ಹಾಗೂ ಇತರೆ ರಾಸಾಯನಿಕಗಳ ಮಾರುಕಟ್ಟೆಯ ಹೆಸರುಗಳು, ಸಿಂಪಡಿಸಬೇಕಾದ ಪ್ರಮಾಣದ ಮಾಹಿತಿಗಳಿಗಾಗಿ ಇತ್ತೀಚಿಗೆ ಒದಗಿಸಲಾಗಿರುವ ಲಘು ಪ್ರಕಟಣೆಯನ್ನು ಅನುಸರಿಸಿ

REWARD-MWAAS-South Interior Karnataka

General micro-watershed level advisories prepared based on general information during Phase-I

Phase-II: Farmer scale customized advisories

Crop and farmer specific advisories on crop-management practices based on the prevailing and forecasted weather are provided. Advisories will be customized to farmers' field scale. The set of advisories developed for one crop as an example is given in Annexure-13.



Pathway of information collection and farmer scale advisory issued

These farmer scale customized advisories are issued in the form of bulletins and automatically pop-ups in the CRM portals of the dissemination partner i.e. KSNDMC.

Biweekly bulletins for issue of general advisories:

- Contain information on suitable crop and cropping system, varieties for that piece of land and length of growing period available based on which the long, medium and short duration variety is recommended, and further good agricultural practices (GAPs) for raising of the recommended crops/ cropping systems with higher productivity.
- These bulletins are shared via WhatsApp groups involving LRI managers and through them shared to local farmers' groups.

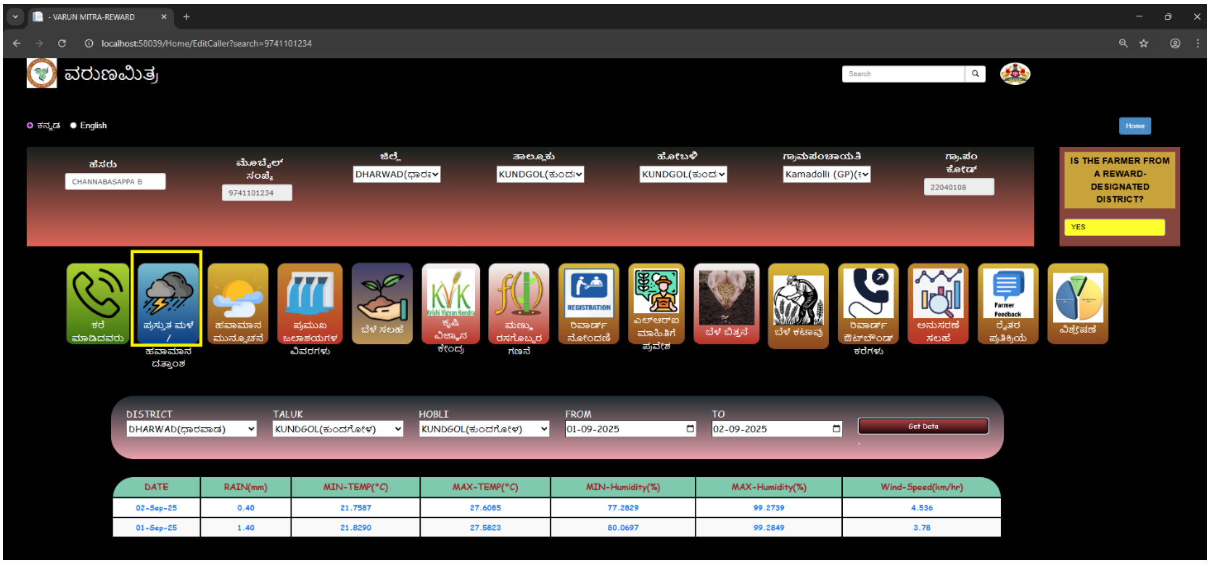
Sample of general bulletin issued at biweekly interval

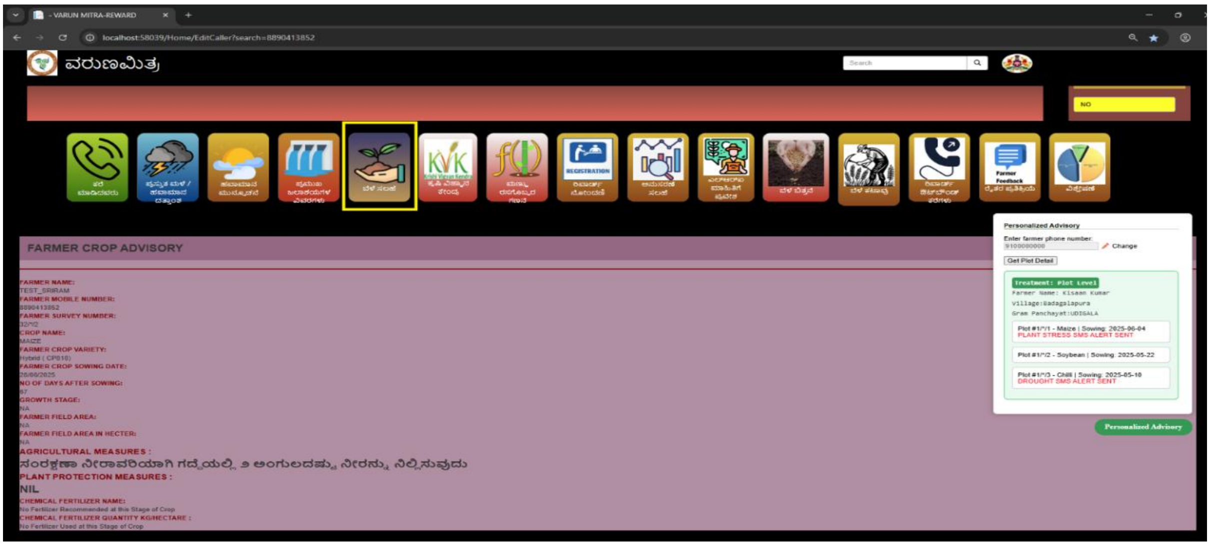
IVRS advisories:

- In order to disseminate an interactive type of advisory to the farmer under aberrant climatic conditions a call centre has been established at KSNDMC, where the agricultural graduates are hired to respond for the queries from farmers.
- They are equipped with a Customized Relationship Management (CRM) portal, backed up with farmers' details (location information, LRI information, crops cultivated, date of sowing of the crop, etc.)
- Considering above information, a set of advisories for different simulated conditions of the past and forecasted weather in each crop growth stage have been developed and incorporated to the database.
- Likewise, a set of advisories for 15 agricultural crops and 19 horticultural crops have been prepared by UAS Bangalore, to cover southern Districts of the State. Similarly, 14 agricultural crops and 21 horticultural crops have been prepared by UAS Dharwad, for Northern Districts of the State. The crops will vary according to the cultivation by the farmers.
- Whenever a farmer call to the Varunamitra help desk, details of the famer such as his location, crop under cultivation will pop-up, its growth stage is estimated based on the sowing date provided by the farmer himself, the past and forecasted weather information accessed form the KSNDMC database itself and based on all this information utilized to pop-up a relevant advisory.

ಬೆಳೆ (Crop)	ಬಿತ್ತನೆ ದಿನಾಂಕ (Sowing date)	ತಳಿ (Variety)	ಬಿತ್ತನೆ ನಂತರದ ದಿನಗಳ ಸಂಖ್ಯೆ (Phenophase period)	ಬೆಳೆಯ ಹಂತ (Crop stage)	ಹಿಂದಿನ ವಾರದ ಹವಾಮಾನ: ಮಳೆ: ವಾಡಿಕೆ, ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ, ವಾಡಿಕೆಗಿಂತ ಹೆಚ್ಚು (Realized Weather - rainfall: Normal/ Less than normal/ more than normal)	ಮುಂದಿನ ವಾರದ ಮಳೆ ಮುನ್ಸೂಚನೆ: ಇದೆ / ಇಲ್ಲ (Weather forecast for next week - rainfall: Yes/No)	ಮಣ್ಣಿನ ತೇವಾಂಶ (ಪ್ರಶಸ್ತ, ಪ್ರಶಸ್ತಕ್ಕಿಂತ ಕಡಿಮೆ, ಪ್ರಶಸ್ತಕ್ಕಿಂತ ಅಧಿಕ) (Soil moisture level: Optimum/ More than optimum/ Less than optimum)	ಸಲಹೆಗಳು (Advisory)

Template of information collected for generation of IVRS advisories

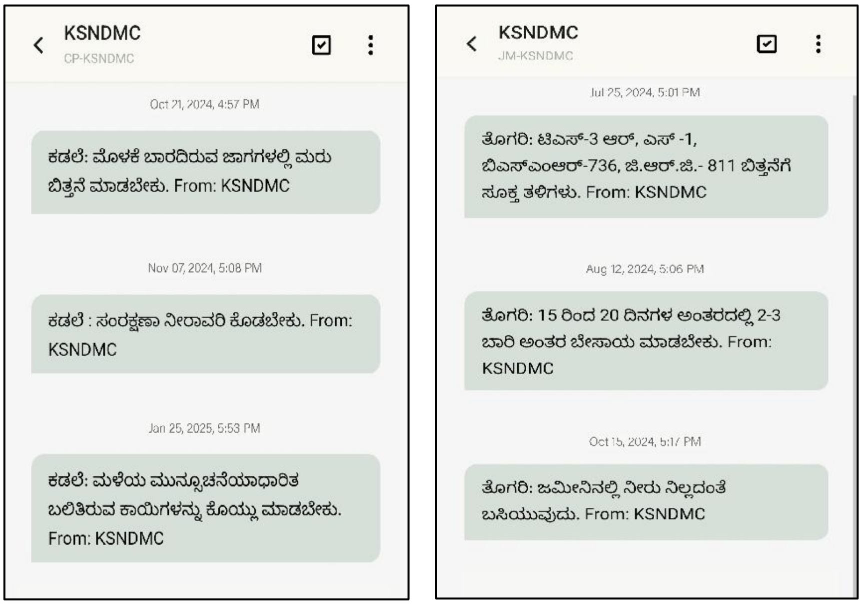




The CRM interface developed for dissemination of agro-met advisories

SMSs:

- Good agricultural practices are simulated for different scenarios of realized and forecasted weather integrating LRI in Phase II. Updating and automation is ongoing using AI/ML platform in Phase III.
- During the start of each growing season, a template for collecting information on crops and cultivars, date of sowing, etc will be shared to LRI managers and the information is gathered and vetted by KSNDMC and SAUs (UASB and UASD).
- The vetted information is utilized for database creation for automation of the dissemination of advisories in the SMS format.
- As in IVRS, a set of criteria for automated advisory dissemination through SMS, especially during critical stages during aberrant weather conditions will be simulated and the automation of the SMSs made.
- The SMSs will be shared to the individual farmer if and only if the criteria for that particular crop such as growth stage, previous week rainfall and forecast information, necessity of the intervention etc.
- Some of the critical operations being insensitive for weather forecast and soil moisture content, needs to be provided to farmer, are shared irrespective of soil moisture content and weather conditions.



Sample of SMSs received by farmers

WhatsApp Channel:

- Though farmers are supplied with timely (biweekly general advisories, specific advisories twice a week, etc.) under sudden weather aberrations they may feel the need for specific management practices.
- For the same, 'Reward Krishi Mitra' WhatsApp channel was created and need based advisories are being posted.

Samples of posts disseminated on 'REWARD Krishi Mitra' WhatsApp channel under aberrant weather conditions

Phase III: Automated AAS using models/ mobile app

- In association with KSNDMC, CoE-WM-MWAAS team is developed a mobile app. The app mainly intends to provide real-time weather conditions, past and forecasted weather information, agro-met advisory considering the crop, its growth stage, past and forecasted weather information.
- It also includes other beneficial aspects like recommending the fellow former to receive messages by entering his information into the app, and many others.

Home page of the mobile app

Conclusion and way forward

The agro-ecosystem being multi-factor dependent production system, highly prone to vulnerability due to aberrations. Climatic conditions being major one being able to alter the system for a maximal extent, needs be monitored and taken care to reduce its impact on agriculture. Systematic study of such changes in climatic conditions is important, on the other hand, the dissemination or creation of awareness about the changes is important for taking precautionary measures. In this view, present project has been rolled out in the micro-watersheds of southern and north interior Karnataka through watershed development department, GoK. The project targets consortium efforts of Watershed Development Department, Revenue Department (KSNDMC) and SAUS (UAS-Bangalore and UAS-Dharwad) for providing comprehensive, timely advisories based on inputs from multi-disciplinary sources like soil, crop information from WDD, Weather information from KSNDMC and advisory for those conditions from SAUs. The application of novel technologies like IVRS, social media (WhatsApp) and SMS etc. has enabled the fast and uninterrupted dissemination of advisories, and efforts are being made to make further improvements on the same.

10. 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

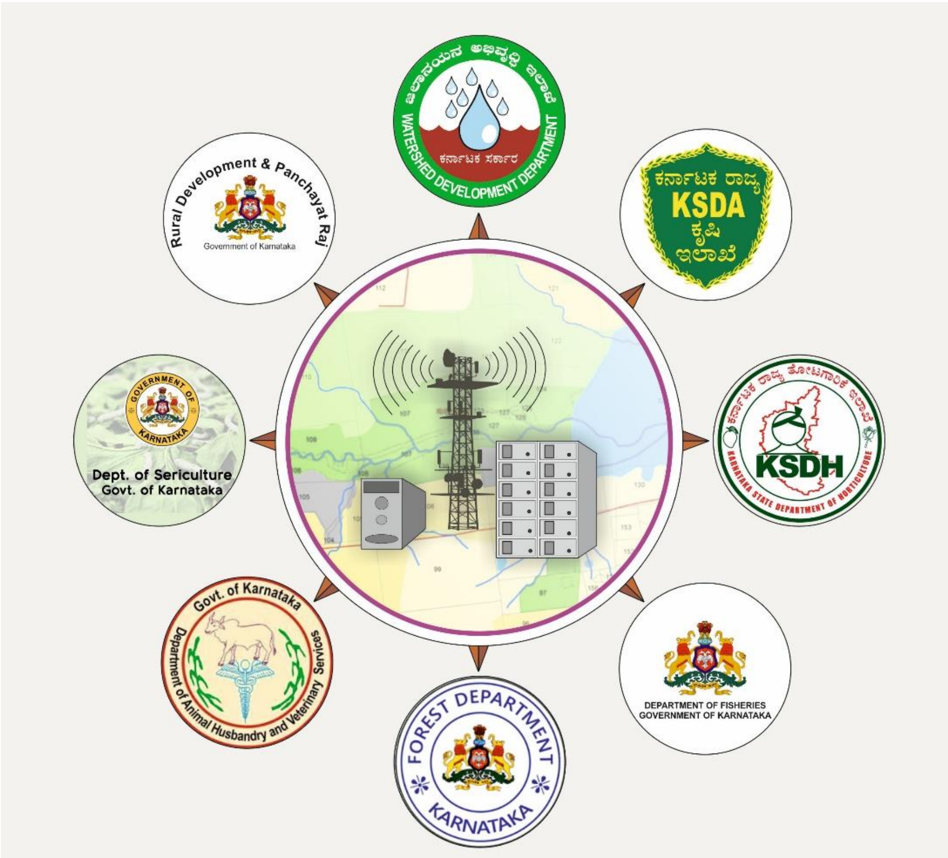
Rural Development and Panchayat Raj (RDPR): is implementing Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) for land treatment especially earthworks such as farm and contour bunds, clearing drainage lines, preparing pits for plantation repair, renovation & restoration (RR&R), water resources (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.

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.



Development Departments can use LRI data

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 REWARD program activities with other departments activities

No.	*DPR items*	*Specific activities identified for convergence*	*Mode of convergence*	*Expected outcomes*	*Remarks*
1	Entry point activities				
2	Capacity building and training				
3	Works				
3.1	Soil and water conservation				
3.2	Agriculture				
3.3	Horticulture				
3.4	Animal husbandry				
3.5	Fisheries				
3.6	Forestry				
3.7	RDPR				
4	Income generating activities				
5	Production improvements and micro enterprises				
6	Any other activity				

11. Application of LRI and Hydrology Data for Planning and Implementation of other Development Departments Programs

Under the World Bank supported Sujala-3 and REWARD programs, huge quantity of diversified data have been collected through scientific partner institutes (SAUs, NBSS&LUP, KSRSAC, KSNDMC, and IISc) and the same is made available in the Geo/ LRI portal of the Watershed Development Department. The information can be accessed from the URL **https://www.sujala3lri.karnataka.gov.in/** by the officers of the various development departments and research institutes to plan and implement their departments programs.

The Inputs available from the portal are given below

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 management, LCC, Runoff estimation, Location of FPs, Crop water, Soil Moisture, Water Balance & Budgeting	√	√	√
Mobile Applications	√	√	√

Application of LRI for Planning and Implementation of DoS Programs

Datasets, Maps, Tools, DSS, etc., developed under REWARD program	*Soil Health*	*Mulberry improvement*
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		√
Suitability maps for Sericulture	√	√
Existing well and conservation structure maps		√
Soil and water conservation plan maps		√
LRI Reports and Atlas	√	√
LRI Cards	√	√
Hydrology Reports and Atlas	√	√
Digital Library	√	√
LRI Portal	√	√
DSS for LCC, Mulberry crop selection, Nutrient management, Crop water, Soil Moisture, Water Balance & Budgeting	√	√

Application of LRI for Planning and Implementation of MGNREGS Programs

Datasets, Maps, Tools, DSS, etc., developed under REWARD program	*Soil & Water Conservation treatments*	*Drainage line treatments*	*Check Dams/ Farm Ponds*
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	√	√	√
Hyd. 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 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 management, LCC, Runoff estimation, Location of FPs, Crop water, Soil Moisture, Water Balance & Budgeting	√	√	√
Mobile Applications	√	√	√

Application of LRI for Planning and Implementation of RDPR Programs

Datasets, Maps, Tools, DSS, etc., developed under REWARD program	*Soil & Water Conservation*	*Drainage line treatment*	*CDs & FPs*	*Crop selection & productivity improvement*	*Livestock, forestry, fisheries, others*
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	√	√	√	√	√
Soil nutrient maps-macro and micro nutrients				√	√
Weather inputs-rainfall, RH, Temp., Wind, PET	√	√	√	√	√
Hyd. data-runoff, soil moisture, GW status and availability	√	√	√	√	√
Socio-economic data and reports	√			√	√
Package of Practices				√	√
Land Capability maps	√	√	√	√	√
Ground water status maps/ Existing wells/Yield	√	√	√	√	√
Crop suitability maps for crops				√	
Suitability maps for horti. crops				√	
Suitability maps for Sericulture				√	√
Suitability maps for forest tree species					√
Suitability maps for forage crops					√
Existing well and conservation structure maps	√	√	√	√	
Soil & 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 management, LCC, Runoff estimation, Location of FPs, Crop water, Soil Moisture, Water Balance & Budgeting	√	√	√	√	√
Mobile Applications	√	√	√	√	√

Application of LRI for Planning and Implementation of DoH Programs

Datasets, Maps, Tools, DSS, etc., developed under REWARD program	*Crop suitability assessment for Horti. crops*	*Selection of areas suited for drip/ sprinkler irrigations*	*Selection of fields for demos and clusters*
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	√	√	√
Hyd. data-runoff, soil moisture, GW status and availability	√	√	√
Socio-economic data and reports	√	√	√
Package of Practices	√	√	√
Land Capability maps	√	√	√
Ground water status maps	√	√	√
Suitability maps for horticultural 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 management, LCC, Runoff estimation, Location of FPs, Crop water, Soil Moisture, Water Balance & Budgeting	√	√	√
Mobile Applications	√	√	√

Annexure-1

Land Resources Inventory for Watershed Planning

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 Activities are grouped into Pre-field, Field, and Post-field activities

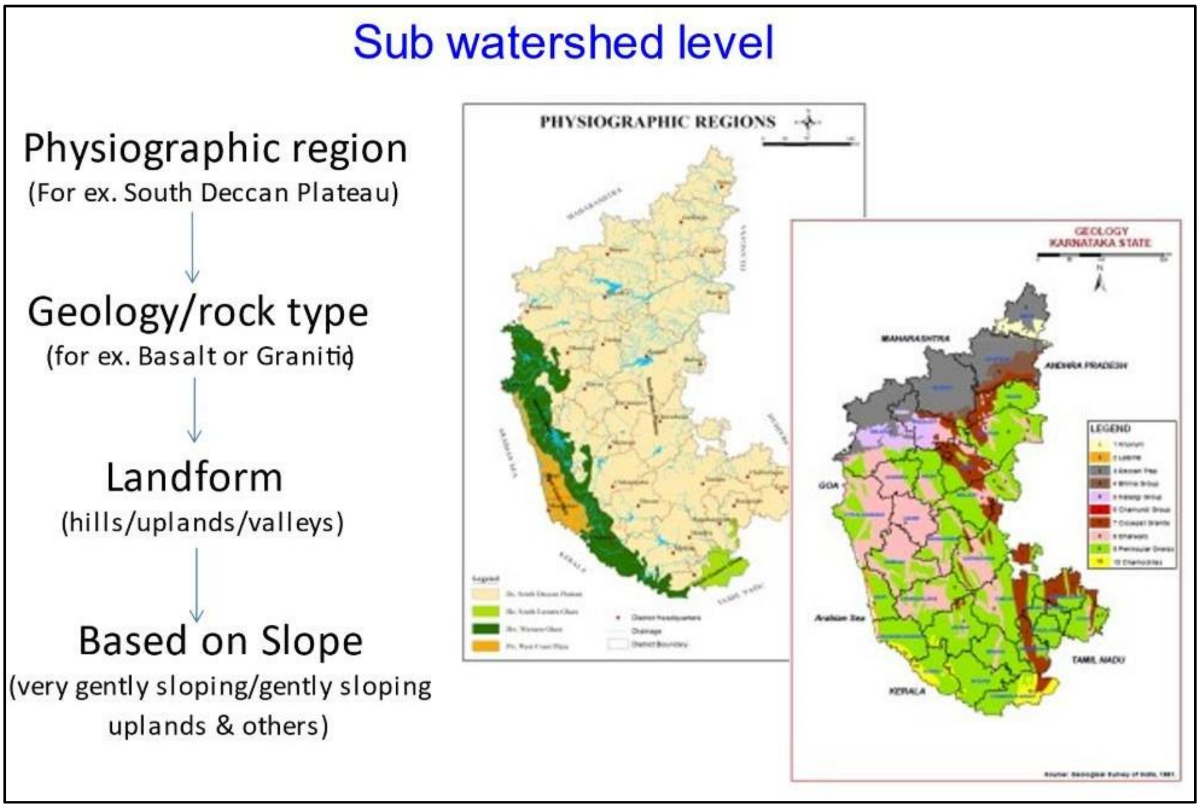
- Pre-field activities include image interpretation; cadastral maps are overlaid on the imagery to get base map and from base map landform units are delineated based on slope and image characteristics
- Field activities include validation of interpreted image in the field, transect identification, soil profile study, collection of surface soil samples for soil fertility status
- Post-field activities include analysis of soil parameters, mapping & atlas preparation

LRI 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 sub-watershed (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.

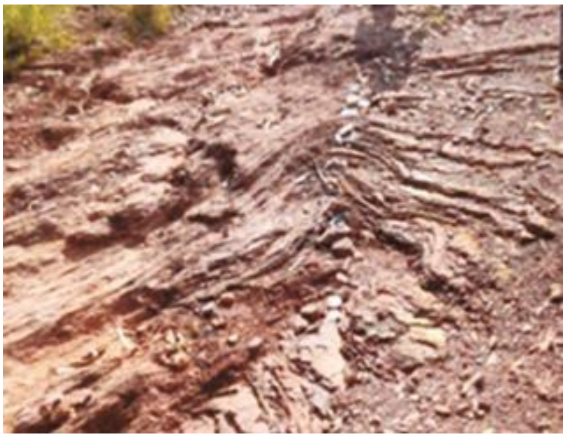
Interpretation at MWS level: At micro-watershed (MWS) level, the landform units identified at SWS level is further subdivided based on change in slope, land use and other surface features as evidenced through the image characteristics and other converging evidence of the area. For example, the hills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

Red sand stone

Basalt Rock

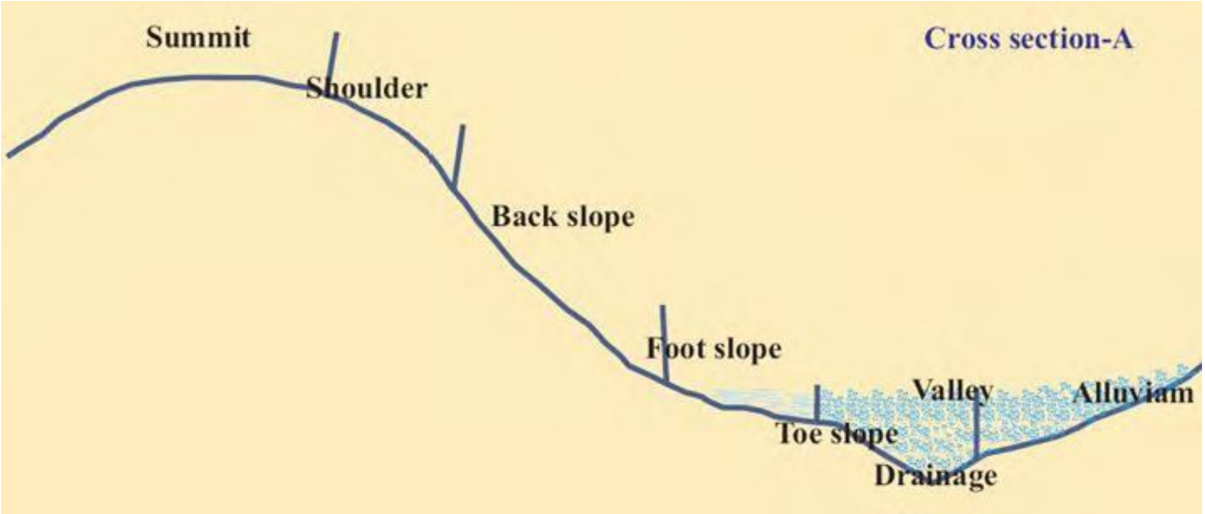
Granite

Laterite



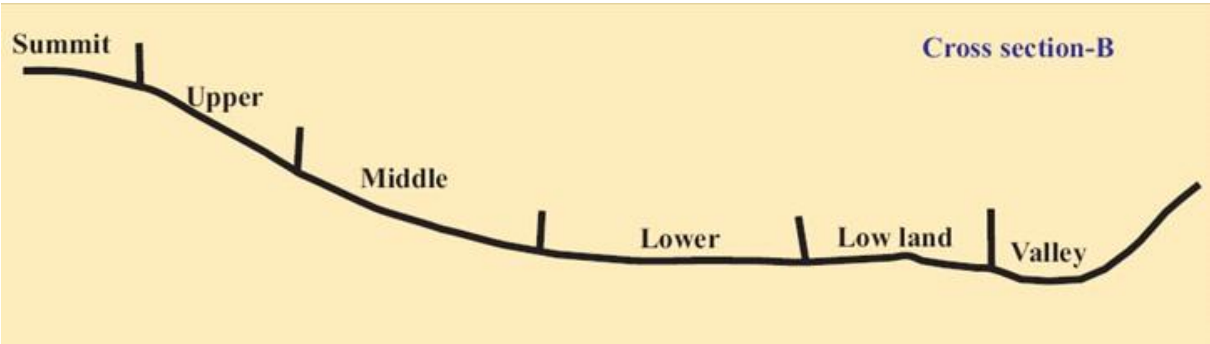
Schist

Major rock types



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**

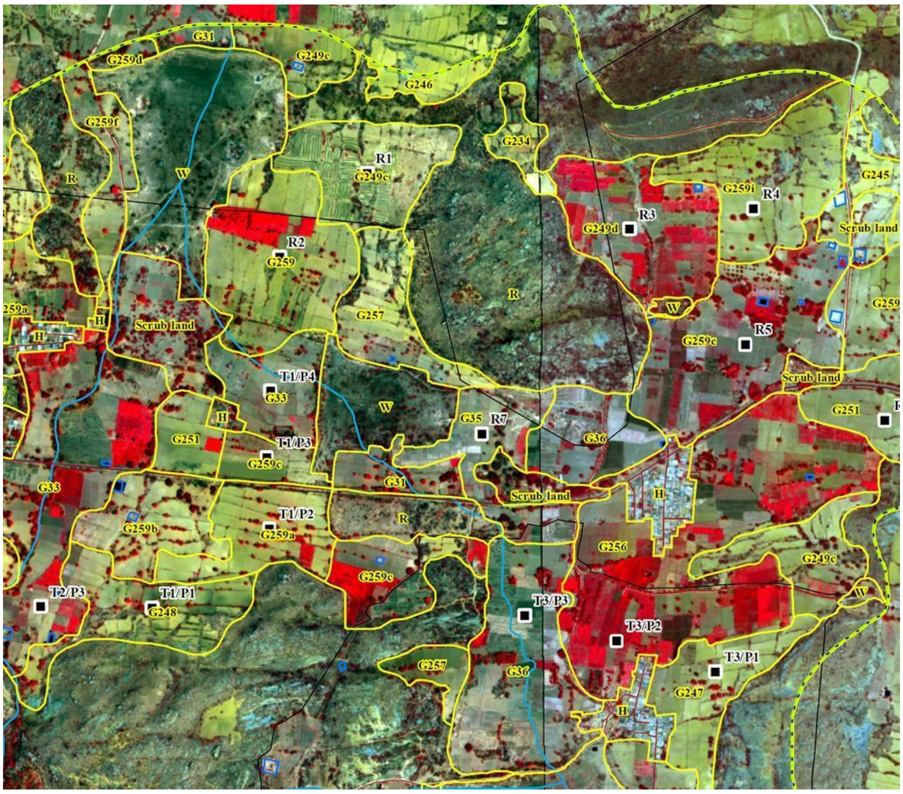
- A1 Nearly level Uplands
- A2 Very gently sloping lands

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

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.

#	*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	

Differentiating Characteristics for identifying Soils at SWS level

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

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 standard format to describe the soil-site characteristics is attached at the end of the chapter in which the first page lists the site characteristics to be recorded and soil characteristics on the back side. The field team should be familiar with the list of soil site characteristics that are to be studied and described in the standard proforma.

Field investigation - Tick in the appropriate box

Author and date - Give the name of the Officer in- charge of the field party and date/time of observation
Example: Date/Month/Year (02/12/2022)

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 No - 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	*Slope %*
Nearly Level	1-3
Undulating	3-8
Rolling	8-16
Hilly	16-30
Steep	30-60
Very steep	>60

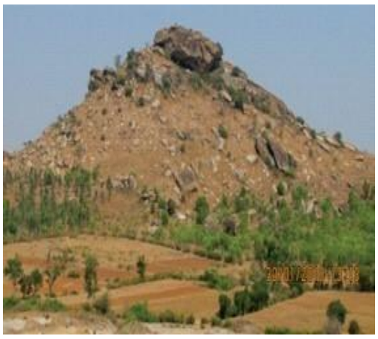
Landform - Based on geology, elevation, location and other features, the four major physiographic regions of the state are further subdivided broadly into nine landscape areas.

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

Gently sloping severely eroded uplands

Elongated plateau in basalt landscape



Conical residual hillock

Gently sloping uplands

Steeply sloping low hills

Level (< 1 %) lowlands

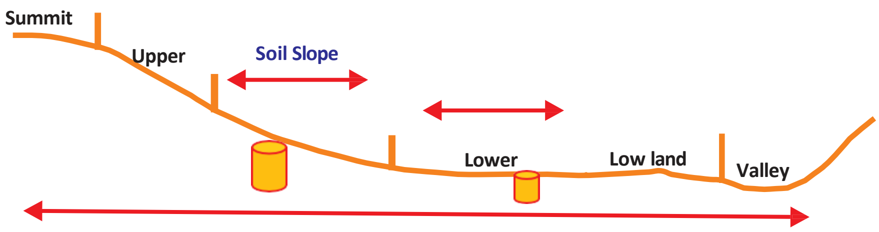
Typical landform units of granite gneiss and basalt landscape

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, foot slope 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:

Code	*Class*	*Range of slope %*	*Abney Level reading*
A	Nearly level	0-1	0°00' to 0°35'
B	Very Gently Sloping	1-3	0°35' to 1°44'
C	Gently Sloping	3-5	1°44' to 2°52'
D	Moderate Sloping	5-10	2°52' to 5°43'
E	Strongly Sloping	10-15	5°43' to 8°32'
F	Moderate Steep	15-25	8°32' to 14°03'
G	Steep	25-33	14°03' to 18°16'
H	Very Steep	33-50	18°16' to 26°34'

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.

- Sheet erosion is responsible for almost uniform removal of soil from an area without leaving any significant marks at the surface.
- Rill erosion is the removal of soil through many small incipient channels or rills.
- Gully erosion is the consequence of water that cuts down into the soil along the line of flow.

Moderately eroded (e2), > 50 % surface soil eroded due to sheet erosion

Very severely eroded (e4), due to deep and wide gully erosion

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 a few rills, an accumulation of sediment at the base of slopes or in depressions, scattered small areas where the plough layer contains material from below, 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.

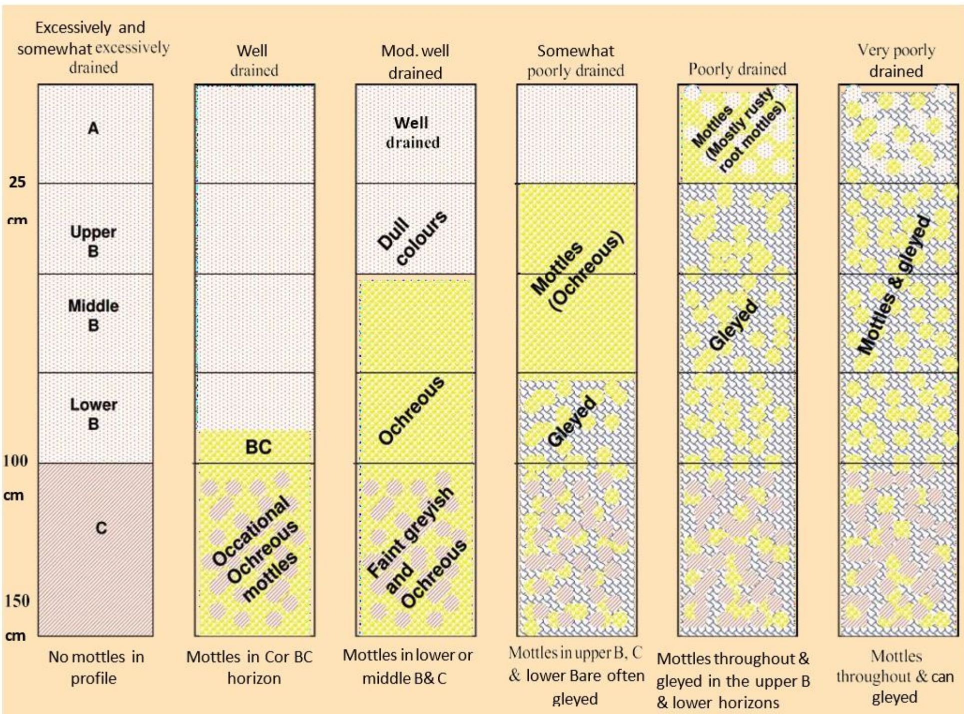
Class 3 (severe erosion) - This class consists of soils that have lost, on the average, 75 per cent or more of the original A horizon. In class 3 erosion, material below the A horizon is exposed at the surface in cultivated areas and some mixing with underlying material is also observed.

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.

- **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.
- **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.
- **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.
- **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.
- **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.
- **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
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.

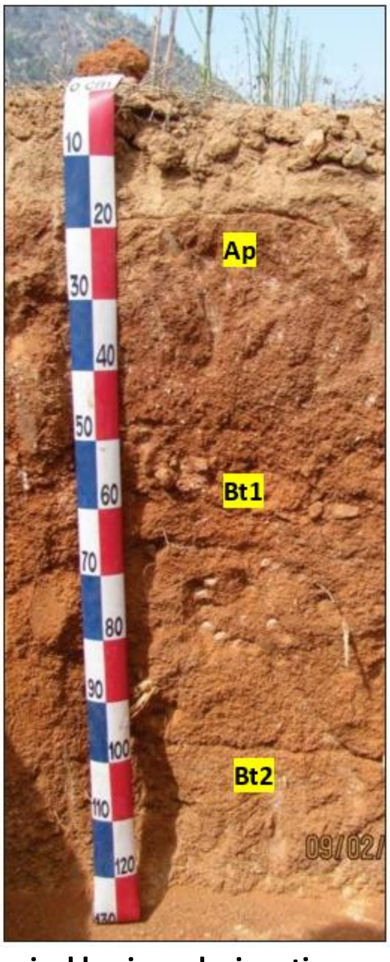
Per cent coverage	*Description*
< 2	No rocks or very few rocks to interfere with tillage
2 to 10	Fairly rocky, sufficient to interfere with tillage but not to make inter-tilled crops impracticable. Exposures are roughly 35 to 100 m apart
10 to 25	Rocky, sufficient to interfere with tillage of inter-tilled 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.

1. **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 horizon symbols. 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.

2. **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 colour 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, aluminium, humus, carbonates, gypsum, or silica, alone / in combination
2. evidence of removal of carbonates
3. residual concentration of sesquioxides
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.

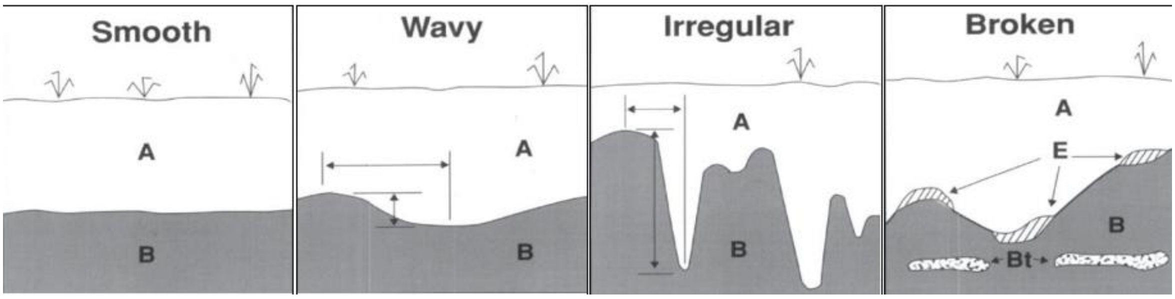
Boundaries of horizons and layers - A transitional area or layer present between two adjoining horizons or layers is known as the boundary. Boundaries vary in **distinctness** (contrast) and in **topography**.

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

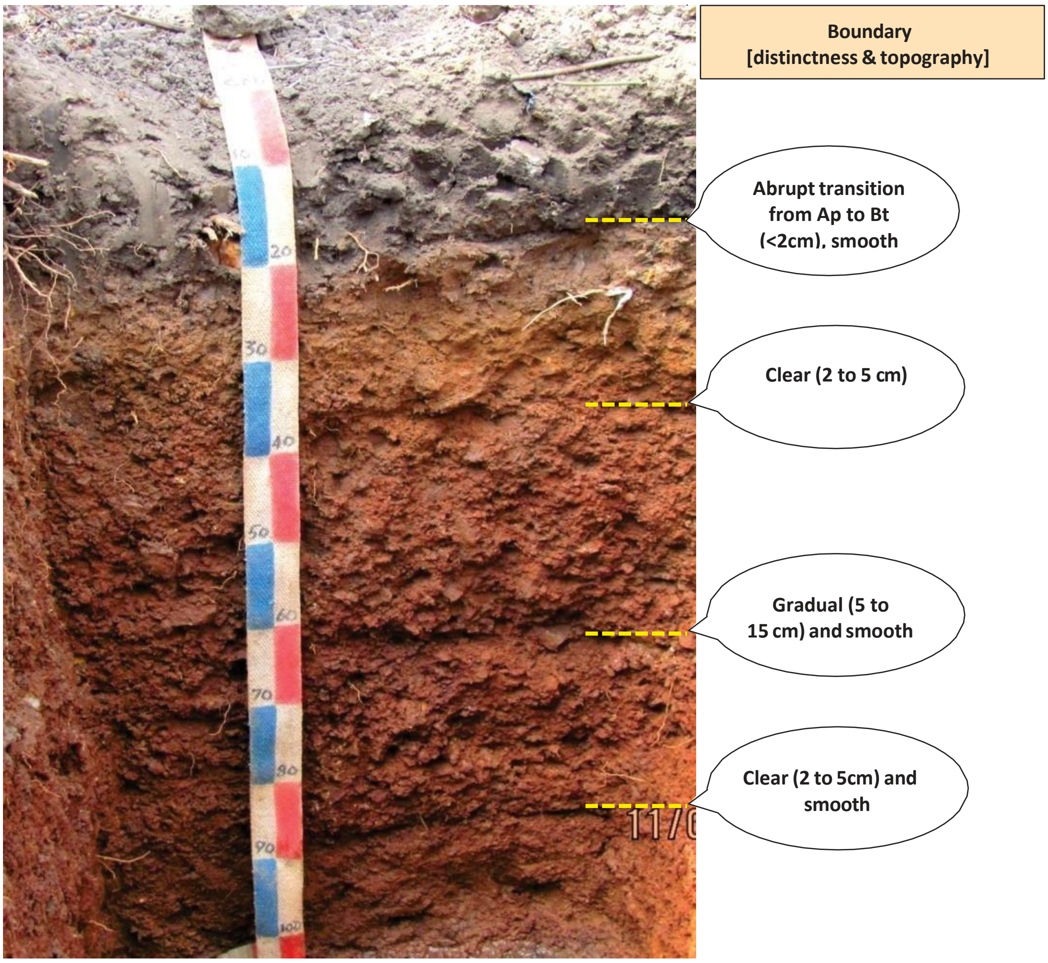
Smooth	The boundary is a plane one with few or no irregularities
Wavy	The boundary has undulations in which the width of undulation is more than the depth
Irregular	Similar to wavy in which the depth of undulation is more than the width
Broken	Discontinuous horizons; discrete but intermingled, or irregular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

Rock fragments % by volume	*Modifier used for texture description*
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	Discolor 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)

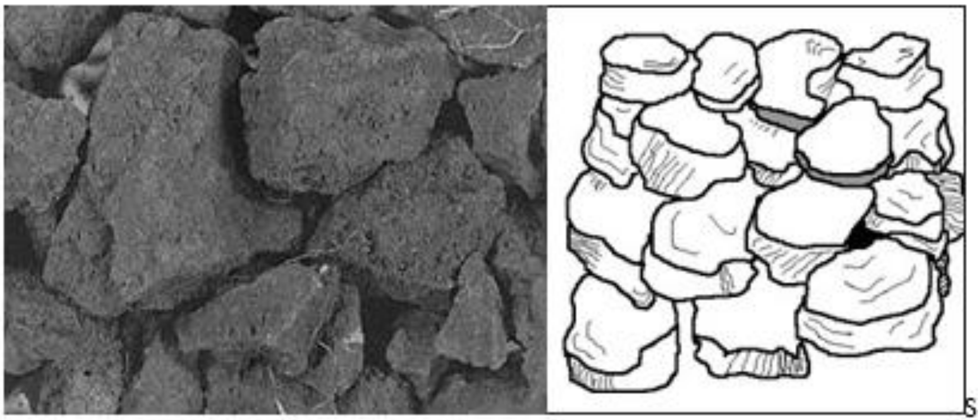
Platy	The units are flat and plate like and horizontally oriented
Prismatic	Vertically elongated units with flat tops, the individual units are bounded by flat to rounded vertical faces
Columnar	The units are like prisms and are bounded by flat or slightly rounded vertical faces and the top of columns 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.

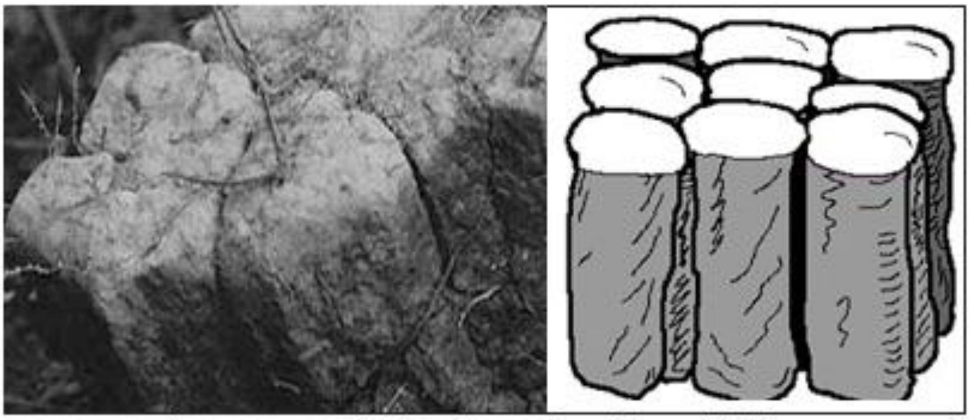
Size classes	*Grannular, Platy (mm)*	*Prismatic & Columnar (mm)*	*Blocky (mm)*
Very fine	< 1	< 10	< 5
Fine	1-2	10-20	5-10
Medium	2-5	20-50	10-20
Coarse	5-10	50-100	20-50
Very Coarse	> 10	> 100	> 50

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

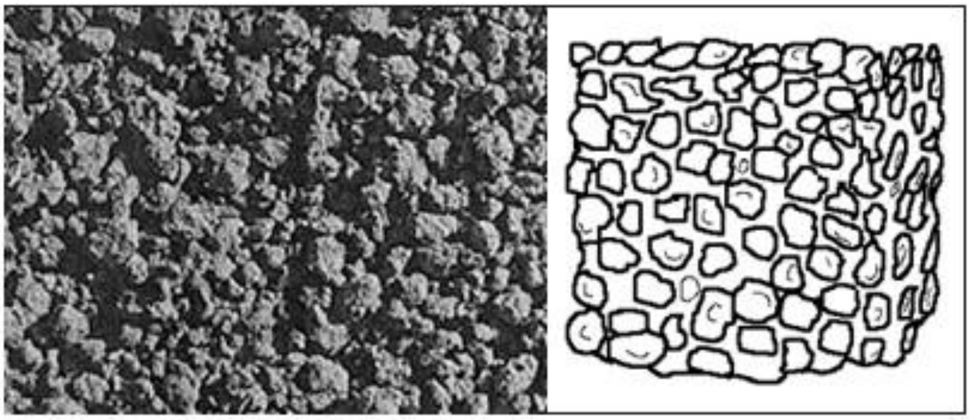
Structureless (0)	No discrete units observable in place or in hand sample
Weak (1)	Units are barely observable in place or in a hand sample
Moderate (2)	Units well-formed and evident in place or in a hand sample
Strong (3)	Units are distinct in place (undisturbed soil) and separate cleanly when disturbed



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 a redder 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

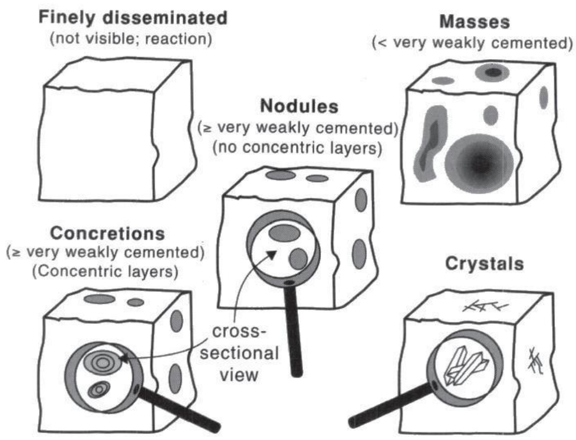
Concentrations - Concentrations are formed by accumulation of material during soil formation due to dissolution, precipitation, oxidation, and reduction and physical and/or biological removal, transport, and accrual. Types of concentrations include

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 developed due to drying of soil mass associated with clayey soils. They are mostly pronounced in high shrink-swell soils. Relative frequency (estimated average number per m^2) and depth are usually recorded.

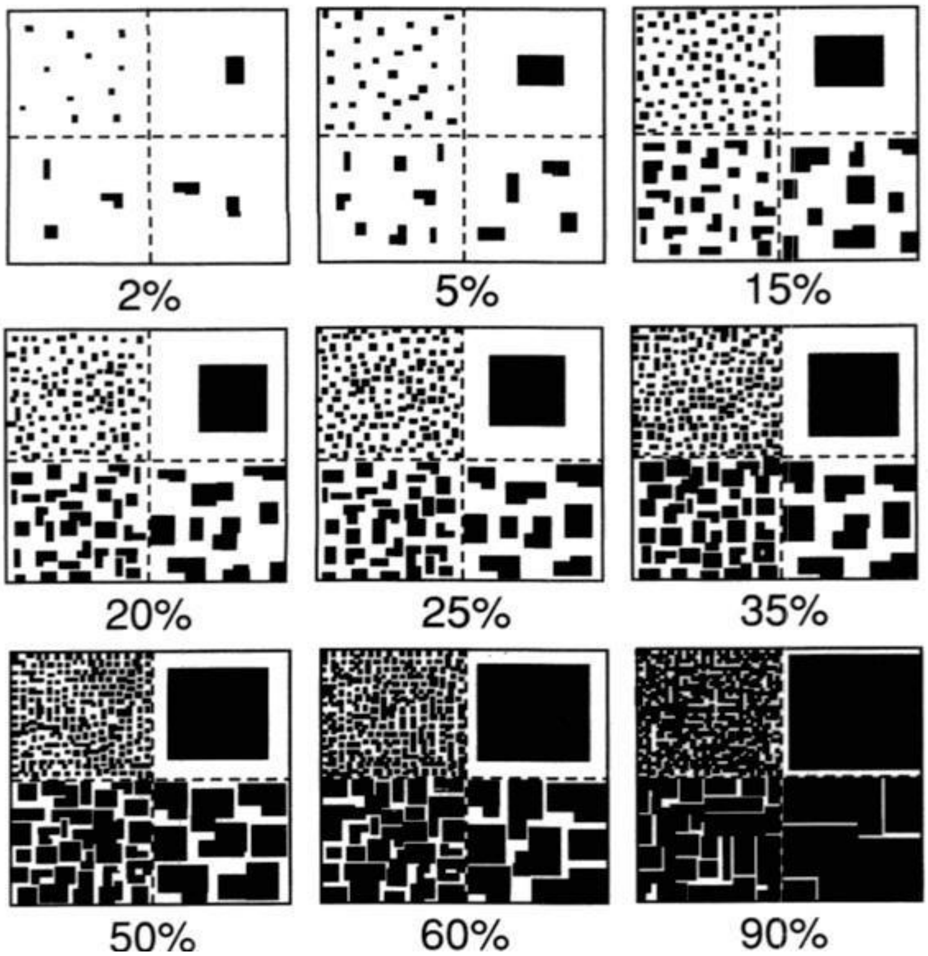
Soil crusts - A soil crust is a thin (e.g. <1 cm up to 10 cm thick) surface layer of soil particles bound together by living organisms and / or by minerals into a horizontal mat or small polygonal plates. Soil crusts form at the soil surface and have different physical and /or chemical characteristics 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 :

	Observation Method:						Auger				Minipit			Roadcut
	Depth (cm)	Horizon	Bnd [1] D T	Diag. Hori.	Matrix Colour Dry	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.

Soil series and Soil Phases

Soil series is the lowest taxonomic unit. It includes soils formed on similar parent material exhibiting same sequence of horizons. Soils of same series are further mapped as phases of soil series based on variation in surface texture, gravelliness, erosion, and slope.

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.

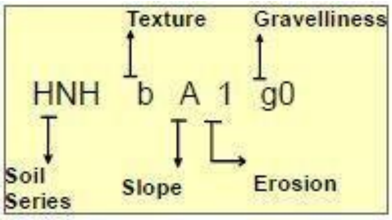
Data products of LRI atlas

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.
   - **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).
   - **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:**
   - **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.
   - **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 serves (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.

Soil-Site Characteristics Criteria

Soil Depth Classes		Soil Gravelliness
<25 cm	Very shallow	g0 - Non gravelly (<15 %)
25-50 cm	Shallow	g1 - Gravelly (15-35 %)
50-75 cm	Moderately shallow	g2 - Very gravelly (35-60 %)
75-100 cm	Moderately deep	g3 - Extremely gravelly (60-80 %)
100-150 cm	Deep	g4 - Considered as part of the topsoil
>150 cm	Very deep	

Soil Texture	Erosion	Soil Slope
a - Sandy	e0 - Nil	A- Nearly level (0-1%)
b – Loamy sand	e1 - Slight	B- Very gently sloping (1-3%)
c – Sandy loam	e2 - Moderate	C- Gently sloping (3-5%)
d – Loam	e3 - Severe	D- Moderately sloping (5-10%)
e - Silt loam	e4 - Very severe	E- Strongly sloping (10-15%)
f - Clay loam		F- Very Strongly sloping (15-25%)
g - Silty clay loam		G- Moderately Steeply Sloping (25-33%)
h – Sandy clay loam		H- Steeply Sloping (33 - 50%)
i – Sandy clay		I- Very Steeply Sloping (>50%)
k - Silty clay		
m – Clay		

Rocks	
No to very few rocks (<2%)	R0
Fairly rocky (2-10%)	R1
Rocky (10-25%)	R2
Very rocky (25-50 %)	R3
Extremely rocky (50-90 %)	R4
Rock out crops (>90%)	R5

Stoniness		
Code	*Area covered*	*Class*
St1	0.01 to 0.1%	Strong
St2	0.1 to 3%	Very strong
St3	3 to 15%	Extremely strong
St4	15 to 50%	Rubbly
St5	50 to 90%	Very rubbly
St6	>90%	Stone

Annexure-2

An Overview 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 MWS 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

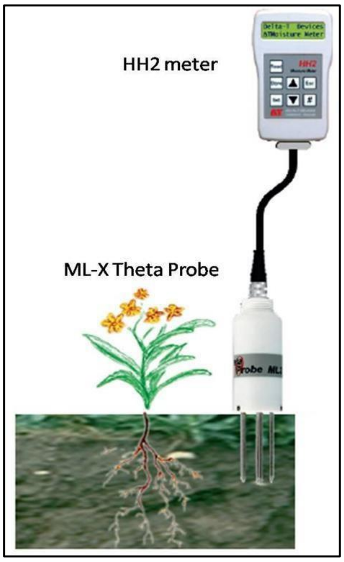
The two methods for measuring the surface soil moisture are detailed in the following two subsections:

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

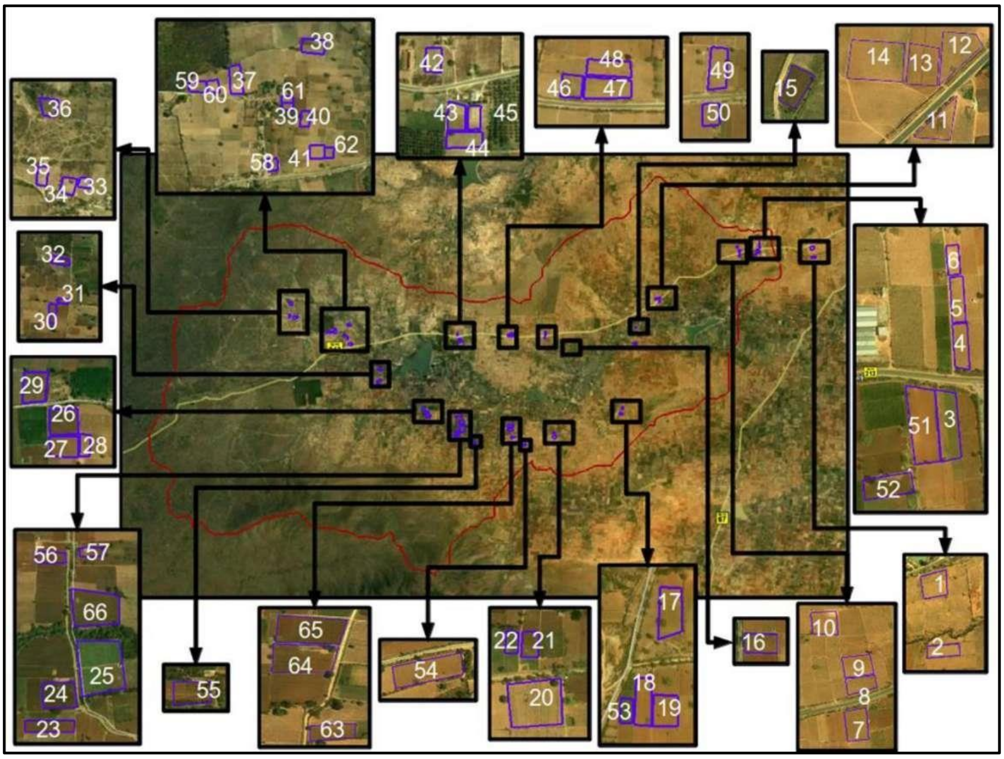
Theta Probe measures soil parameters by applying a 100 MHz signal via a specially designed transmission line whose impedance is changed as the impedance of the soil changes. This impedance has two components; the apparent dielectric constant and the ionic conductivity. The signal frequency has been chosen 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

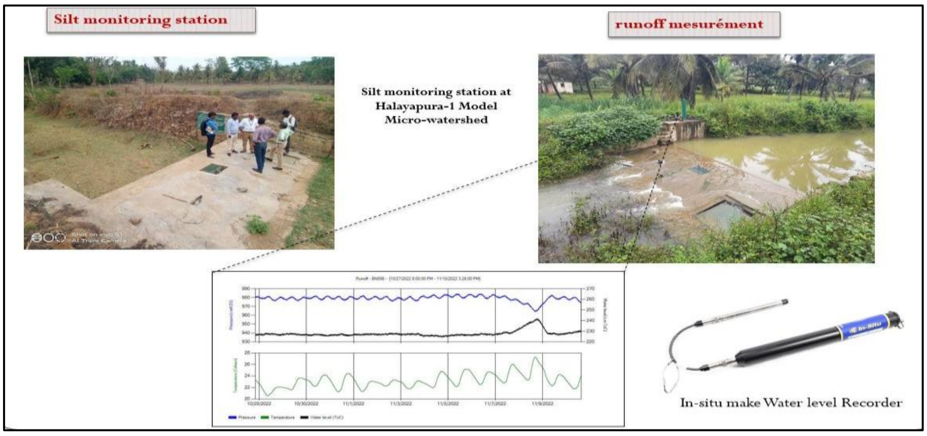
The Hydra Probe sensor uses the Coaxial Impedance Dielectric Reflectometry method in soil moisture measurement. The Coaxial Impedance Dielectric Reflectometry method of soil moisture measurement employs an oscillator to generate an electromagnetic signal that is propagated through the unit (usually by 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

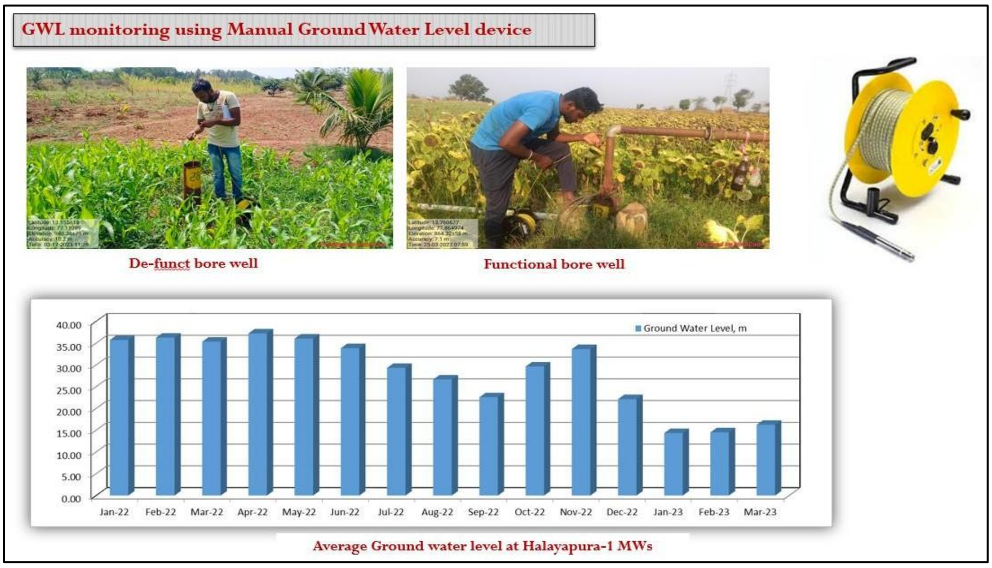
The detailed monitoring surface runoff at the outlet of the micro watershed will be measured using a CTD diver and analysis will be done by using check dam weir formulae.
An in-situ water level recorder is a device designed to measure and record changes in water level within natural water bodies such 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

#	*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 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 radiometers	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, behaviour 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

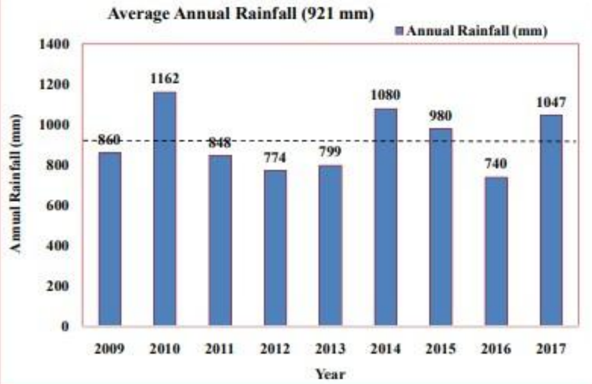
The first task is to compile a catchment-averaged time series by combining the available rainfall data from several sources with lowest possible frequency and longest possible record. Depending upon data availability and context of the project objectives multiple such rainfall series may be prepared. 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

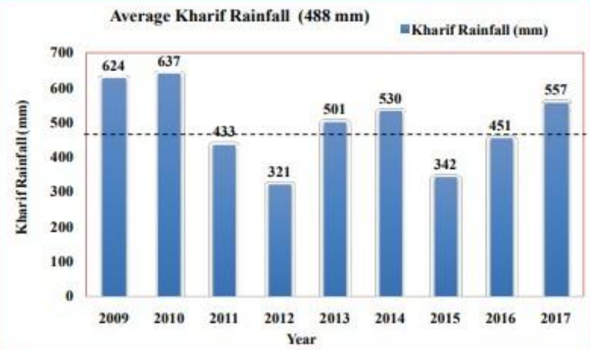
RAINFALL INDEX



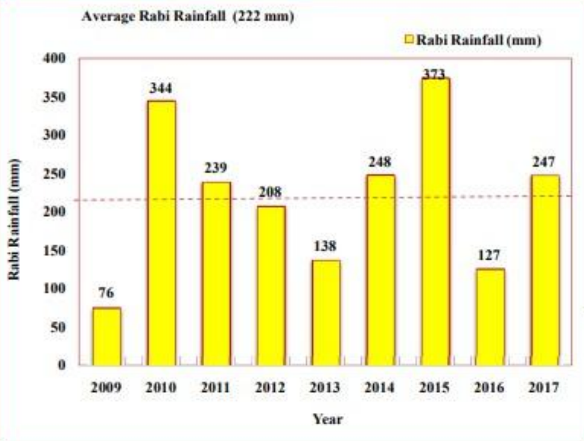
The average annual rainfall observed from the Uradigere rain gauge station found near to Maidalakere SWS in Tumkur taluk was 921.0 mm. 2009 (6.6%), 2011 (7.9%), 2012 (16.0%), 2013 (13.3%) and 2016 (19.7%) were recorded as deficient years during the period 2009-2017.

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.

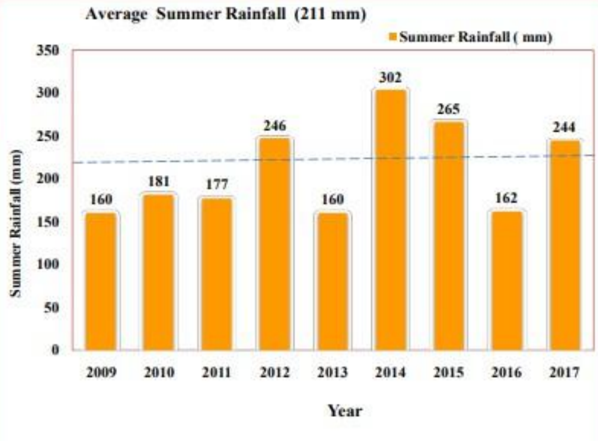


RAINFALL INDEX



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

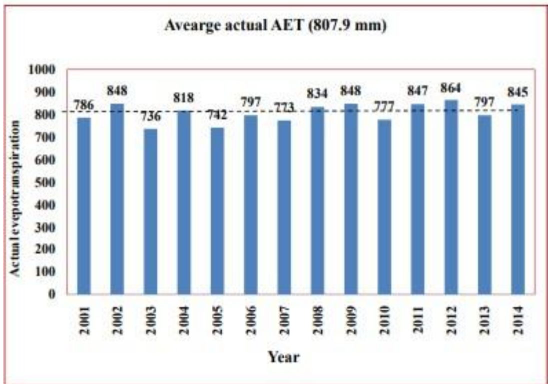
Evapotranspiration and Associated Indices

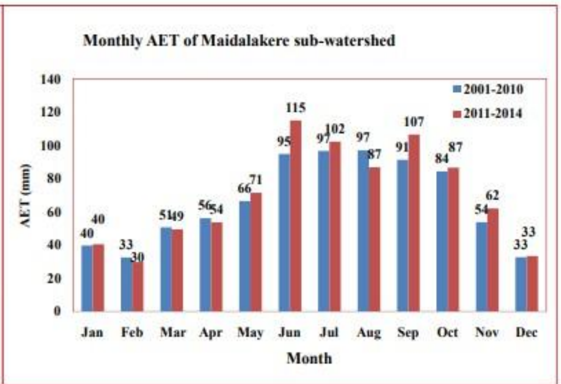
Several types of indices are developed using available time series of Actual Evapotranspiration (AET). Generally, AET time series are compiled at daily time step and with catchment-averaged values. Using this time series data following summary time series are prepared and presented in graphical & tabular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

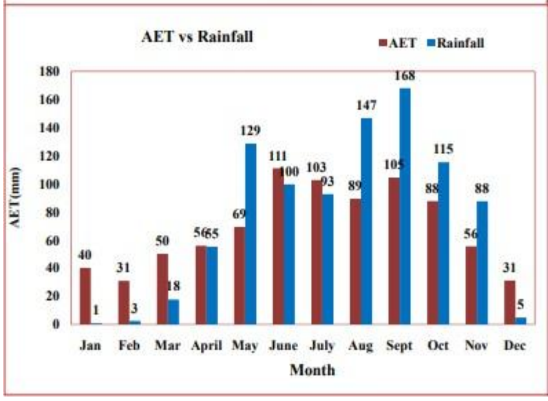
Summary Time Series Plots

- 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.

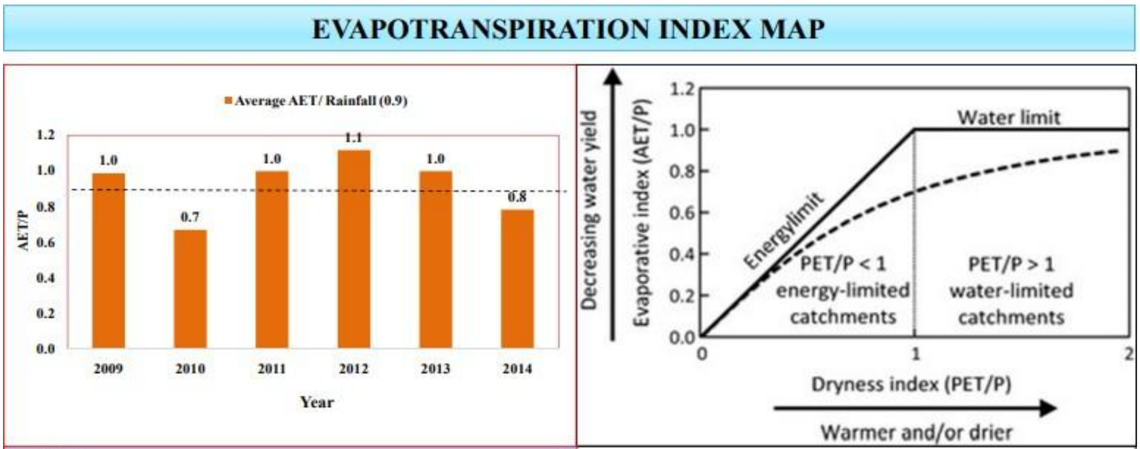
EVAPOTRANSPIRATION

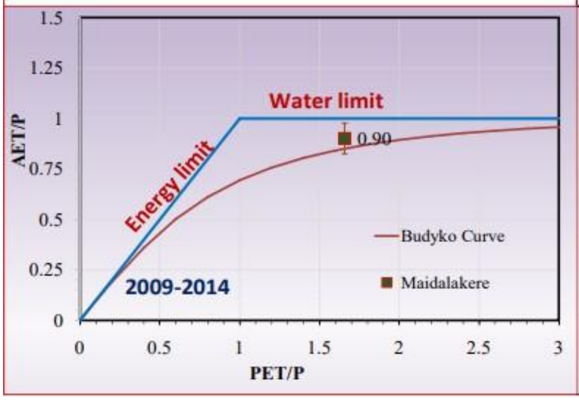






During 2009 to 2014 the average annual AET (829.4 mm) is lower than the average rainfall (920.4 mm). Hence runoff can occur in the watershed. It indicates to change the cropping pattern to maintain AET. During *Kharif*, average rainfall and AET found to be 507.3 mm and 407.7 mm respectively, whereas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





The AET/P suggests severe water deficit during 2010 and 2014. The location value (0.9) on budyko curve shows watershed comes under sustainable condition. The suggested crops would be Maize, Ragi, Arecanut, Coconut, Sorghum and Castor.

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

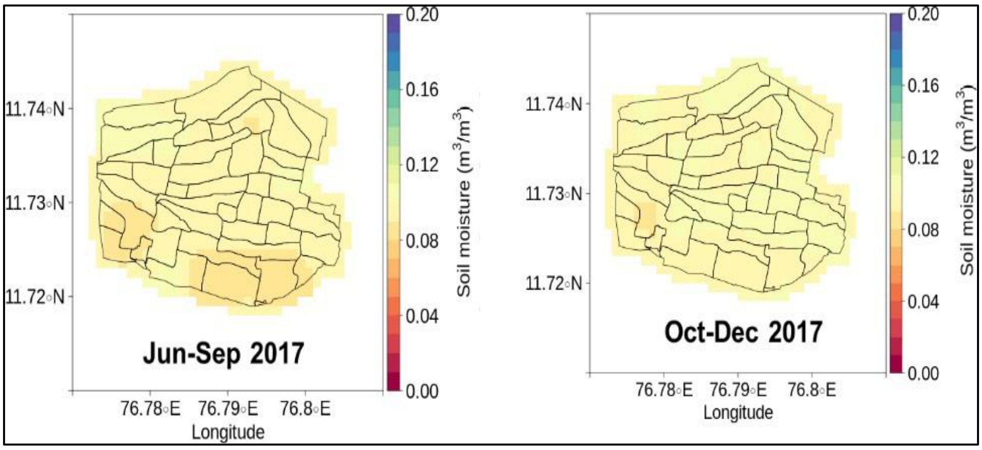
Surface soil moisture maps over a given micro-watershed for Kharif and Rabi Seasons is given below. These maps are prepared using satellite remote sensing products. The following facts are to be noted:

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

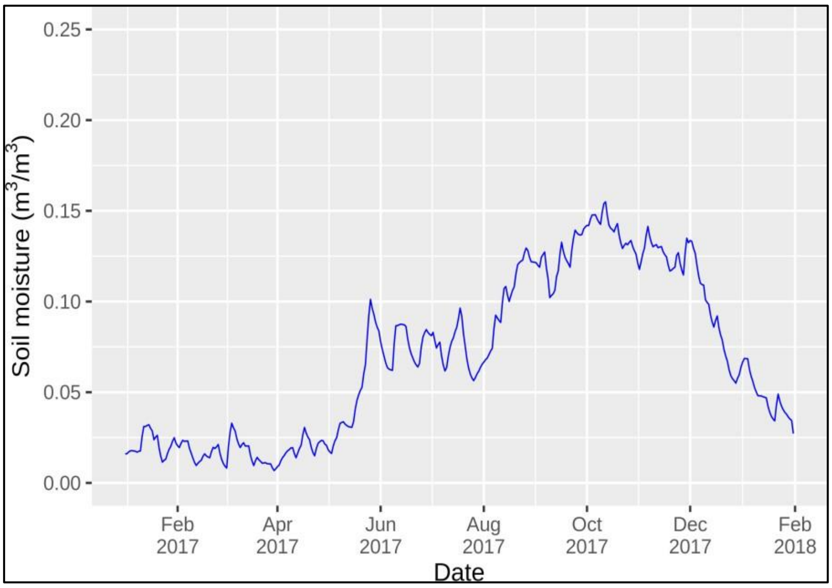
Time Series Plots

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

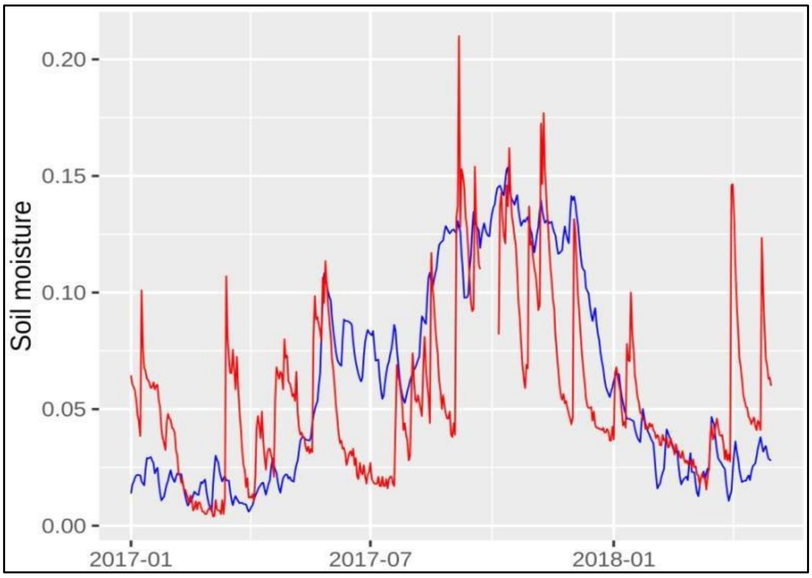


Satellite-derived Surface Soil Moisture Maps over a Study Watershed for Kharif and Rabi Seasons

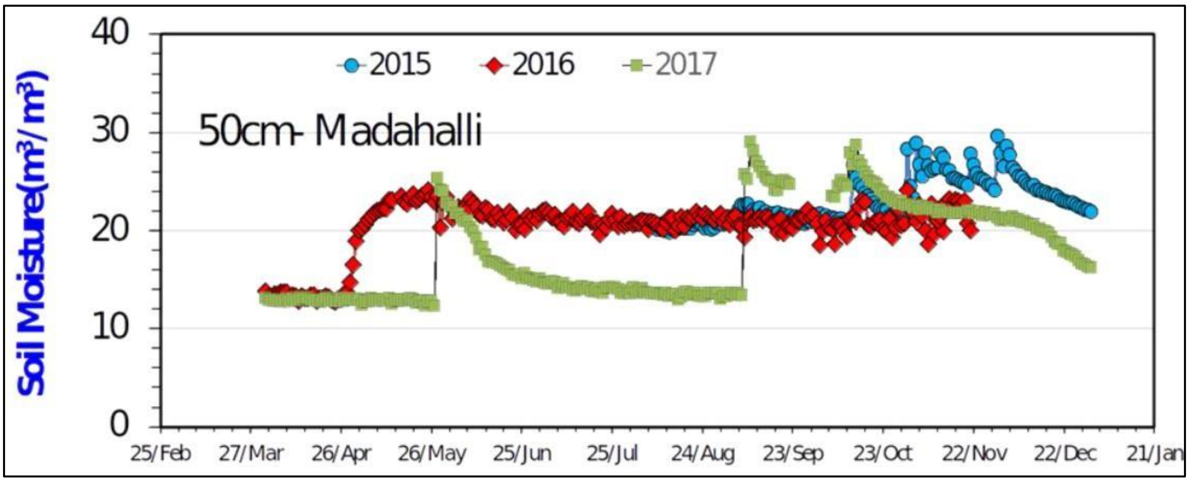


Time Series Plot of Surface Soil Moisture over a Study Watershed

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.



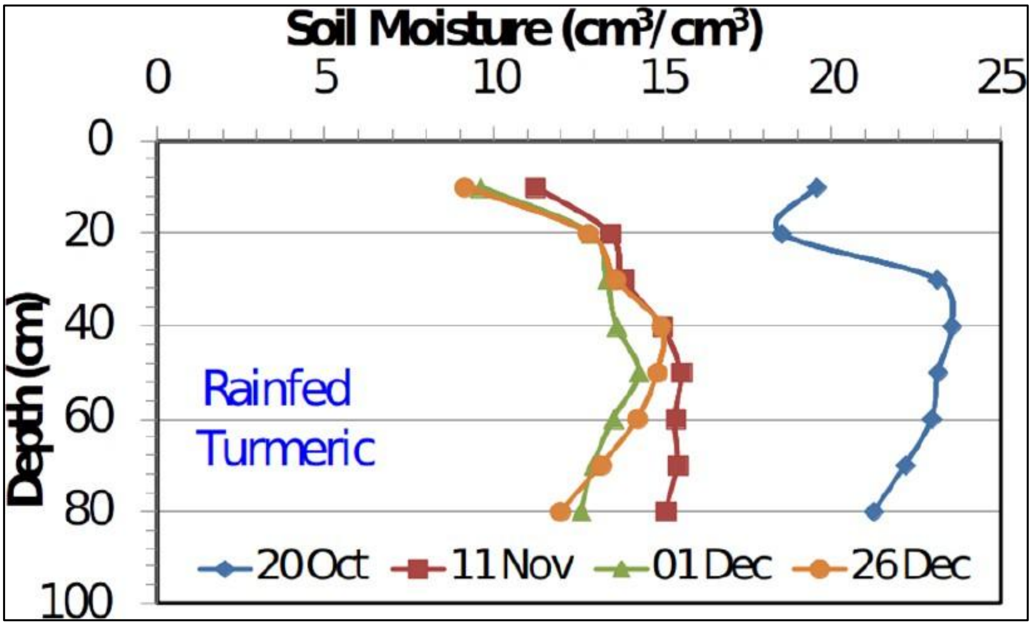
Comparison of Satellite-based and Manual Observation-based Surface Soil Moisture Data



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:

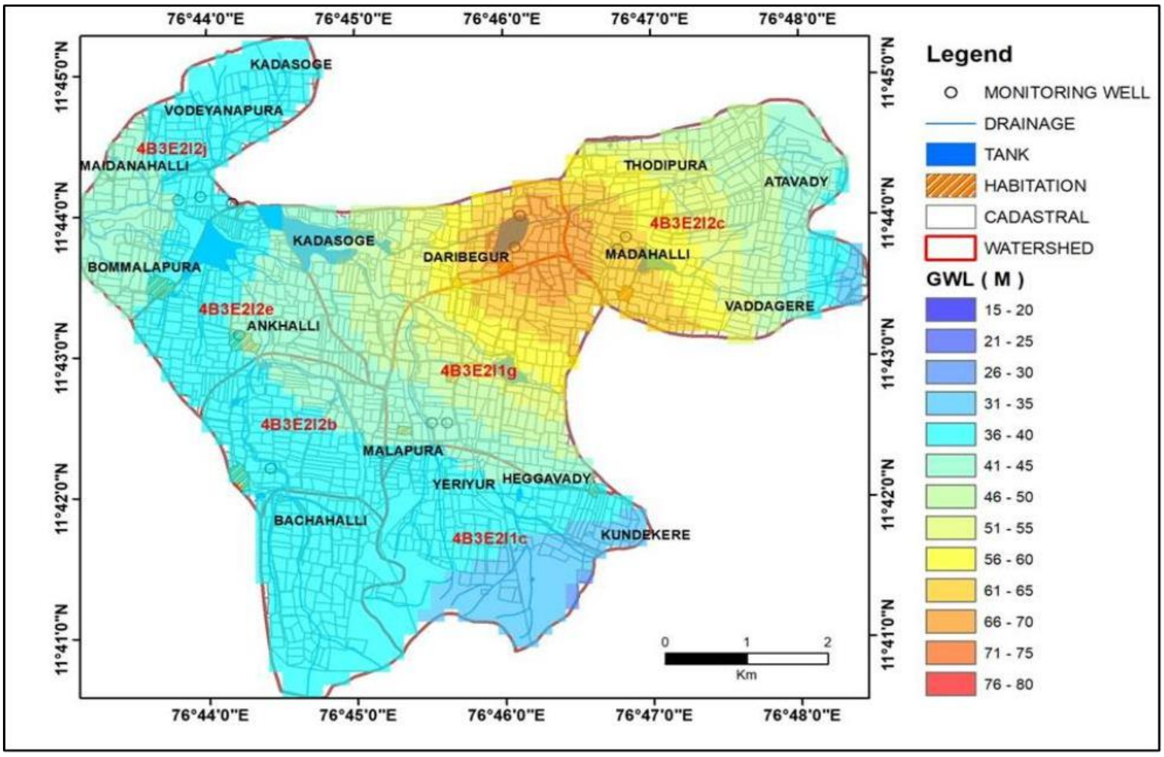
- Inverse Distance Weighted (IDW) Approach: In IDW, the value at an unknown point is estimated by giving weights proportional to the inverse of the distance (between the known locations and the unknown location) raised to the power value p. Typically, a value of p=2 is used; however, care should be taken that it should not result in spurious behaviour 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

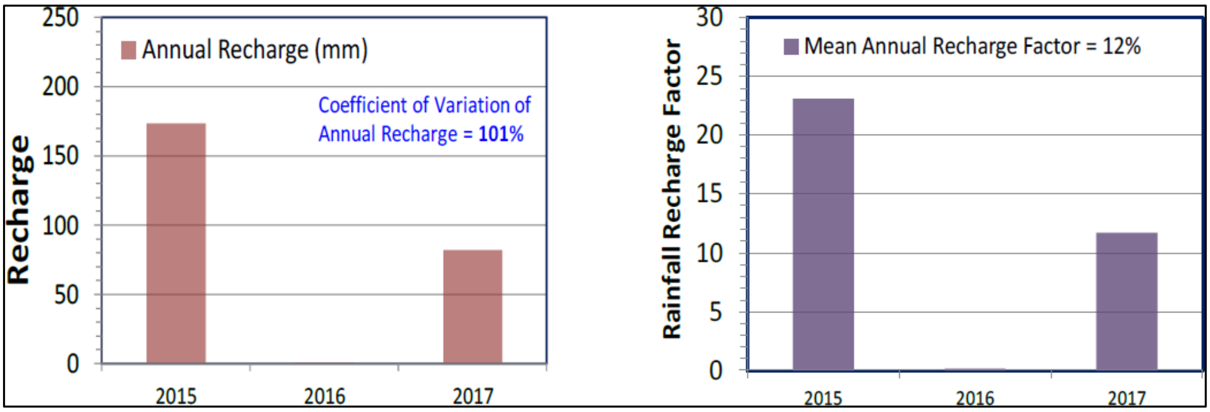
Figure shown below depicts Annual Recharge and Mean Annual Recharge Factor computed for Madahalli Micro-Watershed.

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.

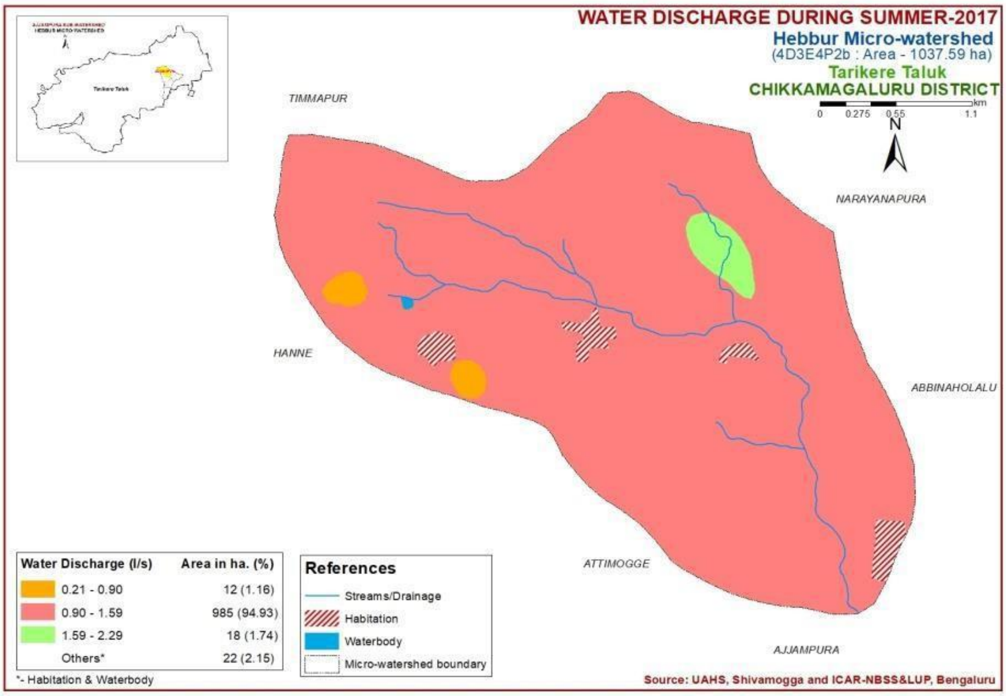


Spatially interpolated map of DGW values over the Madahalli micro-watershed

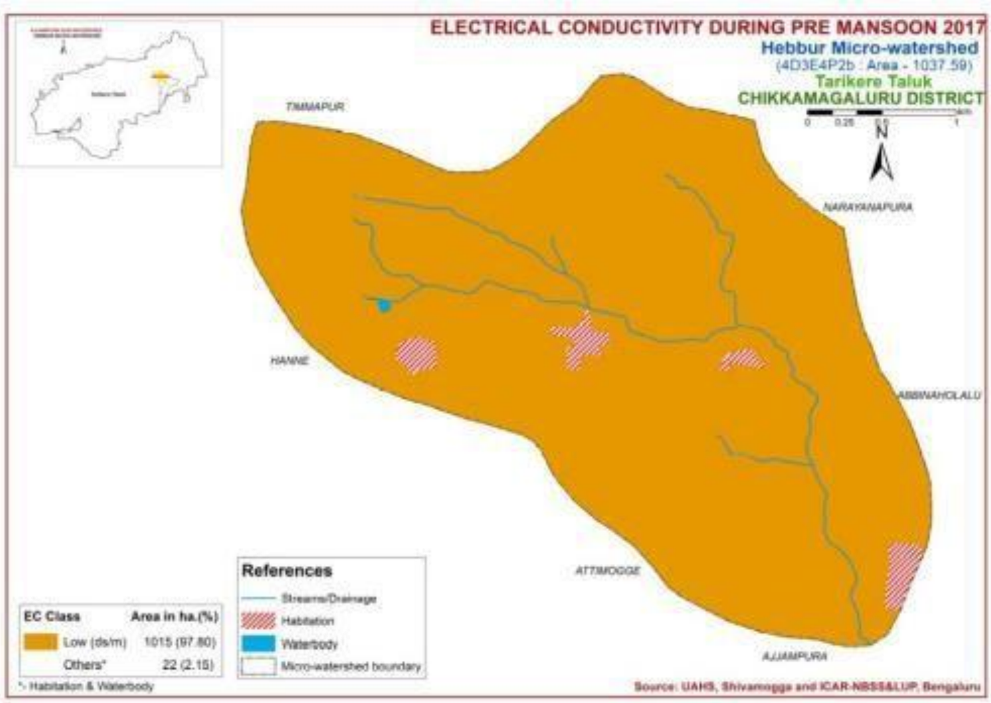


Sample Plot showing Annual Recharge and Mean Annual Recharge Factor for Madahalli Micro-Watershed

Water Quality Maps - 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

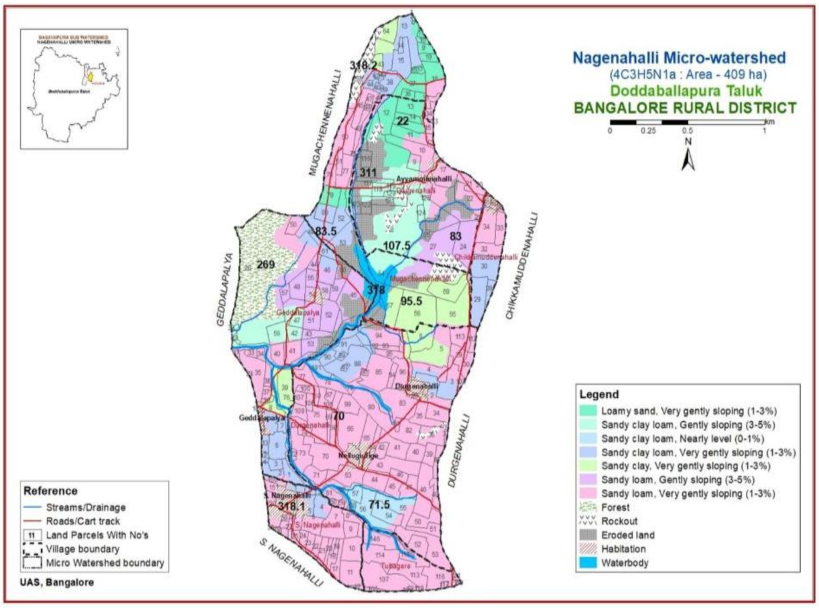


Sample Plot showing Spatially Interpolated Electrical Conductivity Values for the Hebbur Micro-Watershed

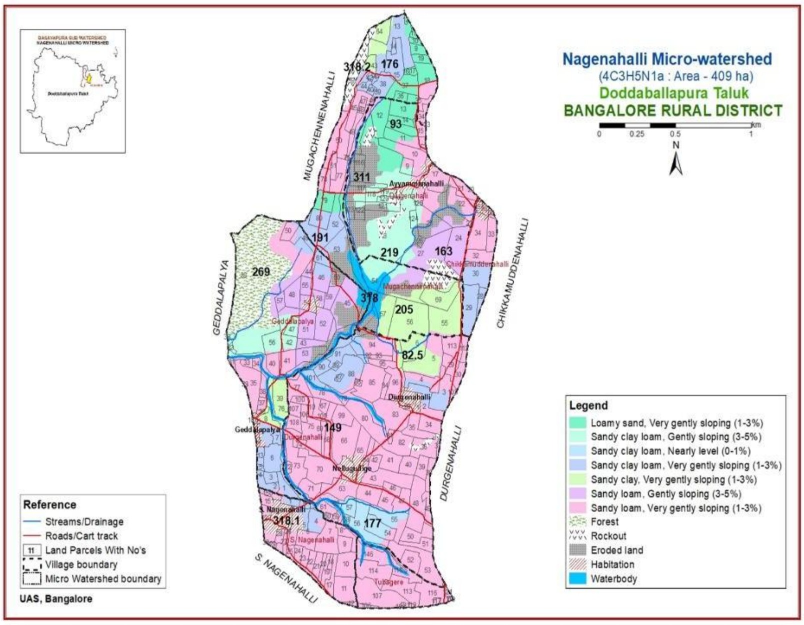
Runoff Potential

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

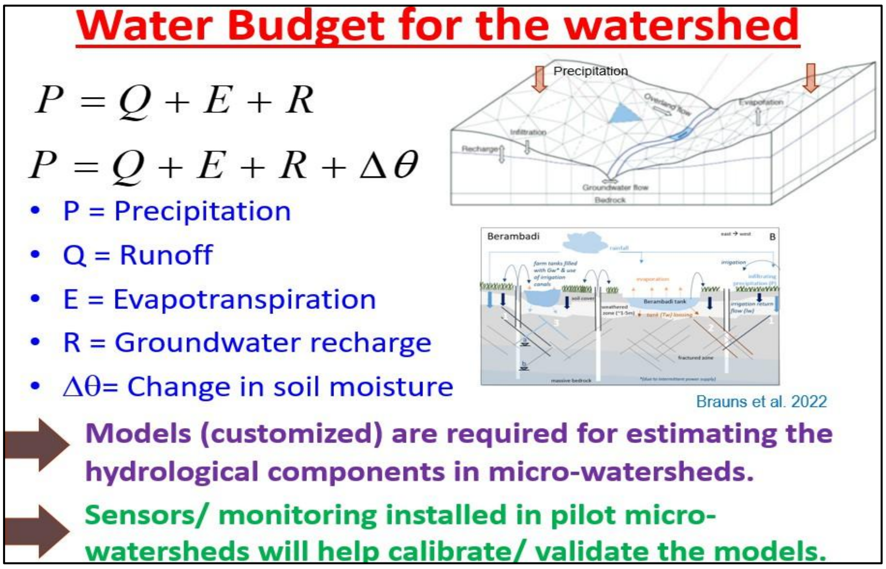
The concept of Water Budgeting aims to use water judiciously for people, agriculture and livestock with a view to optimizing benefits in the context of climate variability, erratic rainfall and drought. Water budget studies consider the volumes of water within the various reservoirs of the hydrologic 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,

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

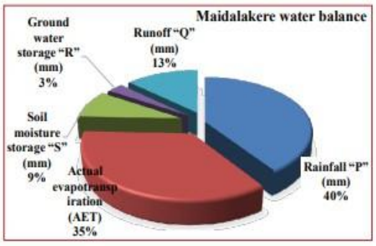
where all the variables are expressed in mm unit. Inserting following known values, P=501, Q=44, AET=540, R=85 into this equation, we get, S=−168 mm. This implies that over the considered time period, precipitation was lower than evapotranspiration. This negative balance when combined with runoff and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

Annexure-3

Decision Support System Criteria and Support Requirements

DSS-1: Soil and Water Conservation Treatments

The sustainability of soil and water resources, particularly of the vast rainfed tracts of the state, depends on the effectiveness of the conservation measures planned and executed at the field level. The availability of cadastral level soil, water, weather, hydrology, land use, cropping pattern etc., generated through LRI helps to design appropriate conservation measures required at the field/watershed level. The conservation plan is prepared by matching the site-specific constraints and potentials of the area with different type of conservation measures and selecting the appropriate one based on the criteria available. The criteria for different type of structures is generated by various agencies (SAU's, WDD, ICAR, ICRISAT and others) over a period through field trials at different locations. The development of DSS for Soil and Water Conservation based on the above criteria enables the user/department to generate the conservation map of any watershed including the budget requirement and inter bund conservation practices to be followed in a fraction of a time.

The major interventions followed for soil and water conservation at the field level are bunding, terracing and trenching. The criteria for selecting the type of treatment to be used depends on the amount of rainfall, type of landform, soils, land use etc. The treatment for arable lands will be different from the non-arable lands. Similarly, the treatment for black soils will be different than the red and lateritic soils observed in the state. Accordingly, the criteria and their range or limits to be used for arable-black soils, arable red and lateritic soils, and non-arable areas occurring in the watershed area is finalized and the same is presented below.

Steps involved in conservation planning

Steps	*Description*
1	Read Soil phase wise soil and land characteristics data
2	Select treatment for land characteristics based on decision rules
3	Select or vertical and horizontal interval based on decision rules
4	Select cross-section of structure based on the decision rules
5	Decide volume of earth work if any, using cross section of structure - horizontal interval - Contour Trench/ Staggered Trench based on decision rules
6	Estimate cost of conservation structure based on decision rules

Criteria for deciding conservation treatment for arable land-black soil

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
1	<1	<50	Loam	Clay	<35%	<750	Contour bunding/TCB[1]
2	<1	<50	Loam	Clay	<35%	750-950	Graded bund
3	1 to 3	<50	Loam	Clay	<35%	<750	Contour bunding/TCB
4	1 to 3	<50	Loam	Clay	<35%	750-950	Graded bund
5	3 to 5	<50	Loam	Clay	<35%	<750	Contour bunding/TCB
6	3 to 5	<50	Loam	Clay	<35%	750-950	Graded bund
7	5 to 10	<50	Loam	Clay	<35%	<750	Graded bund
8	5 to 10	<50	Loam	Clay	<35%	750-950	Graded bund
9	<1	50-100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
10	<1	50-100	Loam	Clay	<35%	750-950	Graded bund
11	1 to 3	50-100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
12	1 to 3	50-100	Loam	Clay	<35%	750-950	Graded bund
13	3 to 5	50-100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
14	3 to 5	50-100	Loam	Clay	<35%	750-950	Graded bund
15	5 to 10	50-100	Loam	Clay	<35%	<750	Graded bund
16	5 to 10	50-100	Loam	Clay	<35%	750-950	Graded bund
17	<1	>100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
18	<1	>100	Loam	Clay	<35%	750-950	Graded bund
19	1 to 3	>100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
20	1 to 3	>100	Loam	Clay	<35%	750-950	Graded bund
21	3 to 5	>100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
22	3 to 5	>100	Loam	Clay	<35%	750-950	Graded bund
23	5 to 10	>100	Loam	Clay	<35%	<750	Graded bund
24	5 to 10	>100	Loam	Clay	<35%	750-950	Graded bund
25	<1	<50	Clay	Clay	<35%	<750	Graded bund
26	<1	<50	Clay	Clay	<35%	750-950	Graded bund
27	1 to 3	<50	Clay	Clay	<35%	<750	Graded bund
28	1 to 3	<50	Clay	Clay	<35%	750-950	Graded bund
29	3 to 5	<50	Clay	Clay	<35%	<750	Graded bund
30	3 to 5	<50	Clay	Clay	<35%	750-950	Graded bund
31	5 to 10	<50	Clay	Clay	<35%	<750	Graded bund
32	5 to 10	<50	Clay	Clay	<35%	750-950	Graded bund
33	<1	50 to 100	Clay	Clay	<35%	<750	Graded bund
34	<1	50 to 100	Clay	Clay	<35%	750-950	Graded bund
35	1 to 3	50 to 100	Clay	Clay	<35%	<750	Graded bund
36	1 to 3	50 to 100	Clay	Clay	<35%	750-950	Graded bund
37	3 to 5	50 to 100	Clay	Clay	<35%	<750	Graded bund
38	3 to 5	50 to 100	Clay	Clay	<35%	750-950	Graded bund
39	5 to 10	50 to 100	Clay	Clay	<35%	<750	Graded bund
40	5 to 10	50 to 100	Clay	Clay	<35%	750-950	Graded bund
41	<1	>100	Clay	Clay	<35%	<750	Graded bund
42	<1	>100	Clay	Clay	<35%	750-950	Graded bund
43	1 to 3	>100	Clay	Clay	<35%	<750	Graded bund
44	1 to 3	>100	Clay	Clay	<35%	750-950	Graded bund

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
45	3 to 5	>100	Clay	Clay	<35%	<750	Graded bund
46	3 to 5	>100	Clay	Clay	<35%	750-950	Graded bund
47	5 to 10	>100	Clay	Clay	<35%	<750	Graded bund
48	5 to 10	>100	Clay	Clay	<35%	750-950	Graded bund
49	<1	<50	Loam	Clay	>35%	<750	Contour bund/TCB
50	<1	<50	Loam	Clay	>35%	750-950	Contour bund/TCB
51	1 to 3	<50	Loam	Clay	>35%	<750	Contour bund/TCB
52	1 to 3	<50	Loam	Clay	>35%	750-950	Contour bund/TCB
53	3 to 5	<50	Loam	Clay	>35%	<750	Contour bund/TCB
54	3 to 5	<50	Loam	Clay	>35%	750-950	Contour bund/TCB
55	5 to 10	<50	Loam	Clay	>35%	<750	Contour bund/TCB
56	5 to 10	<50	Loam	Clay	>35%	750-950	Contour bund/TCB
57	<1	50-100	Loam	Clay	>35%	<750	Contour bund[2]/TCB
58	<1	50-100	Loam	Clay	>35%	750-950	Contour bund[2]/TCB
59	1 to 3	50-100	Loam	Clay	>35%	<750	Contour bund[2]/TCB
60	1 to 3	50-100	Loam	Clay	>35%	750-950	Contour bund[2]/TCB
61	3 to 5	50-100	Loam	Clay	>35%	<750	Contour bund[2]/TCB
62	3 to 5	50-100	Loam	Clay	>35%	750-950	Contour bund[2]/TCB
63	5 to 10	50-100	Loam	Clay	>35%	<750	Contour bund[2]/TCB
64	5 to 10	50-100	Loam	Clay	>35%	750-950	Contour bund[2]/TCB
65	<1	>100	Loam	Clay	>35%	<750	Contour bund[2]/TCB
66	<1	>100	Loam	Clay	>35%	750-950	Contour bund[2]/TCB
67	1 to 3	>100	Loam	Clay	>35%	<750	Contour bund[2]/TCB
68	1 to 3	>100	Loam	Clay	>35%	750-950	Contour bund[2]/TCB
69	3 to 5	>100	Loam	Clay	>35%	<750	Contour bund[2]/TCB
70	3 to 5	>100	Loam	Clay	>35%	750-950	Contour bund[2]/TCB
71	5 to 10	>100	Loam	Clay	>35%	<750	Contour bund[2]/TCB
72	5 to 10	>100	Loam	Clay	>35%	750-950	Contour bund[2]/TCB
73	<1	<50	Clay	Clay	>35%	<750	Contour bund/TCB
74	<1	<50	Clay	Clay	>35%	750-950	Contour bund/TCB
75	1 to 3	<50	Clay	Clay	>35%	<750	Contour bund/TCB
76	1 to 3	<50	Clay	Clay	>35%	750-950	Contour bund/TCB
77	3 to 5	<50	Clay	Clay	>35%	<750	Contour bund/TCB
78	3 to 5	<50	Clay	Clay	>35%	750-950	Contour bund/TCB
79	5 to 10	<50	Clay	Clay	>35%	<750	Contour bund/TCB
80	5 to 10	<50	Clay	Clay	>35%	750-950	Contour bund/TCB
81	<1	50 to 100	Clay	Clay	>35%	<750	Contour bund[2]/TCB
82	<1	50 to 100	Clay	Clay	>35%	750-950	Contour bund[2]/TCB
83	1 to 3	50 to 100	Clay	Clay	>35%	<750	Contour bund[2]/TCB
84	1 to 3	50 to 100	Clay	Clay	>35%	750-950	Contour bund[2]/TCB
85	3 to 5	50 to 100	Clay	Clay	>35%	<750	Contour bund/[2]TCB

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
86	3 to 5	50 to 100	Clay	Clay	>35%	750-950	Contour bund[2]/TCB
87	5 to 10	50 to 100	Clay	Clay	>35%	<750	Contour bund[2]/TCB
88	5 to 10	50 to 100	Clay	Clay	>35%	750-950	Contour bund[2]/TCB
89	<1	>100	Clay	Clay	>35%	<750	Graded bund
90	<1	>100	Clay	Clay	>35%	750-950	Graded bund
91	1 to 3	>100	Clay	Clay	>35%	<750	Graded bund
92	1 to 3	>100	Clay	Clay	>35%	750-950	Graded bund
93	3 to 5	>100	Clay	Clay	>35%	<750	Graded bund
94	3 to 5	>100	Clay	Clay	>35%	750-950	Graded bund
95	5 to 10	>100	Clay	Clay	>35%	<750	Graded bund
96	5 to 10	>100	Clay	Clay	>35%	750-950	Graded bund
97	<1	<50	Loam	Loam	<35%	<750	Contour bund/TCB
98	<1	<50	Loam	Loam	<35%	750-950	Graded bund
99	1 to 3	<50	Loam	Loam	<35%	<750	Contour bunding/TCB
100	1 to 3	<50	Loam	Loam	<35%	750-950	Graded bund
101	3 to 5	<50	Loam	Loam	<35%	<750	Contour bunding/TCB
102	3 to 5	<50	Loam	Loam	<35%	750-950	Graded bund
103	5 to 10	<50	Loam	Loam	<35%	<750	Graded bund
104	5 to 10	<50	Loam	Loam	<35%	750-950	Graded bund
105	<1	50-100	Loam	Loam	<35%	<750	Contour bunding[2]/TCB
106	<1	50-100	Loam	Loam	<35%	750-950	Graded bund
107	1 to 3	50-100	Loam	Loam	<35%	<750	Contour bunding[2]/TCB
108	1 to 3	50-100	Loam	Loam	<35%	750-950	Graded bund
109	3 to 5	50-100	Loam	Loam	<35%	<750	Contour bunding[2]/TCB
110	3 to 5	50-100	Loam	Loam	<35%	750-950	Graded bund
111	5 to 10	50-100	Loam	Loam	<35%	<750	Graded bund
112	5 to 10	50-100	Loam	Loam	<35%	750-950	Graded bund
113	<1	>100	Loam	Loam	<35%	<750	Contour bunding[2]/TCB
114	<1	>100	Loam	Loam	<35%	750-950	Graded bund
115	1 to 3	>100	Loam	Loam	<35%	<750	Contour bunding[2]/TCB
116	1 to 3	>100	Loam	Loam	<35%	750-950	Graded bund
117	3 to 5	>100	Loam	Loam	<35%	<750	Contour bunding[2]/TCB
118	3 to 5	>100	Loam	Loam	<35%	750-950	Graded bund
119	5 to 10	>100	Loam	Loam	<35%	<750	Graded bund
120	5 to 10	>100	Loam	Loam	<35%	750-950	Graded bund
121	<1	<50	Clay	Loam	<35%	<750	Graded bund
122	<1	<50	Clay	Loam	<35%	750-950	Graded bund
123	1 to 3	<50	Clay	Loam	<35%	<750	Graded bund
124	1 to 3	<50	Clay	Loam	<35%	750-950	Graded bund
125	3 to 5	<50	Clay	Loam	<35%	<750	Graded bund
126	3 to 5	<50	Clay	Loam	<35%	750-950	Graded bund
127	5 to 10	<50	Clay	Loam	<35%	<750	Graded bund
128	5 to 10	<50	Clay	Loam	<35%	750-950	Graded bund
129	<1	50 to 100	Clay	Loam	<35%	<750	Graded bund
130	<1	50 to 100	Clay	Loam	<35%	750-950	Graded bund

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
131	1 to 3	50 to 100	Clay	Loam	<35%	<750	Graded bund
132	1 to 3	50 to 100	Clay	Loam	<35%	750-950	Graded bund
133	3 to 5	50 to 100	Clay	Loam	<35%	<750	Graded bund
134	3 to 5	50 to 100	Clay	Loam	<35%	750-950	Graded bund
135	5 to 10	50 to 100	Clay	Loam	<35%	<750	Graded bund
136	5 to 10	50 to 100	Clay	Loam	<35%	750-950	Graded bund
137	<1	>100	Clay	Loam	<35%	<750	Graded bund
138	<1	>100	Clay	Loam	<35%	750-950	Graded bund
139	1 to 3	>100	Clay	Loam	<35%	<750	Graded bund
140	1 to 3	>100	Clay	Loam	<35%	750-950	Graded bund
141	3 to 5	>100	Clay	Loam	<35%	<750	Graded bund
142	3 to 5	>100	Clay	Loam	<35%	750-950	Graded bund
143	5 to 10	>100	Clay	Loam	<35%	<750	Graded bund
144	5 to 10	>100	Clay	Loam	<35%	750-950	Graded bund
145	<1	<50	Loam	Loam	>35%	<750	Contour bund/TCB
146	<1	<50	Loam	Loam	>35%	750-950	Contour bund/TCB
147	1 to 3	<50	Loam	Loam	>35%	<750	Contour bund/TCB
148	1 to 3	<50	Loam	Loam	>35%	750-950	Contour bund/TCB
149	3 to 5	<50	Loam	Loam	>35%	<750	Contour bund/TCB
150	3 to 5	<50	Loam	Loam	>35%	750-950	Contour bund/TCB
151	5 to 10	<50	Loam	Loam	>35%	<750	Contour bund/TCB
152	5 to 10	<50	Loam	Loam	>35%	750-950	Contour bund/TCB
153	<1	50-100	Loam	Loam	>35%	<750	Contour bund[2]/TCB
154	<1	50-100	Loam	Loam	>35%	750-950	Contour bund[2]/TCB
155	1 to 3	50-100	Loam	Loam	>35%	<750	Contour bund[2]/TCB
156	1 to 3	50-100	Loam	Loam	>35%	750-950	Contour bund[2]/TCB
157	3 to 5	50-100	Loam	Loam	>35%	<750	Contour bund[2]/TCB
158	3 to 5	50-100	Loam	Loam	>35%	750-950	Contour bund[2]/TCB
159	5 to 10	50-100	Loam	Loam	>35%	<750	Contour bund/TCB
160	5 to 10	50-100	Loam	Loam	>35%	750-950	Contour bund/TCB
161	<1	>100	Loam	Loam	>35%	<750	Contour bund[2]/TCB
162	<1	>100	Loam	Loam	>35%	750-950	Contour bund[2]/TCB
163	1 to 3	>100	Loam	Loam	>35%	<750	Contour bund[2]/TCB
164	1 to 3	>100	Loam	Loam	>35%	750-950	Contour bund[2]/TCB
165	3 to 5	>100	Loam	Loam	>35%	<750	Contour bund[2]/TCB
166	3 to 5	>100	Loam	Loam	>35%	750-950	Contour bund[2]/TCB
167	5 to 10	>100	Loam	Loam	>35%	<750	Contour bund/TCB
168	5 to 10	>100	Loam	Loam	>35%	750-950	Contour bund/TCB
169	<1	<50	Clay	Loam	>35%	<750	Contour bund/TCB
170	<1	<50	Clay	Loam	>35%	750-950	Contour bund/TCB
171	1 to 3	<50	Clay	Loam	>35%	<750	Contour bund/TCB
172	1 to 3	<50	Clay	Loam	>35%	750-950	Contour bund/TCB
173	3 to 5	<50	Clay	Loam	>35%	<750	Contour bund/TCB
174	3 to 5	<50	Clay	Loam	>35%	750-950	Contour bund/TCB

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
175	5 to 10	<50	Clay	Loam	>35%	<750	Contour bund/TCB
176	5 to 10	<50	Clay	Loam	>35%	750-950	Contour bund/TCB
177	<1	50 to 100	Clay	Loam	>35%	<750	Contour bund/TCB
178	<1	50 to 100	Clay	Loam	>35%	750-950	Contour bund/TCB
179	1 to 3	50 to 100	Clay	Loam	>35%	<750	Contour bund/TCB
180	1 to 3	50 to 100	Clay	Loam	>35%	750-950	Contour bund/TCB
181	3 to 5	50 to 100	Clay	Loam	>35%	<750	Contour bund/TCB
182	3 to 5	50 to 100	Clay	Loam	>35%	750-950	Contour bund/TCB
183	5 to 10	50 to 100	Clay	Loam	>35%	<750	Contour bund/TCB
184	5 to 10	50 to 100	Clay	Loam	>35%	750-950	Contour bund/TCB
185	<1	>100	Clay	Loam	>35%	<750	Contour bund/TCB
186	<1	>100	Clay	Loam	>35%	750-950	Contour bund/TCB
187	1 to 3	>100	Clay	Loam	>35%	<750	Graded bund
188	1 to 3	>100	Clay	Loam	>35%	750-950	Graded bund
189	3 to 5	>100	Clay	Loam	>35%	<750	Graded bund
190	3 to 5	>100	Clay	Loam	>35%	750-950	Graded bund
191	5 to 10	>100	Clay	Loam	>35%	<750	Graded bund
192	5 to 10	>100	Clay	Loam	>35%	750-950	Graded bund

Note: [1]As per the criteria, the recommended conservation measure is contour bunding, but in practice, TCB is commonly adopted by the department in the field. However, the cost of bunding for both remains the same.

[2]If the surface soil texture is loamy or lighter and the depth is more than 50 cm, then along with contour bunding, zing terracing may be recommended in black soils up to 5 per cent land slope.

Normally in black soils, terracing is not a common practice, but if the slope exceeds 5 per cent in black soils, terracing is preferred instead of graded bunds. In red and lateritic soils, terracing is recommended if the slope exceeds 10 per cent.

Criteria for deciding conservation treatment for arable-red and lateritic soils

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
1	<1	25-50	Loam	Clay	<35%	<750	Contour bunding/TCB
2	<1	25-50	Loam	Clay	<35%	750-950	Graded bund
3	1 to 3	25-50	Loam	Clay	<35%	<750	Contour bunding/TCB
4	1 to 3	25-50	Loam	Clay	<35%	750-950	Graded bund
5	3 to 5	25-50	Loam	Clay	<35%	<750	Contour bunding/TCB
6	3 to 5	25-50	Loam	Clay	<35%	750-950	Graded bund
7	5 to 10	25-50	Loam	Clay	<35%	<750	Contour bunding/TCB
8	5 to 10	25-50	Loam	Clay	<35%	750-950	Graded bund
9	10 to 15	25-50	Loam	Clay	<35%	<950	Terracing (Sloping outward/Level terrace)
10	10 to 15	25-50	Loam	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
11	15 to 25	25-50	Loam	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)
12	15 to 25	25-50	Loam	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
13	25 to 33	25-50	Loam	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
14	25 to 33	25-50	Loam	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
15	>33	25-50	Loam	Clay	<35%	<=950	Plantation terrace
16	>33	25-50	Loam	Clay	<35%	>950	Puertorican terrace
17	<1	25-50	Loam	Loam	<35%	<=750	Contour bunding/TCB
18	<1	25-50	Loam	Loam	<35%	750-950	Graded bund
19	1 to 3	25-50	Loam	Loam	<35%	<=750	Contour bunding/TCB
20	1 to 3	25-50	Loam	Loam	<35%	750-950	Graded bund
21	3 to 5	25-50	Loam	Loam	<35%	<=750	Contour bunding/TCB
22	3 to 5	25-50	Loam	Loam	<35%	750-950	Graded bund
23	5 to 10	25-50	Loam	Loam	<35%	<=750	Contour bunding/TCB
24	5 to 10	25-50	Loam	Loam	<35%	750-950	Graded bund
25	10 to 15	25-50	Loam	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
26	10 to 15	25-50	Loam	Loam	<35%	>950	Terracing (Sloping inwards/ Level terrace)
27	15 to 25	25-50	Loam	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
28	15 to 25	25-50	Loam	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)
29	25 to 33	25-50	Loam	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
30	25 to 33	25-50	Loam	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)
31	>33	25-50	Loam	Loam	<35%	<=950	Plantation terrace
32	>33	25-50	Loam	Loam	<35%	>950	Puertorican terrace
33	<1	25-50	Clay	Clay	<35%	<750	Contour bunding/TCB
34	<1	25-50	Clay	Clay	<35%	750-950	Graded bund
35	1 to 3	25-50	Clay	Clay	<35%	<750	Contour bunding/TCB
36	1 to 3	25-50	Clay	Clay	<35%	750-950	Graded bund
37	3 to 5	25-50	Clay	Clay	<35%	<750	Contour bunding/TCB
38	3 to 5	25-50	Clay	Clay	<35%	750-950	Graded bund
39	5 to 10	25-50	Clay	Clay	<35%	<750	Contour bunding/TCB
40	5 to 10	25-50	Clay	Clay	<35%	750-950	Graded bund
41	10 to 15	25-50	Clay	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)
42	10 to 15	25-50	Clay	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
43	15 to 25	25-50	Clay	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)
44	15 to 25	25-50	Clay	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
45	25 to 33	25-50	Clay	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)
46	25 to 33	25-50	Clay	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
47	>33	25-50	Clay	Clay	<35%	<=950	Plantation terrace
48	>33	25-50	Clay	Clay	<35%	>950	Puertorican terrace
49	<1	25-50	Clay	Loam	<35%	<=950	Contour bunding/TCB
50	<1	25-50	Clay	Loam	<35%	>950	Graded bund
51	1 to 3	25-50	Clay	Loam	<35%	<=950	Contour bunding/TCB
52	1 to 3	25-50	Clay	Loam	<35%	>950	Graded bund
53	3 to 5	25-50	Clay	Loam	<35%	<=950	Contour bunding/TCB
54	3 to 5	25-50	Clay	Loam	<35%	>950	Graded bund
55	5 to 10	25-50	Clay	Loam	<35%	<=950	Contour bunding/TCB
56	5 to 10	25-50	Clay	Loam	<35%	>950	Graded bund

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
57	10 to 15	25-50	Clay	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
58	10 to 15	25-50	Clay	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)
59	15 to 25	25-50	Clay	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
60	15 to 25	25-50	Clay	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)
61	25 to 33	25-50	Clay	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
62	25 to 33	25-50	Clay	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)
63	>33	25-50	Clay	Loam	<35%	<=950	Plantation terrace
64	>33	25-50	Clay	Loam	<35%	>950	Puertorican terrace
65	<1	25-50	Loam	Clay	>35%	750-950	Contour bunding/TCB
66	<1	25-50	Loam	Clay	>35%	>950	Contour bunding/TCB
67	1 to 3	25-50	Loam	Clay	>35%	750-950	Contour bunding/TCB
68	1 to 3	25-50	Loam	Clay	>35%	>950	Contour bunding/TCB
69	3 to 5	25-50	Loam	Clay	>35%	750-950	Contour bunding/TCB
70	3 to 5	25-50	Loam	Clay	>35%	>950	Contour bunding/TCB
71	5 to 10	25-50	Loam	Clay	>35%	750-950	Contour bunding/TCB
72	5 to 10	25-50	Loam	Clay	>35%	>950	Contour bunding/TCB
73	10 to 15	25-50	Loam	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
74	10 to 15	25-50	Loam	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
75	15 to 25	25-50	Loam	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
76	15 to 25	25-50	Loam	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
77	25 to 33	25-50	Loam	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
78	25 to 33	25-50	Loam	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
79	>33	25-50	Loam	Clay	>35%	750-950	Plantation terrace
80	>33	25-50	Loam	Clay	>35%	>950	Puertorican terrace
81	<1	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
82	<1	25-50	Loam	Loam	>35%	>950	Contour bunding/TCB
83	1 to 3	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
84	1 to 3	25-50	Loam	Loam	>35%	>950	Contour bunding/TCB
85	3 to 5	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
86	3 to 5	25-50	Loam	Loam	>35%	>950	Contour bunding/TCB
87	5 to 10	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
88	5 to 10	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
89	10 to 15	25-50	Loam	Loam	>35%	>950	Terracing (Sloping outward/Level terrace)
90	10 to 15	25-50	Loam	Loam	>35%	750-950	Terracing (Sloping inwards/Level terrace)
91	15 to 25	25-50	Loam	Loam	>35%	>950	Terracing (Sloping outward/Level terrace)
92	15 to 25	25-50	Loam	Loam	>35%	750-950	Terracing (Sloping inwards/Level terrace)
93	25 to 33	25-50	Loam	Loam	>35%	>950	Terracing (Sloping outward/Level terrace)
94	25 to 33	25-50	Loam	Loam	>35%	750-950	Terracing (Sloping inwards/Level terrace)

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	*Subsurface*			
95	>33	25-50	Loam	Loam	>35%	>950	Plantation terrace
96	>33	25-50	Loam	Loam	>35%	>950	Puertorican terrace
97	<1	25-50	Clay	Clay	>35%	750-950	Contour bunding/TCB
98	<1	25-50	Clay	Clay	>35%	>950	Contour bunding/TCB
99	1 to 3	25-50	Clay	Clay	>35%	750-950	Contour bunding/TCB
100	1 to 3	25-50	Clay	Clay	>35%	>950	Contour bunding/TCB
101	3 to 5	25-50	Clay	Clay	>35%	750-950	Contour bunding/TCB
102	3 to 5	25-50	Clay	Clay	>35%	>950	Contour bunding/TCB
103	5 to 10	25-50	Clay	Clay	>35%	750-950	Contour bunding/TCB
104	5 to 10	25-50	Clay	Clay	>35%	>950	Contour bunding/TCB
105	10 to 15	25-50	Clay	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
106	10 to 15	25-50	Clay	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
107	15 to 25	25-50	Clay	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
108	15 to 25	25-50	Clay	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
109	25 to 33	25-50	Clay	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
110	25 to 33	25-50	Clay	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
111	>33	25-50	Clay	Clay	>35%	>950	Plantation terrace
112	>33	25-50	Clay	Clay	>35%	>950	Puertorican terrace
113	<1	25-50	Clay	Loam	>35%	750-950	Contour bunding/TCB
114	<1	25-50	Clay	Loam	>35%	>950	Contour bunding/TCB
115	1 to 3	25-50	Clay	Loam	>35%	750-950	Contour bunding/TCB
116	1 to 3	25-50	Clay	Loam	>35%	>950	Contour bunding/TCB
117	3 to 5	25-50	Clay	Loam	>35%	750-950	Contour bunding/TCB
118	3 to 5	25-50	Clay	Loam	>35%	>950	Contour bunding/TCB
119	5 to 10	25-50	Clay	Loam	>35%	750-950	Contour bunding/TCB
120	5 to 10	25-50	Clay	Loam	>35%	>950	Contour bunding/TCB
121	10 to 15	25-50	Clay	Loam	>35%	750-950	Terracing (Sloping outward/Level terrace)
122	10 to 15	25-50	Clay	Loam	>35%	>950	Terracing (Sloping inwards/Level terrace)
123	15 to 25	25-50	Clay	Loam	>35%	750-950	Terracing (Sloping outward/Level terrace)
124	15 to 25	25-50	Clay	Loam	>35%	>950	Terracing (Sloping inwards/Level terrace)
125	25 to 33	25-50	Clay	Loam	>35%	750-950	Terracing (Sloping outward/Level terrace)
126	25 to 33	25-50	Clay	Loam	>35%	>950	Terracing (Sloping inwards/Level terrace)
127	>33	25-50	Clay	Loam	>35%	750-950	Plantation terrace
128	>33	25-50	Clay	Loam	>35%	>950	Puertorican terrace

Note: [1]As per the criteria, the recommended conservation measure is contour bunding, but in practice, TCB is commonly adopted by the department in the field. However, the cost of bunding for both remains the same.

Decision criteria for selecting treatment for non-arable lands

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
1	<5	<25	Loam	Clay	<35%	<=750	Contour trenching (continuous/staggered contour trench)
2	<5	<25	Loam	Clay	<35%	750-950	Graded trenching
3	>5	<25	Loam	Clay	<35%	<=750	Contour trenching (continuous/staggered contour trench)
4	>5	<25	Loam	Clay	<35%	750-950	Graded trenching
5	<5	>25	Loam	Clay	<35%	<=750	Contour trenching (continuous/staggered contour trench)
6	<5	>25	Loam	Clay	<35%	750-950	Graded trenching
7	>5	>25	Loam	Clay	<35%	<=750	Contour trenching (continuous/staggered contour trench)
8	>5	>25	Loam	Clay	<35%	750-950	Graded trenching
9	<5	<25	Clay	Clay	<35%	<=750	Graded trenching
10	<5	<25	Clay	Clay	<35%	750-950	Graded trenching
11	>5	<25	Clay	Clay	<35%	<=750	Graded trenching
12	>5	<25	Clay	Clay	<35%	750-950	Graded trenching
13	<5	>25	Clay	Clay	<35%	<=750	Graded trenching
14	<5	>25	Clay	Clay	<35%	750-950	Graded trenching
15	>5	>25	Clay	Clay	<35%	<=750	Graded trenching
16	>5	>25	Clay	Clay	<35%	750-950	Graded trenching
17	<5	<25	Loam	Clay	>35%	<=750	Contour trenching (continuous/staggered contour trench)
18	<5	<25	Loam	Clay	>35%	750-950	Graded trenching
19	>5	<25	Loam	Clay	>35%	<=750	Contour trenching (continuous/staggered contour trench)
20	>5	<25	Loam	Clay	>35%	750-950	Graded trenching
21	<5	>25	Loam	Clay	>35%	<=750	Contour trenching (continuous/staggered contour trench)
22	<5	>25	Loam	Clay	>35%	750-950	Graded trenching
23	>5	>25	Loam	Clay	>35%	<=750	Contour trenching (continuous/staggered contour trench)
24	>5	>25	Loam	Clay	>35%	750-950	Graded trenching
25	<5	<25	Clay	Clay	>35%	<=750	Graded trenching
26	<5	<25	Clay	Clay	>35%	750-950	Graded trenching
27	>5	<25	Clay	Clay	>35%	<=750	Graded trenching
28	>5	<25	Clay	Clay	>35%	750-950	Graded trenching
29	<5	>25	Clay	Clay	>35%	<=750	Graded trenching
30	<5	>25	Clay	Clay	>35%	750-950	Graded trenching
31	>5	>25	Clay	Clay	>35%	<=750	Graded trenching
32	>5	>25	Clay	Clay	>35%	750-950	Graded trenching
33	<5	<25	Loam	Loam	<35%	<=750	Contour trenching (continuous/staggered contour trench)
34	<5	<25	Loam	Loam	<35%	750-950	Graded trenching
35	>5	<25	Loam	Loam	<35%	<=750	Contour trenching (continuous/staggered contour trench)
36	>5	<25	Loam	Loam	<35%	750-950	Graded trenching

#	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
37	<5	>25	Loam	Loam	<35%	<=750	Contour trenching (continuous/staggered contour trench)
38	<5	>25	Loam	Loam	<35%	750-950	Graded trenching
39	>5	>25	Loam	Loam	<35%	<=750	Contour trenching (continuous/staggered contour trench)
40	>5	>25	Loam	Loam	<35%	750-950	Graded trenching
41	<5	<25	Clay	Loam	<35%	<=750	Graded trenching
42	<5	<25	Clay	Loam	<35%	750-950	Graded trenching
43	>5	<25	Clay	Loam	<35%	<=750	Graded trenching
44	>5	<25	Clay	Loam	<35%	750-950	Graded trenching
45	<5	>25	Clay	Loam	<35%	<=750	Graded trenching
46	<5	>25	Clay	Loam	<35%	750-950	Graded trenching
47	>5	>25	Clay	Loam	<35%	<=750	Graded trenching
48	>5	>25	Clay	Loam	<35%	750-950	Graded trenching
49	<5	<25	Loam	Loam	>35%	<=750	Contour trenching (continuous/staggered contour trench)
50	<5	<25	Loam	Loam	>35%	750-950	Graded trenching
51	>5	<25	Loam	Loam	>35%	<=750	Contour trenching (continuous/staggered contour trench)
52	>5	<25	Loam	Loam	>35%	750-950	Graded trenching
53	<5	>25	Loam	Loam	>35%	<=750	Contour trenching (continuous/staggered contour trench)
54	<5	>25	Loam	Loam	>35%	750-950	Graded trenching
55	>5	>25	Loam	Loam	>35%	<=750	Contour trenching (continuous/staggered contour trench)
56	>5	>25	Loam	Loam	>35%	750-950	Graded trenching
57	<5	<25	Clay	Loam	>35%	<=750	Graded trenching
58	<5	<25	Clay	Loam	>35%	750-950	Graded trenching
59	>5	<25	Clay	Loam	>35%	<=750	Graded trenching
60	>5	<25	Clay	Loam	>35%	750-950	Graded trenching
61	<5	>25	Clay	Loam	>35%	<=750	Graded trenching
62	<5	>25	Clay	Loam	>35%	750-950	Graded trenching
63	>5	>25	Clay	Loam	>35%	<=750	Graded trenching
64	>5	>25	Clay	Loam	>35%	750-950	Graded trenching

Criteria for deciding horizontal and vertical intervals for soil conservation treatments

Treatment	Slope %	Loamy		Clayey	
		VI	HI	VI	HI
Contour Bunding/TCB	<1	0.6	60	0.9	90
Contour Bunding/TCB	1 to 3	0.6	39	1	55
Contour Bunding/TCB	3 to 5	0.9	21	1.5	33
Contour Bunding/TCB	5 to 10	1.2	21	1.5	27
Graded Bunding	<=5	0.75-1.0		1 to 1.2	
Graded Bunding	5-10			0.75-1.5	
Trenching (Non arable land)	<5		10.0		10.0
Trenching (Non arable land)	5 to 10		7.5		7.5
Trenching (Non arable land)	10 to 25		5.0		5.0

Treatment	*Slope %*	*Loamy*		*Clayey*	
		VI	*HI*	*VI*	*HI*
Terracing	VI = Width x Slope/(100-Slope) for Black soil (batter slope 1:1; horizontal: vertical) VI = 2 x Width x Slope/(200-Slope)-for Red and lateritic soils (batter slope 0.5:1) HI = Width /VI Note: For designing the Width = 200 x depth of cut/slope Depth of cut* = Profile depth x (1-(slope/100)) *minimum depth of cut = 0.3 m or (Profile depth - (VI/2)) Note: Volume of earth excavation for Terrace strips are estimated using the formula: Q = L x W x D/8 Where, l = Length of the Terrace strip, W = Designed Terrace width, D = Fall between two Terrace strips				

Note: *This table needs refinement in future based on further research.

Source:
Technical Manual for Integrated Watershed Development, 2006, (Sponsored by Watershed Development Department, Government of Karnataka), Institution of Agricultural Technologists (IAT), Queen's Road, Bengaluru-560 052

Criteria for deciding cross-section of contour bund and TCB under field crops

Texture	*Gravel*	*Depth*	*Top width*	*Base width*	*Height*	*Side slope*	*Cross section*
Contour bunding							
Loam	>35%	<50	0.3	1.2	0.6	0.75:1	0.45
Loam	<35%	<50	0.3	1.5	0.6	1:1	0.54
Clay	<35%	<50	0.3	2.1	0.6	1.5:1	0.72
Clay	>35%	<50	0.3	2.1	0.6	1.5:1	0.72
Loam	<35%	50-75	0.3	1.5	0.6	1:1	0.54
Loam	>35%	50-75	0.3	1.5	0.6	1:1	0.54
Clay	<35%	50-75	0.45	2.0	0.75	1:1	0.92
Clay	>35%	50-75	0.45	2.0	0.75	1:1	0.92
Loam	<35%	75-100	0.3	2.1	0.6	1.5:1	0.72
Loam	>35%	75-100	0.3	2.1	0.6	1.5:1	0.72
Clay	<35%	75-100	0.45	2.4	0.75	1.3:1	1.07
Clay	>35%	75-100	0.45	2.4	0.75	1.3:1	1.07
Loam	<35%	100-150	0.3	2.1	0.6	1.5:1	0.72
Loam	>35%	100-150	0.3	2.1	0.6	1.5:1	0.72
Clay	<35%	100-150	0.6	3.1	0.7	1.78:1	1.29
Clay	>35%	100-150	0.6	3.1	0.7	1.78:1	1.29
Loam	<35%	>150	0.3	2.1	0.6	1.5:1	0.72
Loam	>35%	>150	0.3	2.1	0.6	1.5:1	0.72
Clay	<35%	>150	0.5	3.0	0.85	1.47:1	1.49
Clay	>35%	>150	0.5	3.0	0.85	1.47:1	1.49
Graded bunding							
Clay	<35	50-100	0.3	1.2	0.5	0.9:1.0	0.375

Texture	*Gravel*	*Depth*	*Top width*	*Base width*	*Height*	*Side slope*	*Cross section*
Clay	<35	50-100	0.3	1.2	0.6	0.75:1.0	0.45
Clay	<35	50-100	0.3	2.1	0.6	1:1	0.72
Clay	<35	100-150	0.3	5.175	0.75	u/s 5:1 d/s 1.5:1	2.06
Clay	>35	100-150	0.3	5.175	0.75	u/s 5:1 d/s 1.5:1	2.06
Clay	<35	>150	0.3	5.175	0.75	u/s 5:1 d/s 1.5:1	2.06
Clay	>35	>150	0.3	5.175	0.75	u/s 5:1 d/s 1.5:1	2.06
For Plantation crops							
Loam	>35%	<50	0.3	1.2	0.5	0.9;1	0.375

Note: Length of side bund = 10% of main bund length

Source:
Technical Manual for Integrated Watershed Development, 2006, (Sponsored by Watershed Development Department, Government of Karnataka), Institution of Agricultural Technologists (IAT), Queen's Road, Bengaluru-560 052

Criteria for selecting the cost rate for contour bund/TCB

Mode of execution	*Gravel*	*Main/ Side bund*	*Cost of bunding per metre length of bund (Rs.) as per the cross section given above, [which is arrived as per the Table 4]*							
Main bund section (m^2)			0.375	0.45	0.54	0.72	0.92	1.07	1.29	1.49
Side bund section (m^2)			0.251	0.302	0.362	0.482	0.616	0.717	0.864	0.998
a) Black Soils/Red Soils										
Machinery-WDD SOR	<35% gravel	Main bund	25.11	28.61	33.40	42.49	57.79	68.26	81.49	91.21
		Side bund	18.47	21.29	24.08	31.17	41.94	46.61	53.98	60.61
		Waste weir	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	Total		49.07	55.40	62.98	79.16	105.23	120.38	140.96	157.32
	>35% gravel	Main bund	27.81	31.79	37.19	47.54	64.25	75.79	90.57	101.71
		Side bund	20.21	23.48	26.62	34.67	46.37	46.37	60.03	67.57
		Waste weir	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		Total	53.52	60.77	69.31	87.71	116.12	127.66	156.09	174.77
b) Lateritic Soils										
Machinery-WDD SOR		Main bund	33.55	38.80	44.86	58.15	77.56	95.73	110.48	126.58
		Side bund	23.69	27.65	31.63	41.35	54.91	54.91	71.99	81.38
		Waste weir	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28

Mode of execution	Gravel	Main/ Side bund	Cost of bunding per metre length of bund (Rs.) as per the cross section given above, [which is arrived as per the Table 4]							
		Total	62.74	71.96	81.98	105.00	137.96	156.13	187.97	213.46
a) Black Soils/Red Soils										
		Main bund	90.66	108.79	130.54	174.06	222.41	258.67	311.85	360.20
Manual- MGNREGS	<35% gravel	Side bund	60.74	72.89	87.46	116.62	149.01	173.31	208.94	241.34
		Waste weir	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		Total	156.89	187.17	223.51	296.18	376.92	437.48	526.30	607.04
	>35% gravel	Main bund	90.66	108.79	130.54	174.06	222.41	258.67	311.85	360.20
		Side bund	60.74	72.89	87.46	116.62	149.01	173.31	208.94	241.34
		Waste weir	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		Total								
b) Lateritic Soils										
Manual- MGNREGS	-	Main bund	90.66	108.79	130.54	174.06	222.41	258.67	311.85	360.20
		Side bund	60.74	72.89	87.46	116.62	149.01	173.31	208.94	241.34
		Waste weir	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		Total	156.89	187.17	223.51	296.18	376.92	437.48	526.30	607.04
a) Black Soils/Red Sandy Soils										
Manual- WDD SOR	<35% gravel	Main bund	31.13	37.35	44.82	59.76	76.36	88.81	107.07	123.67
		Side bund	20.85	25.02	30.03	40.04	51.16	59.50	71.74	82.86
		Waste weir	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		Total	57.48	67.87	80.35	105.30	133.02	153.81	184.31	212.03
	>35% gravel	Main bund	34.13	40.95	49.14	65.52	83.72	97.37	117.39	135.59
		Side bund	22.86	27.44	32.92	43.90	56.09	65.24	78.65	90.85
		Waste weir	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		Total	62.49	73.89	87.56	114.92	145.31	168.11	201.54	231.94
b) Lateritic Soils										
Manual- WDD SOR	-	Main bund	42.75	51.30	61.56	82.08	104.88	121.98	147.06	169.86
		Side bund	28.64	34.37	41.25	54.99	70.27	81.73	98.53	113.81
		Waste weir	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		Total	76.89	91.17	108.31	142.57	180.65	209.21	251.09	289.17

Source: SoR-2018-19

Criteria for selecting the cost rate for construction of contour bund with zing terrace (summary of rates as per SoR 2018-19)

Slope (%)	*Cost (Rs./ha)*			
	Bund Section (m^2)			
	0.92	1.07	1.29	1.49
1-3	18801	25229	29995	33614
3-5	25069	32401	38464	43264

Note: Cost includes contour bunding/strengthening of existing bunds, waste weirs and sowing of seeds on the bunds

Criteria for selecting the cost rate for graded bund

Soil type	*Gravel*	*Soil texture*	*Mode of execution*	*SoR*	*Cost of earth work per metre bund length (Rs.) as per bund sections (m^2) given below*			
					0.375	0.45	0.72	2.06
a) Black soils/Red Sandy soils	<35%	Loam	Machinery	WDD	25.11	28.61	42.49	78.02
		Clay	Machinery	WDD	25.11	28.61	42.49	78.02
	>35%	Loam	Machinery	WDD	27.81	31.79	47.54	0.00
		Clay	Machinery	WDD	27.81	31.79	47.54	0.00
b) Lateritic soils	<35%	Lateritic	Machinery	WDD	33.55	38.80	58.15	187.46
	>35%	Lateritic	Machinery	WDD	33.55	38.80	58.15	187.46
a) Black soils/Red Sandy soils	<35%	Loam	Manual	MGNREGS	90.66	108.79	174.06	498.00
		Clay	Manual	MGNREGS	90.66	108.79	174.06	498.00
	>35%	Loam	Manual	MGNREGS	90.66	108.79	174.06	498.00
		Clay	Manual	MGNREGS	90.66	108.79	174.06	498.00
b) Lateritic soils	<35%	Lateritic	Manual	MGNREGS	90.66	108.79	174.06	498.00
	>35%	Lateritic	Manual	MGNREGS	90.66	108.79	174.06	498.00
a) Black soils/Red Sandy soils	<35%	Loam	Manual	WDD	31.13	37.35	59.76	170.98
		Clay	Manual	WDD	31.13	37.35	59.76	170.98
	>35%	Loam	Manual	WDD	34.13	40.95	65.52	187.46
		Clay	Manual	WDD	34.13	40.95	65.52	187.46
b) Lateritic soils	<35%	Loam	Manual	WDD	42.75	51.30	82.08	234.84
	>35%	Clay	Manual	WDD	42.75	51.30	82.08	234.84

Source: SoR-2018-19

Criteria for selecting the cost rate for channel weir in graded bunds

Bund section m^2	*Average cost/ channel weir*	*Average cost/ channel weir*
0.375	992	1117
0.45	1016	1142
0.72	2092	2164
2.06	10054	1087
	Note: WDD SoR 2018-19	Note: MGNREGS SoR 2018

Criteria for selection of costing for Bench Terraces

Sloping inward terrace-riser 0.5:1.0; H:V in red and lateritic soils (mostly loamy soils)

#	*Land slope (%)*	*Profile depth (cm)*	*Total cost of terracing (Rs./ha)*
1	10 to 15	25-50	107450
2	15 to 25	25-50	121591
3	>25	25-50	136389
4	10 to 15	>50	281957
5	15 to 25	>50	276907
6	>25	>50	271622

Note:

1. Costing is as per WDD SOR 2018-19

2. Cost of terracing includes 0.06m^2 Lip Bund, 0.3m thick stone pitching of the riser, waterways with drops, survey and alignment charges

Sloping inward terrace-riser 1:1; H:V in black soils (clayey soils) and rainfall >750 mm

#	*Land Slope (%)*	*Profile depth (cm)*	*Total cost of terracing (Rs./ha)*
1	10 to 15	25-50	101470
2	15 to 25	25-50	111228
3	>25	25-50	120846
4	10 to 15	>50	266329
5	15 to 25	>50	253435
6	>25	>50	240726

Note:

1. Costing is as per WDD SOR 2018-19

2. Cost of terracing includes 0.06m^2 Lip Bund, 0.3m thick stone pitching of the riser, waterways with drops, survey and alignment charges

Sloping outward terrace-riser 1:1; H:V in loamy (red)/clayey soils

#	*Land Slope (%)*	*Profile Depth (cm)*	*Total cost of terracing (Rs./ha)*
1	10 to 15	25-50	505561
2	15 to 25	25-50	704397
3	>25	25-50	900386
4	10 to 15	>50	516473
5	15 to 25	>50	548703
6	>25	>50	580470

Note: 1. Costing is as per WDD SoR 2018-19

2. Cost of terracing includes 0.54 m^2 Lip Bund, 0.3m thick stone pitching of the riser, waterways with drops, survey and alignment charges

Plantation terraces with 1:1; H:V riser

#	*Land slope (%)*	*Profile depth (cm)*	*Total cost of terracing (Rs./ha)*
1	10 to 15	25-50	117106
2	15 to 25	25-50	192055
3	>25	25-50	276371
4	10 to 15	>50	71481
5	15 to 25	>50	117228
6	>25	>50	168

Note: 1. Costing is as per WDD SoR 2018-19

2. Cost of terracing includes 0.54 m^2 Lip Bund, 0.3m thick stone pitching of the riser, waterways with drops, survey and alignment charges

Criteria for selecting the dimensions for opening of trenches

Contour trench		*Staggered trench*					
Width (m.)	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Depth (m.)	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Length (m.)1*	15.0	4.0	6.0	8.0	10.0	12.0	15.0
Quantity per trench (Cum)	4.05	1.08	1.62	2.16	2.7	3.24	4.05

Note: 1*Decided based on the presence of obstacles (rock out crop/trees) on the ground surface

Criteria for selecting the quantity of earth excavation for opening of trenches

#	*Slope (%)*	*Horizontal interval (m)*	*Volume of earth excavation (m^3) per ha*	
			Continuous contour trenches	*Staggered contour trenches*
1	5	10.0	218.7	169.8
2	5 to 10	7.5	291.6	222.2
3	10 to 15	5.0	434	321.4

Criteria for selecting the cost rate for trenching

Soil type	*Gravel*	*Soil*	*Mode of execution*	*SoR*	*Cost of earth work per metre length of trench (Rs.) Trench section: 0.27m^2*
Black Soils/Red Sandy Soils	<35%	loam	Manual	WDD	22.41
		clay	Manual	WDD	22.41
		lateritic	Manual	WDD	24.57
Hard Soils	>35%	loam	Manual	WDD	22.41
		clay	Manual	WDD	22.41
		lateritic	Manual	WDD	24.57

Annexure-4

DSS-2: Land Suitability for Crops Selection

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

1. Land Capability Classification (Klingbiel & Montgomery, 1961).
2. Land Irrigability Classification (Soil Survey Staff, 1951; USBR, 1953).
3. Fertility Capability Classification
4. Crop Suitability Classification (FAO, 1976; Sys, 1985; Sys et al. 1993)
5. Prime Land Classification (Ramamurthy et al., 2012)

B. Quantitative evaluation

1. Soil index rating (Shome and Raychaudhari, 1960; Storie, 1978)
2. Actual and potential productivity (Riquier et al., 1970)
3. Soil suitability classification- statistical approach (Sehgal et al., 1989)
4. Land use planning and analysis system (LUPAS) (Laborte et al., 2002):
5. Land suitability assessment by parametric approach (Rabia and Terribile, 2013)
6. Land suitability by fuzzy AHP and TOPSIS methods (Mukhtar Elaalem et al., 2010)
7. 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 needs 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

Note: Additional limitations and changes, not provided in FAO, are from NBSS
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.

1. Selection of the crop and the survey number or land parcel to be assessed for suitability evaluation
2. 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
3. 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
4. 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
5. 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.

Annexure-5

DSS-3: 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.

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 (e1)	√							
	Moderate (e2)		√						
	Severe (e3)			√					
	Very Severe (e4)				√				
Drainage	Excessive						√		
	Well drained	√							
	Mod.WD		√						
	Imperfect			√					
	Poor				√				
	Very Poor					√			
Soil depth	> 100 cm	√							
	50 –100 cm		√						
	25-50 cm			√					

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
	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							√	

Annexure-6

DSS-4: Nutrient Management and 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 tool 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
P2O5					
K2O					

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.

Annexure-7

DSS-5: 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.

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:

$$C_W = A_1 C_I + A_2\ C_2 + \ldots\ldots A_n\ C_n / A$$

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= (ΔH /L) *100 in % ΔH=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*	*K1*	*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.

1. A query will be executed to find the Cadastral ID on basis of Selected Village, Taluk, District, and Survey Number from CADASTRAL table.
2. Get the Soil Texture, Slope, Landform (Black, Red/ lateritic) from the Parcel characteristics table for the respective cadastral ID.
3. A query will be executed to find current Land use for the selected survey number.
4. A query will be executed on Master Infiltration Rate to get constant infiltration rate depending Soil Texture and Land use.
5. 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.

Annexure-8

DSS-6: Designing Size and Location of Farm Ponds and Check Dams

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		Bagalkote					
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 analyse 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.

Decision Criteria for Check Dam:

1. Estimate the Net runoff available for harvesting by deducting the quantity of runoff likely to be captured/retained in the proposed and existing conservation structures and farm ponds (about 50% of the runoff, if no data is available) from the total quantity of available runoff. Deduct 30 per cent of the Runoff from the Total runoff towards Environmental flow. (Out of estimated runoff average 70 per cent of water to be targeted for harvesting within watershed boundary and rest amount to be allowed to flow at downstream location such that it will not significantly affect riverine ecosystem)
2. If net runoff (available for storage) is sufficient (Minimum of 850 m^3) Check dam can be proposed at the point where quantity of runoff is sufficient for Check dam. It can be in 1st, 2nd, or 3rd order stream or if the runoff is not enough at any point in the Micro watershed, then there is no need to construct a Check dam & runoff can be allowed to run into the stream. (Option should be given to enter the Storage Capacity of the Check Dam anything greater than 850),
   Number of Check Dams = Net Runoff / Minimum Storage
3. Based on the quantity of Net runoff available, number and storage capacity of the Check Dam, Cost of the structure is decided based on the cost for per Cum (Approximately, South Zone Rs 502/-, North Zone Rs 464/-, North East Zone Rs.601/) as per the prevailing rates in the districts.
4. Type of the check dam is decided based on the shape of the nala banks as per ground truth or with the help of DEM data wherever available & availability of the stones nearby.
5. Design of Check dam [Impounding height(h), Spillage/depth of flow over the crest(d) and free board depth(f)], type of the check dam and its components are decided based on the spot selected after Field survey/verification

In order to reduce silt load to Check dams, vegetative or dry boulder checks are provided at a vertical interval of 1 to 1.5m. with a crest height of o.6 to 1.25 m. depending on the depth of the drainage line. If head of the gully or starting point of the drainage line is more than 1 m depth, chute spill way or Boulder flume with Dry boulders are provided. In Black soil area and hilly zone, Gabion checks are preferred. Designing of dimension of these checks are based on the Total Station Survey or survey using Dumpy Level.

Criteria for deciding crest height and cost of check dam

#	*Storage capacity (m^3)*	*Cost (Rs.)*	*Check dam-apron type*	*Catchment area (ha)*	*Gully depth (m)*	*Crest height (h) (m)*
1	859	342328	Sloping Apron Type	25	2.4	1.25
2	859	302989	Solid Apron type	25	2.3	1.25
3	703	227782	Stilling basin type	25	2.5	1.25
4	859	397132	Sloping Apron Type	50	2.6	1.25
5	859	336306	Solid Apron type	50	2.4	1.25
	703	264233	Stilling basin type	50	2.7	1.25
6	859	426703	Sloping Apron Type	75	2.7	1.25
7	859	378050	Solid Apron type	75	2.5	1.25
8	703	293227	Stilling basin type	75	2.8	1.25
9	859	464677	Sloping Apron Type	100	2.8	1.25
10	859	417877	Solid Apron type	100	2.6	1.25
11	703	316668	Stilling basin type	100	2.9	1.25
12	859	497115	Sloping Apron Type	125	2.9	1.25
13	859	460812	Solid Apron type	125	2.7	1.25
14	703	341135	Stilling basin type	125	2.9	1.25
15	859	538132	Sloping Apron Type	150	3	1.25
16	859	507143	Solid Apron type	150	2.8	1.25
17	703	373284	Stilling basin type	150	3	1.25
18	859	580771	Sloping Apron Type	175	3.1	1.25
19	859	507143	Solid Apron type	175	2.8	1.25
20	703	399675	Stilling basin type	175	3.1	1.25
21	859	580771	Sloping Apron Type	200	3.2	1.25
22	859	562328	Solid Apron type	200	2.9	1.25
23	703	434107	Stilling basin type	200	3.2	1.25
24	1088	449349	Sloping Apron Type	25	2.6	1.50
25	1088	399529	Solid Apron type	25	2.6	1.50
26	863	264090	Stilling basin type	25	2.7	1.50
27	1088	513982	Sloping Apron Type	50	2.8	1.50
28	1088	440895	Solid Apron type	50	2.7	1.50
29	863	287183	Stilling basin type	50	2.8	1.50
30	1088	548469	Sloping Apron Type	75	2.9	1.50
31	1088	462223	Solid Apron type	75	2.8	1.50
32	863	336222	Stilling basin type	75	3	1.50
33	1088	592776	Sloping Apron Type	100	3	1.50
34	1088	520044	Solid Apron type	100	2.9	1.50
35	863	362125	Stilling basin type	100	3.1	1.50
36	1088	629983	Sloping Apron Type	125	3.1	1.50
37	1088	520044	Solid Apron type	125	2.9	1.50
38	863	389018	Stilling basin type	125	3.2	1.50
39	1088	629983	Sloping Apron Type	150	3.1	1.50
40	1088	582070	Solid Apron type	150	3	1.50
41	863	389018	Stilling basin type	150	3.2	1.50

#	Storage capacity (m^3)	Cost (Rs.)	Check dam-apron type	Catchment area (ha)	Gully depth (m)	Crest height (h) (m)
42	1088	668668	Sloping Apron Type	175	3.1	1.50
43	1088	642906	Solid Apron type	175	3.1	1.50
44	863	416646	Stilling basin type	175	3.3	1.50
45	1088	708560	Sloping Apron Type	200	3.2	1.50
46	1088	710739	Solid Apron type	200	3.2	1.50
47	863	445390	Stilling basin type	200	3.4	1.50
48	1334	575633	Sloping Apron Type	25	2.9	1.75
49	1334	431994	Solid Apron type	25	2.7	1.75
50	1028	378216	Stilling basin type	25	3	1.75
51	1334	613285	Sloping Apron Type	50	3	1.75
52	1334	543010	Solid Apron type	50	2.9	1.75
53	1028	390019	Stilling basin type	50	3.1	1.75
54	1334	690268	Sloping Apron Type	75	3.1	1.75
55	1334	603543	Solid Apron type	75	3	1.75
56	1028	419108	Stilling basin type	75	3.2	1.75
57	1334	690268	Sloping Apron Type	100	3.2	1.75
58	1334	603543	Solid Apron type	100	3	1.75
59	1028	480240	Stilling basin type	100	3.4	1.75
60	1334	739550	Sloping Apron Type	125	3.3	1.75
61	1334	666105	Solid Apron type	125	3.1	1.75
62	1028	480240	Stilling basin type	125	3.4	1.75
63	1334	773298	Sloping Apron Type	150	3.4	1.75
64	1334	732756	Solid Apron type	150	3.2	1.75
65	1028	512335	Stilling basin type	150	3.5	1.75
66	1334	817042	Sloping Apron Type	175	3.5	1.75
67	1334	732756	Solid Apron type	175	3.2	1.75
68	1028	545416	Stilling basin type	175	3.6	1.75
69	1334	871650	Sloping Apron Type	200	3.6	1.75
70	1334	804059	Solid Apron type	200	3.4	1.75
71	1028	579519	Stilling basin type	200	3.7	1.75
72	1600	723204	Sloping Apron Type	25	3.1	2.0
73	1600	568390	Solid Apron type	25	3	2.0
74	1200	407702	Stilling basin type	25	3.1	2.0
75	1600	764852	Sloping Apron Type	50	3.2	2.0
76	1600	692788	Solid Apron type	50	3.2	2.0
77	1200	472013	Stilling basin type	50	3.3	2.0
78	1600	807814	Sloping Apron Type	75	3.3	2.0
79	1600	692788	Solid Apron type	75	3.2	2.0
80	1200	495774	Stilling basin type	75	3.4	2.0
81	1600	842156	Sloping Apron Type	100	3.4	2.0
82	1600	761472	Solid Apron type	100	3.3	2.0
83	1200	530478	Stilling basin type	100	3.5	2.0
84	1600	898578	Sloping Apron Type	125	3.5	2.0

#	*Storage capacity (m^3)*	*Cost (Rs.)*	*Check dam-apron type*	*Catchment area (ha)*	*Gully depth (m)*	*Crest height (h) (m)*
85	1600	834611	Solid Apron type	125	3.4	2.0
86	1200	566242	Stilling basin type	125	3.6	2.0
87	1600	946057	Sloping Apron Type	150	3.6	2.0
88	1600	834611	Solid Apron type	150	3.4	2.0
89	1200	603119	Stilling basin type	150	3.7	2.0
90	1600	946057	Sloping Apron Type	175	3.6	2.0
91	1600	922633	Solid Apron type	175	3.5	2.0
92	1200	640979	Stilling basin type	175	3.8	2.0
93	1600	1085830	Sloping Apron Type	200	3.7	2.0
94	1600	1005462	Solid Apron type	200	3.4	2.0
95	1200	679939	Stilling basin type	200	3.9	2.0
	NOTE: 1. Gully bed width considered is 5m. 2. Gully bed slope considered is 1% 3. Cost is as per WDD SOR: 2018-19 - SUTH ZONE(PWP&ILWTD)					

Type of check dam

Shape of Nala banks	*Stone availability*	*Nala bed Condition*	*Type of check dam*
'V' Shape Nala bank with side slope milde than 1:1	Available at less than 5km distance	Hard strata at a depth less than 1.0m	Sloping Apron type.
'V' Shape Nala bank with side slope milde than 1:1	Available at more than 5km distance	Clayey/ lateritic soil	Solid Apron Type
'U' Shape Nala bank with side slope steepe than 1:1		Hard strata at a depth more than1.0m	Stilling Basin Type

Location of check dams in MWS/SWS area:

Identifying proper site for a check dam or Gokatta (cattle pool) or any other harvesting structure in a watershed area needs information on the length, width and depth of the stream/drainage line and nature of the substratum apart from the amount of runoff available for harvest in the selected location. At present this information is not available from the LRI/Hydrology data collected from the watersheds. An attempt can be made to collect the above information in the areas already covered by LRI and included as a part of LRI for the new areas in future. Once this information is available, tentative locations for check dams can be identified, which can be verified later in the field. Alternatively, attempts can be made to identify suitable locations by using higher resolution imagery available from the project and DEM wherever available. Once the protocol for the use of the imagery/DEM is established for locating Check dams, the same can be integrated in the DSS already developed.

Annexure-9

DSS-7: Estimating 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 is mentioned in Table 4. Steps for estimating the crop water requirement given in Table.

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	Max., Min. 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

#	*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*
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
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
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
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
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
Beans (green)		0.5	1.05	0.90
Fibre Crops				
1	Cotton	0.35	1.15-1.20	0 0.70-0.50
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
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	Millet		1.00	0.30
4	Bajra		1.00	0.30

	Crop	*Initial stage Kc*	*Midseason Kc*	*End season Kc*
5	Rice	1.05	1.20	0.90-0.60
Sugarcane		0.40	1.25	0.75
Berries/ Bushes (applies to Mulberry)		0.30	1.05	0.50
Banana				
1	1st year	0.50	1.10	1.00
2	2nd year	1.00	1.20	1.10
Grapes– Table or Raisin		0.30	0.85	0.45
Pineapple with grass cover		0.50	0.50	0.50
Citrus				
1	70% canopy	0.75	0.70	0.75
2	50% canopy	0.80	0.80	0.80

Source: FAO, 1998, crop evapotranspiration guidelines for computing crop water requirement, FAO irrigation and drainage paper-56

Annexure-10

DSS-8: Estimating Soil Water Balance

Soil Water (Moisture) is a fundamental hydrological variable affecting physical, chemical and biological properties of soils and in turn impacts the growth and yield of crops. It is influenced by the amount of rainfall, topography, land use, type of soil, substratum and management practices followed in an area. Estimation of the amount of water present in the soil on real time basis will help to take up appropriate contingency measures needed to overcome the stress period wherever possible.

Soil Water (Moisture) balance equation can be defined as:

Change in soil moisture storage = Rainfall + Irrigation - Surface runoff - Evapotranspiration - Deep percolation

Input parameters required for estimation of Soil Water (Moisture) balance

Data base	*Required parameter*	*Master table*	*Remarks*
Soil data base	FC, PWP (Wherever the values are not available the same may be computed from LRI database through PTF models)	Texture, organic carbon, bulk density	(Calculated using *pedo- transfer* function using Texture, OC, BD etc.)
	Soil depth, Infiltration rate (IR values to be provided for major soils in the MWS based on LRI)	Soil depth, infiltration rate	Soil depth from LRI, Infiltration rate based on infiltrometer studies
Weather	Rainfall and weather parameters (max and min temp, relative humidity, wind speed, solar radiation)	Daily rainfall (actual and normal)	Based on weather data, estimate ETo
Crop management details	Date of sowing, crop duration	Farmers data, remote sensing data base,	Crop duration from the POP. Date of sowing will be input by the user
Crop growth parameters	Crop coefficient and root growth function at different stages	FAO, NBSS&LUP NWDA data base for crop coefficients	

Step-by-step process for estimating Soil Water (Moisture) balance

#	*Steps involved*	*Data requirement*
1	Define soil profile and assign initial boundary condition	Soil data base, WHC (soil series wise), soil depth
2	Define land use class/cropping system and its management details	Crop management details in case of agricultural land
3	Initialize the process for computing the water balance components at daily time scale (Soil moisture, Eta, runoff and deep percolation) at individual field scale	
4	Estimate runoff on daily time scale based on selected model (SCS Method)	Runoff model based on IR and precipitation-not done
5	Calculate balance water by subtracting runoff from rainfall	
6	Distribute balance water into soil by following one-dimensional model	
7	Excess balance water beyond soil depth may be assumed as deep percolation	
8	Estimate crop water requirement on daily time scale	As per the DSS on Crop water requirement
9	Estimate available moisture content in soil up to root zone depth	
10	Estimate soil water storage by subtracting crop water requirement from available moisture content up to root depth	
11	Repeat step 4-11 at daily scale for entire crop growth period	
12	Display water balance component at land parcel scale	

Annexure-11

DSS-9: Water Budgeting

Water budgeting is critical for the sustainable management of available water resources at field, watershed, or any other scales. It indicates the rate of change in the water stored or available in a watershed based on the demand and supply. It shows the net balance based on the inflow and outflow of water in a year or any selected period. The inflow includes precipitation, surface and ground water storage and the outflow includes the drinking water needs of the population, livestock, irrigation, evaporation, runoff, mandatory environmental flow, industrial and other uses. Water budget helps to understand the surplus or deficit status of the watershed, and accordingly helps to design corrective/mitigation measures wherever there is a deficit and plan for the use of surplus water by increasing area under irrigation, livestock and livelihood activities to bring in additional and sustainable benefits to the society as a whole. Though water budgets can be worked out at any scale, ranging from parcel to basins, the present DSS is confined to the datasets required and sequence of activities involved in arriving water budgets at the watershed scale under Suajal III project.

Input parameter required for water budgeting

Data base	*Required parameter*	*Master table*	*Note*
Crop water requirement	Details of the land use/ cropping pattern and area under different land use		
Water balance component	Rainfall, runoff, soil moisture, ground water recharge		
Demographic details	Human population, livestock population, per capita water consumption for domestic use, livestock use	Human population, livestock population, per capita water consumption for domestic use, livestock use	Information to be compiled from the Census data
Water availability	Existing water resource availability per year	Inventory of water resources-both surface and subsurface water	

Step-by-step process for Water budgeting

#	*Steps*	*Data requirement*
1	Estimate Soil water balance component for selected micro-watershed	Based on the DSS already executed-Soil moisture/water
2	Estimate water availability in micro-watershed using 1. Measured capacities of surface water bodies	
	2. Runoff generated through watershed based on runoff from Infiltration method	
	3. Amount of water percolation in soil-ground water (deep percolation component in water balance)	
3	Estimate water required for irrigation based on the crop water requirement and irrigation requirement	

#	Steps	Data requirement
4	Estimate water requirement for household use	Use national standards for human consumption
5	Estimate water required for livestock purpose	Data from livestock census and national standards for their requirement
6	Estimate water required for the existing industrial activities	
7	Estimate water available for irrigation by subtracting water requirement for human and livestock from total water available in micro watershed	
8	Display water budget for micro-watershed and higher levels	

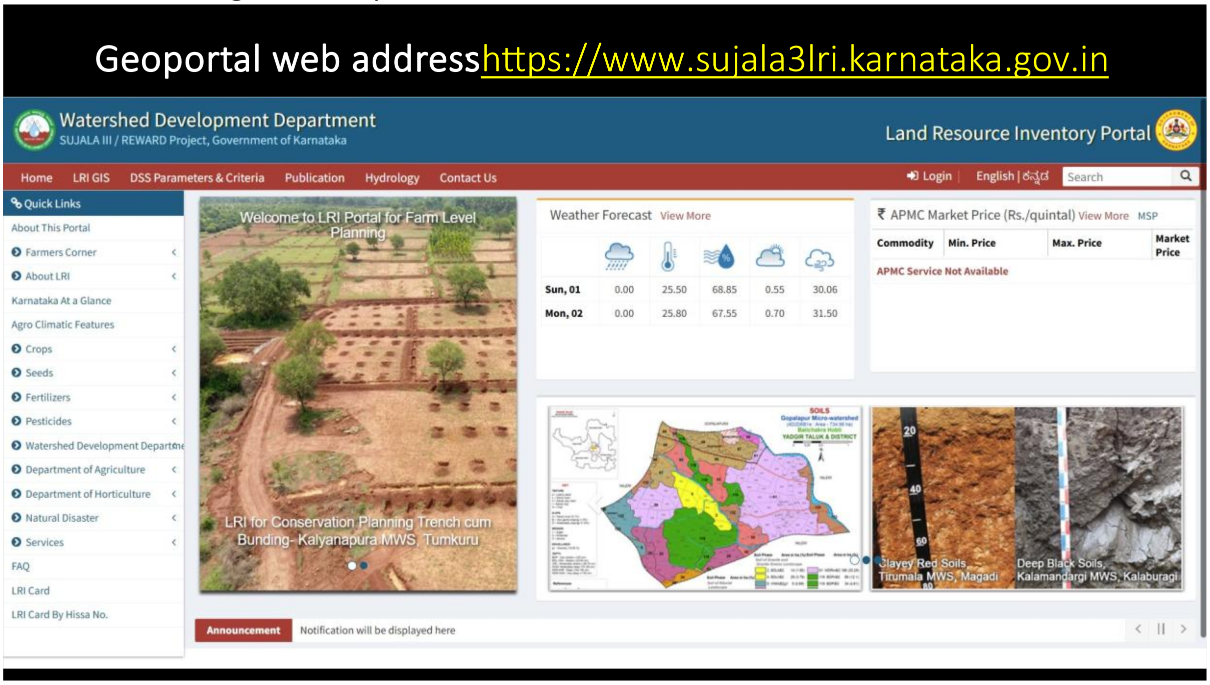
Annexure-12

Downloading Draft DPR from LRI Geoportal

The step-by-step procedure to download the Draft Detailed Project Report (DPR) using the Decision Support System (DSS) available on the LRI Geoportal is given below. Each step corresponds to a specific action, supported by an indicative screenshot.

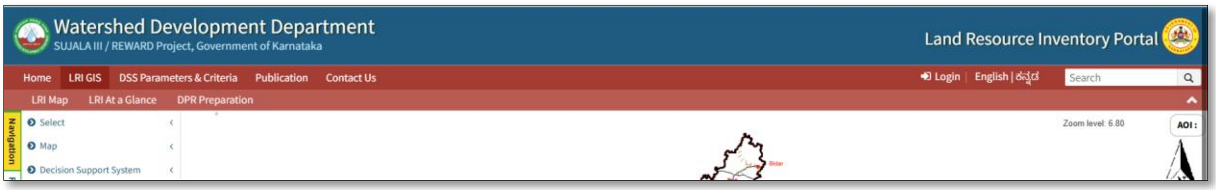
Step 1

Instruction: Open the LRI Geoportal (https://www.sujala3lri.karnataka.gov.in). The registration and login are not mandatory. Therefore, user can directly access the geoportal functionalities to get the output.



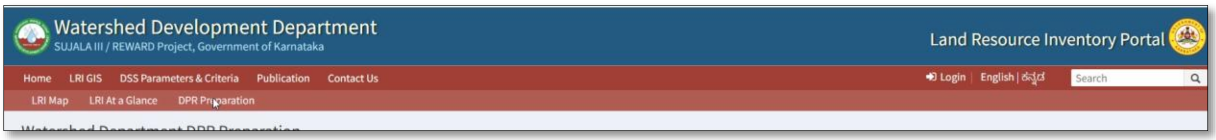
Step 2

Instruction: From the dashboard, click on the 'LRI GIS' tab next to "Home" tab.



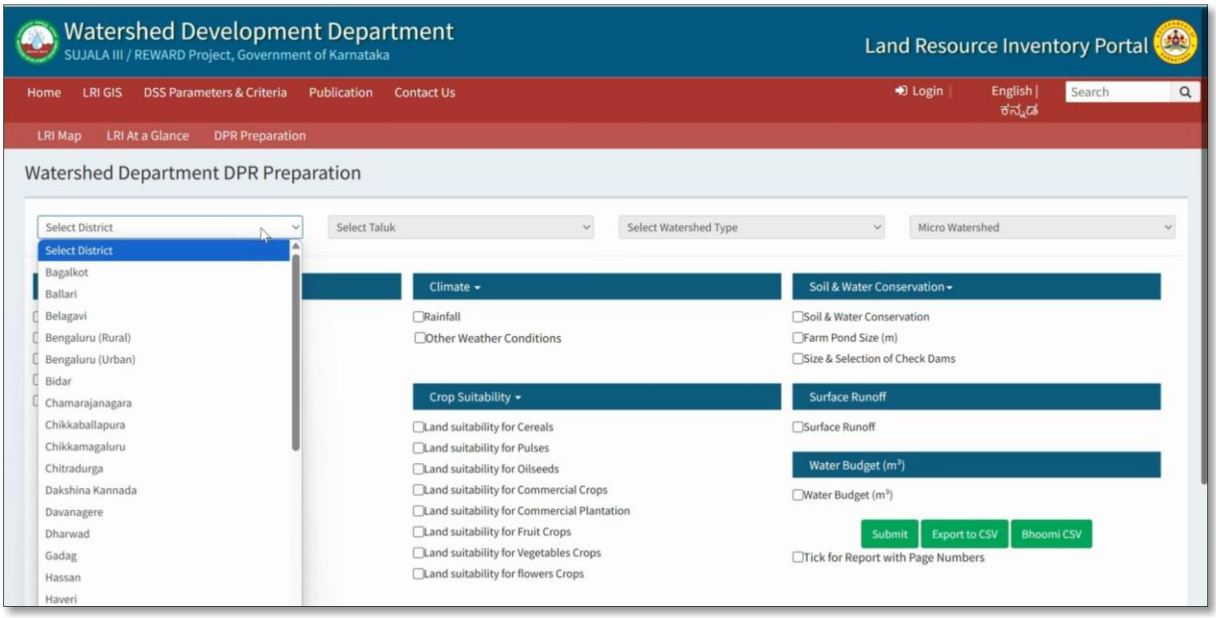
Step 3

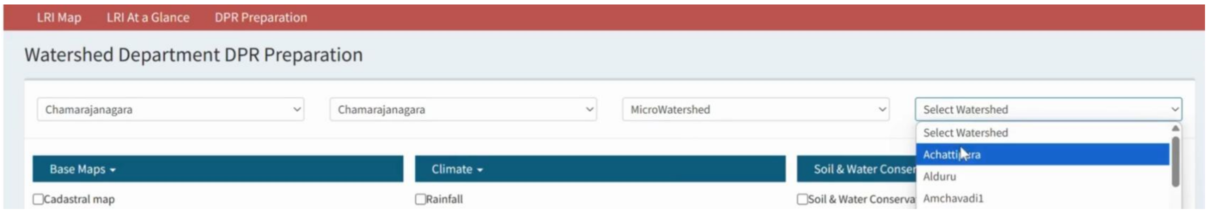
Instruction: Next, click on the "DPR Preparation" module to initiate the process.



Step 4

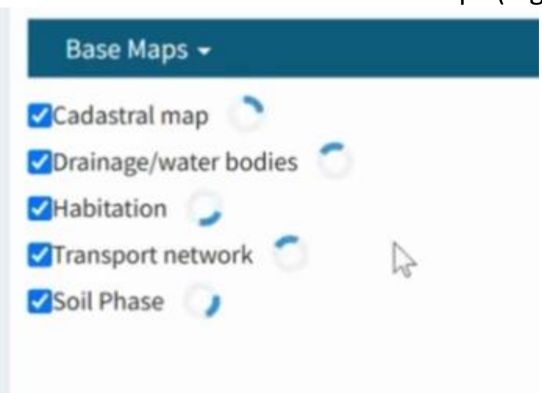
Instruction: Choose the required administrative units: District, Taluk, and Watershed.





Step 5

Instruction: Select desired base maps (e.g., Cadastral map, Habitation, etc).

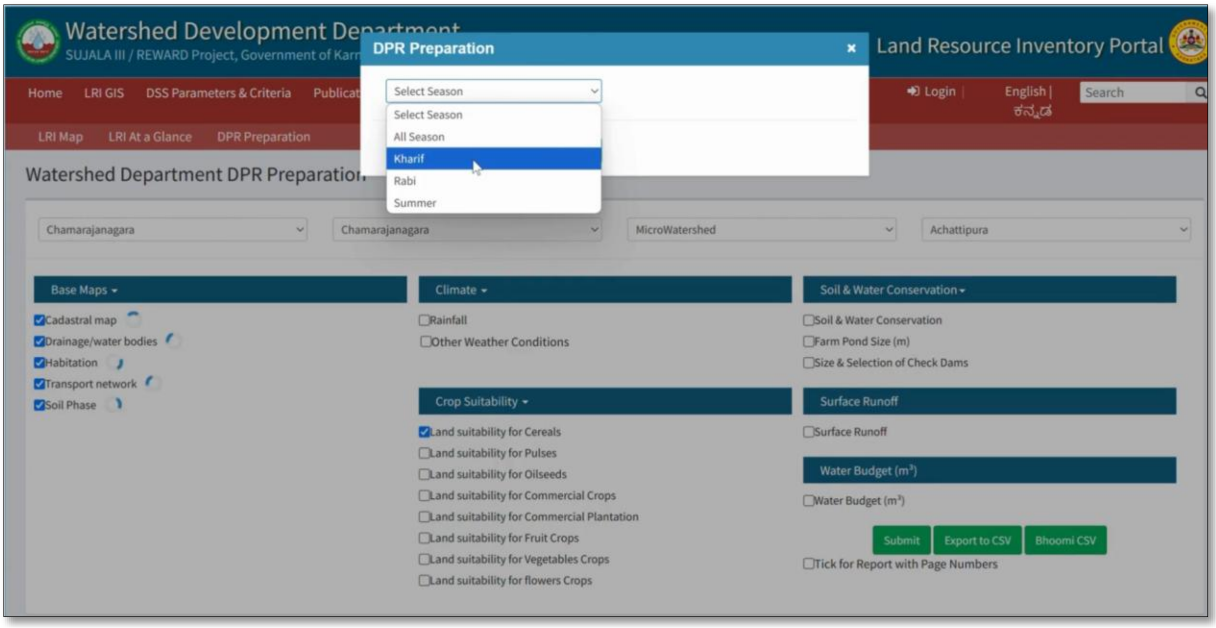


NOTE: Once the Base maps are selected, the user can only opt for PDF version of the draft DPR. But, if the user wants to download the DPR in the CSV (similar to Excel) format, then the base maps are not to be selected.

Step 6

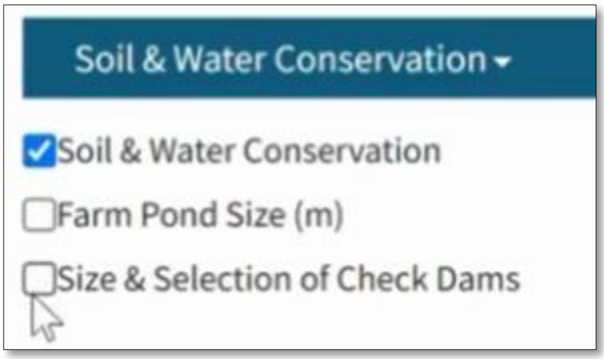
Instruction: In the "Crop Suitability" section, select the crop type category using tick marks, for which the DPR is needed.

Next, a pop-up window appears to select the Season. The user should know the appropriate season for the selected type of crop category. For example, the cereals cannot be "All season" crop but either "Kharif", "Rabi", or "Summer".

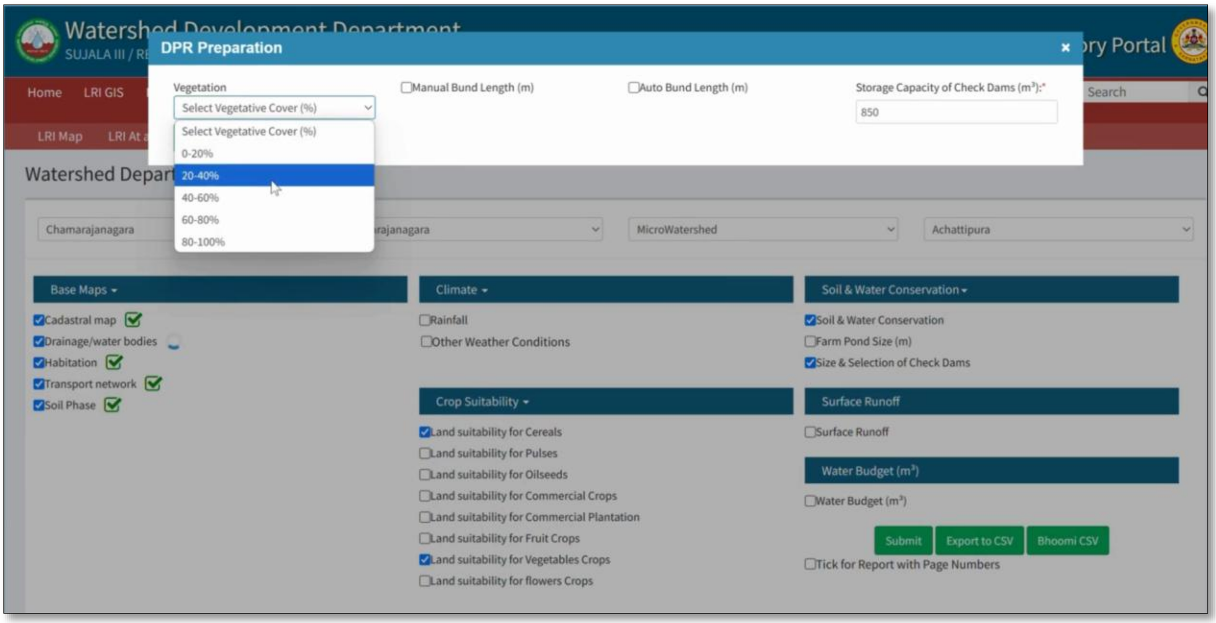


Step 7

Instruction: In the “Soil & Water Conservation” section, select the required conservation measure using tick marks.



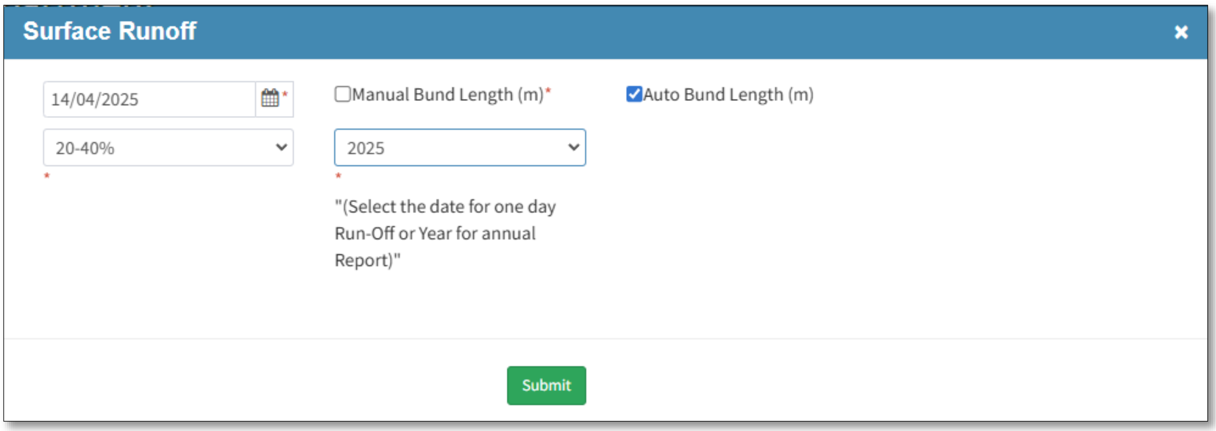
NOTE: For the “Size and Selection of Check Dams”, a pop-up window appears. Provide the inputs like “Percentage of vegetative cover, Bund Length (If it is not known, then user can opt for “Auto Bund Length”, and the “Storage Capacity of the proposed Check Dams” (by default it will be 850 m^3).



Step 8

Instruction: In the “Surface Runoff” section, select the required conservation measure using tick marks. This method uses “Infiltration method” to calculate the surface runoff volume by default.

NOTE: For the “Surface Runoff”, a pop-up window appears. Provide the inputs like “Date of runoff causing event”, Bund Length (If it is not known, then user can opt for “Auto Bund Length”), and the “Vegetative cover percentage” of that location.

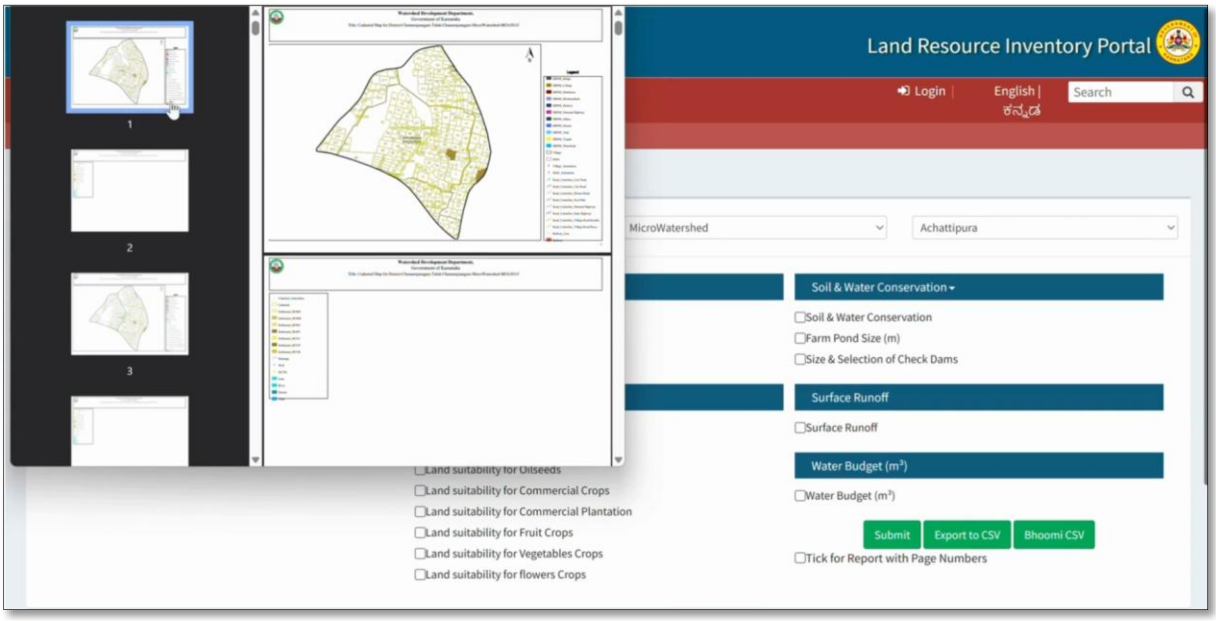


Next, hit the small submit button in the pop-up window of the “Surface Runoff”.

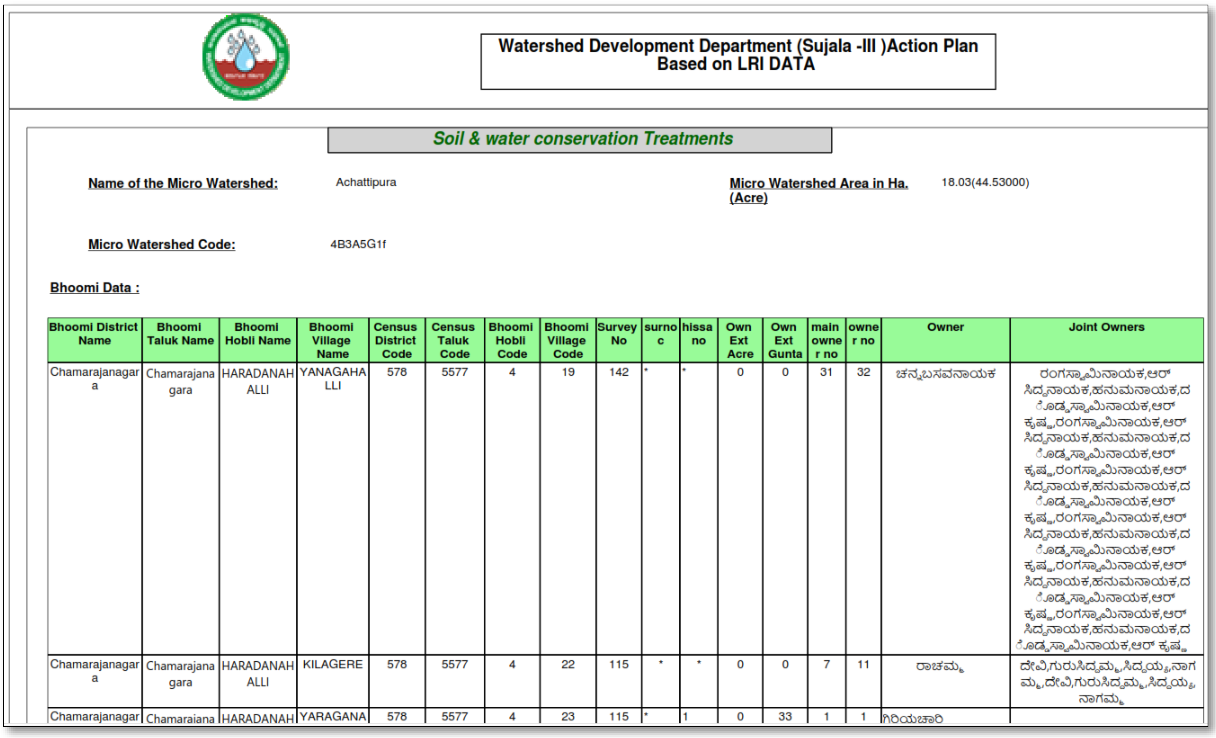
Step 9

Instruction: Review the report contents on-screen to ensure accuracy.

Click the 'Submit' button to save the PDF version of the DPR locally.



A sample of the PDF version of the draft DPF is given below.



Watershed Development Department (Sujala -III)Action Plan Based on LRI DATA

Soil & water conservation Treatments

Name of the Micro Watershed: Achattipura

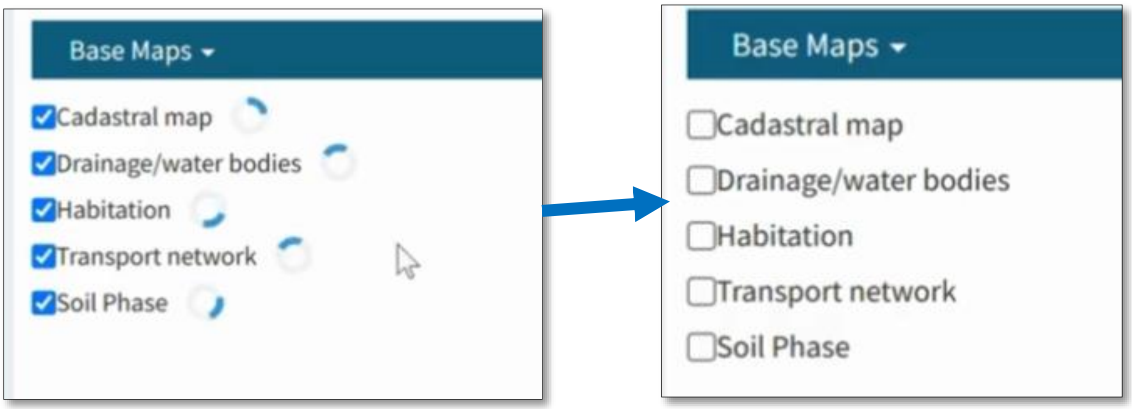
Micro Watershed Area in Ha. (Acre) 18.03(44.53000)

Micro Watershed Code: 4B3A5G1f

Bhoomi Data :

Bhoomi District Name	Bhoomi Taluk Name	Bhoomi Hobli Name	Bhoomi Village Name	Census District Code	Census Taluk Code	Bhoomi Hobli Code	Bhoomi Village Code	Survey No	surnoc	hissa no	Own Ext Acre	Own Ext Gunta	main owner no	owner no	Owner	Joint Owners
Chamarajanagara	Chamarajanagara	HARADANAHALLI	YANAGAHALLI	578	5577	4	19	142	*	*	0	0	31	32	ಚನ್ನಬಸವನಾಯಕ	ರಂಗಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಸಿದ್ದನಾಯಕ,ಹನುಮನಾಯಕ,ದೊಡ್ಡಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಕೃಷ್ಣ,ರಂಗಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಸಿದ್ದನಾಯಕ,ಹನುಮನಾಯಕ,ದೊಡ್ಡಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಕೃಷ್ಣ,ರಂಗಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಸಿದ್ದನಾಯಕ,ಹನುಮನಾಯಕ,ದೊಡ್ಡಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಕೃಷ್ಣ,ರಂಗಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಸಿದ್ದನಾಯಕ,ಹನುಮನಾಯಕ,ದೊಡ್ಡಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಕೃಷ್ಣ,ರಂಗಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಸಿದ್ದನಾಯಕ,ಹನುಮನಾಯಕ,ದೊಡ್ಡಸ್ವಾಮಿನಾಯಕ,ಆರ್ ಕೃಷ್ಣ
Chamarajanagara	Chamarajanagara	HARADANAHALLI	KILAGERE	578	5577	4	22	115	*	*	0	0	7	11	ರಾಚಮ್ಮ	ದೇವಿ,ಗುರುಸಿದ್ದಮ್ಮ,ಸಿದ್ದಯ್ಯ,ನಾಗಮ್ಮ,ದೇವಿ,ಗುರುಸಿದ್ದಮ್ಮ,ಸಿದ್ದಯ್ಯ,ನಾಗಮ್ಮ
Chamarajanagar	Chamarajana	HARADANAH	YARAGANA	578	5577	4	23	115	*	1	0	33	1	1	ಗಿರಿಯಚಾರಿ	

NOTE: If the user wants to download the CSV version of the DPR, then



The user has to "Un-check" the Base maps and click the "Export to CSV" button.

Step 10

Instruction: Review the report contents in the PDF and CSV files to ensure the accuracy. Refer to the file *"DownloadDRPDSSAllReport.pdf"* and the *"ZipDRPDSSReportCSV_2025-Oct-27-175221.zip"* file to verify that your downloaded Draft DPR. The sample CSV file for the "Crop Suitability" is provided below.

VillageName	Survey_No	Bajra	BarnyardMilletMinorMillet	FoxtailMilletNavaneDry	Hybridmaizeirrigated	Hybridmaizerainfed	KodoMilletHaraka	LittleMilletSame	Maize	PaddyLongDurationKharif	Pr
Yanagalli	142	S1 dcset	S1dcset	S1dcset	S1dcset	S1	S1	S1	S1	S1	
Keelagere	200	S2	S2	S2	S2	Not Assessed	S3	S3	S3dcset	S1	
Yanagalli	124	S3cs	S3cs	S3cs	S2cs	S2e	S3	S3	S3cs	S3	
Yanagalli	128	S3dcset	S3dcset	S3dcset	S3dcset	Not Assessed	S2dcset	S2dcset	S1dcset	S3detc	
Yanagalli	122	S3 dcset	S3dcset	S3dcset	S3dcset	Not Assessed	S3dcset	S3dcset	S2	S3 dsetc	
Yanagalli	123	S3 dcset	S3dcset	S3dcset	S3dcset	S3e	S3dcset	S3dcset	S2	S3 dsetc	
Yanagalli	93	S3 dcset	S3dcset	S3dcset	S3dcset	S3e	S3dcset	S3dcset	S2	S3 dsetc	
Yanagalli	92	S3	S2	S2	S3	Not Assessed	S2dcset	S2dcset	S2dcset	S3detc	
Yanagalli	121	S3 dcset	S3dcset	S3dcset	S3dcset	Not Assessed	S3dcset	S3dcset	S2	S3 dsetc	
Yanagalli	120	S3	S1dcset	S1dcset	S3	S3	S2dcset	S2dcset	S2dcset	S2	
Yanagalli	89	S3	S2	S2	S3	Not Assessed	S2dcset	S2dcset	S2dcset	S3detc	
Yanagalli	94	S3 dcset	S3dcset	S3dcset	S3dcset	S3e	S3dcset	S3dcset	S2dcset	S3 dsetc	
Yanagalli	118	S3 dcset	S3dcset	S3dcset	S2	Not Assessed	S3	S3	S1dcset	S2	
Yanagalli	88	S3	S2	S2	S3	Not Assessed	S3	S3	S3dcset	S1	
Yanagalli	119	S3 dcset	S3dcset	S3dcset	S3dcset	S3e	S2dcset	S2dcset	S2dcset	S3 dsetc	
Keelagere	218	S3	S2	S2	S2	Not Assessed	S3	S3	S2dcset	S3	
Yanagalli	96	S3 dcset	S3dcset	S3dcset	S3dcset	Not Assessed	S3dcset	S3dcset	S3dcset	S3 dsetc	
Yanagalli	117	S3 dcset	S3dcset	S3dcset	S3	S2e	S3dcset	S3dcset	S2dcset	S3	
Keelagere	228	S3 dcset	S3dcset	S3dcset	S3	Not Assessed	S3dcset	S3dcset	S1dcset	S1 dsetc	
Yanagalli	116	S3 dcset	S3dcset	S3dcset	S3dcset	Not Assessed	S3dcset	S3dcset	S1dcset	S3	
Yanagalli	97	S2	S1dcset	S1dcset	S3dcset	Not Assessed	S3dcset	S3dcset	S1dcset	S3	
Keelagere	217	S3	S2	S2	S2	Not Assessed	S3	S3	S2dcset	S3	
Yanagalli	115	S3 dcset	S3dcset	S3dcset	S3dcset	Not Assessed	S3dcset	S3dcset	S1dcset	S3	
Yanagalli	98	S2	S1dcset	S1dcset	S3dcset	Not Assessed	S3dcset	S3dcset	S1dcset	S3	
Yanagalli	103	S3	S3dcset	S3dcset	S3dcset	Not Assessed	S3dcset	S3dcset	S2dcset	S3 dsetc	
Yanagalli	84	S3dcset	S3dcset	S3dcset	S3dcse	Not Assessed	S2dcset	S2dcset	S1dcse	S3detc	
Yanagalli	99	S3	S2	S2	S2	Not Assessed	S3	S3	S2dcset	S2 dsetc	
Yanagalli	83	S2	S2	S2	S3	Not Assessed	S3	S3	S2dcse	S2	
Yanagalli	78	S3dcset	S3dcset	S3dcset	S3dcse	Not Assessed	S2dcset	S2dcset	S1dcse	S3detc	

The sample CSV file for the “Soil & Water Conservation” is provided below.

Sl No	MWS Code	MWS Name	Village	Soilphase	Survey_No	Total Area in ha of survey number	treatement	Length (m)	Cross Section	Main Bund Cost (Rs.)	Side Bund Cost (Rs.)	Cost Of Waste Weir (Rs.)
2356	4B3A5G1f	Achattipura	Yanagalli	CKMmB1	103	67.53(166.80000)	Graded Bunding	472.74	0	20086.8	0	20086.8
2357	4B3A5G1f	Achattipura	Yanagalli	CKMmB1	103	67.53(166.80000)	Graded Bunding	472.74	0	20086.8	0	20086.8
2358	4B3A5G1f	Achattipura	Yanagalli	CKMmB1	103	67.53(166.80000)	Graded Bunding	472.74	0	20086.8	0	20086.8
2359	4B3A5G1f	Achattipura	Yanagalli	CKMmB1	103	67.53(166.80000)	Graded Bunding	472.74	0	20086.8	0	20086.8
2360	4B3A5G1f	Achattipura	Yanagalli	CKMmB1	103	67.53(166.80000)	Graded Bunding	472.74	0	20086.8	0	20086.8
2361	4B3A5G1f	Achattipura	Yanagalli	CKMmB1	103	67.53(166.80000)	Graded Bunding	472.74	0	20086.8	0	20086.8
1171	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	92	67.53(166.80000)	Graded Bunding	462.7	0	19660	0	19660
1172	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	92	67.53(166.80000)	Graded Bunding	462.7	0	19660	0	19660
1173	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	92	67.53(166.80000)	Graded Bunding	462.7	0	19660	0	19660
1073	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	15	67.53(166.80000)	Graded Bunding	358.13	0	15216.9	0	15216.9
1074	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	15	67.53(166.80000)	Graded Bunding	358.13	0	15216.9	0	15216.9
1075	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	15	67.53(166.80000)	Graded Bunding	358.13	0	15216.9	0	15216.9
1076	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	15	67.53(166.80000)	Graded Bunding	358.13	0	15216.9	0	15216.9
1077	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	15	67.53(166.80000)	Graded Bunding	358.13	0	15216.9	0	15216.9
1078	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	15	67.53(166.80000)	Graded Bunding	358.13	0	15216.9	0	15216.9
1079	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	15	67.53(166.80000)	Graded Bunding	358.13	0	15216.9	0	15216.9
1080	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	15	67.53(166.80000)	Graded Bunding	358.13	0	15216.9	0	15216.9
1081	4B3A5G1f	Achattipura	Acchattepura	HLKmB1	15	67.53(166.80000)	Graded Bunding	358.13	0	15216.9	0	15216.9

The user can also select other DSS options and can download the draft DPR. Once the draft DPR is downloaded, the user has to take caution to verify the outputs and proceed accordingly. This automated system is helping the user to support the decisions of the user, and thus the user can take their own decisions based on the recommendations of the portal.

Annexure-13

Set of advisories developed for finger millet crop under different past and forecasted weather conditions, growth stages.

ಬಿತ್ತ ದಿನಾಂಕ	ತಳಿಗಳು	ಬಿತ್ತನೆ ನಂತರದ ದಿನಗಳ ಸಂಖ್ಯೆ	ಬೆಳೆಯ ಹಂತ	ಹಿಂದಿನ ವಾರದ ಹವಾಮಾನ: ಮಳೆ: ವಾಡಿಕೆ, ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ, ವಾಡಿಕೆಗಿಂತ ಹೆಚ್ಚು	ಮುಂದಿನ ವಾರದ ಮುನ್ಸೂಚನೆ: ಮಳೆ: ಇದೆ, ಇಲ್ಲ	ಮಣ್ಣಿನಲ್ಲಿ ನೀರನ್ನು ಹಿಡಿದಿಟ್ಟುಕೊಳ್ಳುವ ಸಾಮರ್ಥ್ಯ	ಸಲಹೆಗಳು	ಸಲಹೆಗಳು (ಸಸ್ಯ ಸಂರಕ್ಷಣೆ)
ಜೂನ್ - ಜುಲೈ	ಇಂಡಾಫ್–8, ಎಮ್ ಆರ್–1, ಎಮ್ ಆರ್–6, ಎಲ್–5 (ದೀರ್ಘಾವಧಿ ತಳಿಗಳು 120–130 ದಿನಗಳು)	0–5	Germination (ಮೊಳಕೆಯೊಡೆಯುವಿಕೆ)	ವಾಡಿಕೆ	ಇದೆ		8 ಕೆ.ಜಿ./ಎಕರೆ ಬಿತ್ತನೆ ಬೀಜಗಳನ್ನು 1 ಅಡಿ ಸಾಲುಗಳ ಅಂತರದಲ್ಲಿ ಬಿತ್ತನೆ ಮಾಡುವುದು. ಭೂ.ಸಂ.ಆ. ಆಧಾರಿಸಿ ಶಿಫಾರಸ್ಸು ಮಾಡಲಾದ ರಸಗೊಬ್ಬರಗಳ ಬಳಕೆ + ಜೈವಿಕ ಗೊಬ್ಬರಗಳ ಬಳಕೆ (ರೈಜೊಬಿಯಂ, ರಂಜಕ ಕರಗಿಸುವ ಜೀವಾಣುಗಳ ಬಳಕೆ).	
ಜುಲೈ–ಆಗಸ್ಟ್	ಜಿಪಿಯು–28, ಜಿಪಿಯು–66, ಎಮ್ ಎಲ್–365, ಇಂಡಾಫ್–5 (ಮಧ್ಯಮಾವಧಿ ತಳಿಗಳು 106–120 ದಿನಗಳು)	05–12	Establishment (ಮೊಳಕೆ ಜೊರಜೊಮ್ಮುವಿಕೆ)	ವಾಡಿಕೆ	ಇದೆ		ಮೊಳಕೆ ಬಾರದಿರುವ ಜಾಗಗಳಲ್ಲಿ ಬಿತ್ತನೆ ಮಾಡುವುದು	
ಆಗಸ್ಟ್– ಸೆಪ್ಟೆಂಬರ್	ಇಂಡಾಫ್–9, ಜಿಪಿಯು–45, ಜಿಪಿಯು–28, ಜಿಪಿಯು–48 (ಅಲ್ಪಾವಧಿ ತಳಿಗಳು 95 ರಿಂದ 105 ದಿನಗಳು)			ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇದೆ		ಮಳೆಯ ಮುನ್ಸೂಚನೆಗನುಸಾರ ಮರುಬಿತ್ತನೆ ಕೈಗೊಳ್ಳುವುದು	
				ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇಲ್ಲ	ಕಡಿಮೆ	ಸಂರಕ್ಷಣಾ ನೀರಾವರಿ ಕೊಡುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಹೆಚ್ಚು	ಇದೆ	ಅಧಿಕ	ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಲ್ಲದಂತೆ ಬಸಿಯುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಹೆಚ್ಚು	ಇಲ್ಲ		ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಂತಿದ್ದರೆ ಬಸಿಯುವುದು.	

ವಾರ ತಿಂಗಳು	ತಳಿಗಳು	ಬಿತ್ತನೆ ನಂತರದ ದಿನಗಳ ಸಂಖ್ಯೆ	ಬೆಳೆ ಹಂತ	ಹಿಂದಿನ ವಾರದ ಹವಾಮಾನ: ಮಳೆ: ವಾಡಿಕೆ, ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ, ವಾಡಿಕೆಗಿಂತ ಹೆಚ್ಚು	ಮುಂದಿನ ವಾರದ ಮುನ್ಸೂಚನೆ: ಮಳೆ: ಇದೆ, ಇಲ್ಲ	ಮಣ್ಣಿನಲ್ಲಿ ನೀರನ್ನು ಹಿಡಿದಿಟ್ಟುಕೊಳ್ಳುವ ಸಾಮರ್ಥ್ಯ	ಸಲಹೆಗಳು	ಸಲಹೆಗಳು (ಸಸ್ಯ ಸಂರಕ್ಷಣೆ)
		.12–22	Vegetative stage (ಬೆಳವಣಿಗೆ ಹಂತ)	ವಾಡಿಕೆ	ಇದೆ		ಹೆಚ್ಚಾಗಿರುವ (4 ಅಂಗುಲ ಅಂತರಕ್ಕೆ ಒಂದರಂತೆ) ಗಿಡಗಳನ್ನು ತೆಗೆದುಹಾಕುವುದು.	ಎಲೆ ಬೆಂಕಿರೋಗ ಹಾಗೂ ಕುತ್ತಿಗೆ ರೋಗ ಕಂಡು ಬಂದಲ್ಲಿ ಲೀ. ನೀರಿಗೆ 2 ಗ್ರಾಂ ಮ್ಯಾಂಕೋಜೆಬ್ 75 ಡಬ್ಲ್ಯೂಪಿ. ಅಥವಾ 5 ಗ್ರಾಂ. ಟ್ರೈಸೈಕ್ಲಾಜೋಲ್ ಶೇ. 18 + ಮ್ಯಾಂಕೋಜೆಬ್ ಶೇ. 62 ಡಬ್ಲ್ಯೂಪಿ. ಯನ್ನು ಬೆರೆಸಿ ಸಿಂಪರಣೆ ಮಾಡುವುದು
	ಪೂರ್ವ ಸಿದ್ದತೆ: ೧. ಭೂಮಿಯನ್ನು ೧–೨ ಬಾರಿ ಉಳುಮೆ ಮಾಡುವುದು			ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇದೆ		ಸಸ್ಯ ಸಂಖ್ಯೆ ಶೇ70 ಕ್ಕಿಂತ ಕಡಿಮೆಯಿದ್ದಲ್ಲಿ ಮರುಬಿತ್ತನೆ ಕೈಗೊಳ್ಳಲು ಯೋಜಿಸುವುದು	
	೨. ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರವನ್ನು (೩ ಟನ್/ಎಕರೆ)ಗೆ ೩–೪ ವಾರ ಬಿತ್ತನೆಗೆ ಮುಂಚಿತವಾಗಿ ಮಣ್ಣಿಗೆ ಸೇರಿಸುವುದು			ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇಲ್ಲ	ಕಡಿಮೆ	ಸಾಧಾರಣ ಸಸ್ಯಸಂಖ್ಯೆಯಿದ್ದಲ್ಲಿ ಸಂರಕ್ಷಣಾ ನೀರಾವರಿ ಕೊಡುವುದು.	
	೩. ಪೂರ್ವ ಮುಂಗಾರಿನ ತೇವಾಂಶದನುಸಾರ ಏಪ್ರಿಲ್–ಮೇ ತಿಂಗಳಿನಲ್ಲಿ ಹಸಿರೆಲೆ ಗೊಬ್ಬರವಾಗಿ ಅಪ್‌ಸೆಣಬು, ಹುರುಳಿ ಅಥವಾ ಅಲಸಂದೆಯನ್ನು ಬಿತ್ತುವುದು			ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇದೆ	ಅಧಿಕ	ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಲ್ಲದಂತೆ ಬಸಿಯುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇಲ್ಲ		ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಂತಿದ್ದರೆ ಬಸಿಯುವುದು.	

[illegible]	ತಳಿಗಳು	ಬಿತ್ತನೆ ನಂತರದ ದಿನಗಳ ಸಂಖ್ಯೆ	ಬೆಳೆ ಹಂತ	ಹಿಂದಿನ ವಾರದ ಹವಾಮಾನ: ಮಳೆ: ವಾಡಿಕೆ, ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ, ವಾಡಿಕೆಗಿಂತ ಹೆಚ್ಚು	ಮುಂದಿನ ವಾರದ ಮುನ್ಸೂಚನೆ: ಮಳೆ: ಇದೆ, ಇಲ್ಲ	ಮಣ್ಣಿನಲ್ಲಿ ನೀರನ್ನು ಹಿಡಿದಿಟ್ಟುಕೊಳ್ಳುವ ಸಾಮರ್ಥ್ಯ	ಸಲಹೆಗಳು	ಸಲಹೆಗಳು (ಸಸ್ಯ ಸಂರಕ್ಷಣೆ)
		22–35	Tillering (ತೆಂಡೆಯೊಡೆಯುವ ಹಂತ)	ವಾಡಿಕೆ	ಇದೆ		ಬಿತ್ತಿದ 30–35 ದಿನಗಳೊಳಗೆ ಅಂತರಬೇಸಾಯದ ಮೂಲಕ ಕಳೆ ನಿರ್ವಹಣೆ ಮತ್ತು ಭೂ.ಸಂ.ಅ. ಆಧಾರಿತ ಸಾರಜನಕ ಮೇಲುಗೊಬ್ಬರ ಕೊಡುವುದು.	ಕಾಂಡಕೊರಕ ಅಥವಾ ಸಸ್ಯಹೇನು ಕಂಡುಬಂದಲ್ಲಿ ಕ್ಲೋರ್‌ಪೈರಿಪಾಸ್ 20 ಇ. ಸಿ. 2 ಮಿ. ಲೀ/ಲೀ ಅಥವಾ 0.4 ಮಿ.ಲೀ. ಇಮಿಡಾಕ್ಲೋಪ್ರಿಡ್ 17.8 ಎಸ್.ಎಲ್. ಬೆರೆಸಿ ಸಿಂಪರಣೆ ಮಾಡುವುದು.
				ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇದೆ		ಬಿತ್ತಿದ 30–35 ದಿನಗಳೊಳಗ ಕಳೆ ನಿರ್ವಹಣೆ ಮತ್ತು ಅಂತರ ಬೇಸಾಯ ಕೈಗೊಳ್ಳುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇಲ್ಲ	ಕಡಿಮೆ	ಸಾಧ್ಯವಿದ್ದಲ್ಲಿ ಸಂರಕ್ಷಣಾ ನೀರಾವರಿ ಕೊಡುವುದು, ಮಣ್ಣಿನ ತೇವಾಂಶವನ್ನು ಉಳಿಸಿಕೊಳ್ಳಲು ಅನುಪಯುಕ್ತ ಸಸ್ಯದ ಭಾಗಗಳನ್ನು ಮಣ್ಣಿನ ಮೇಲೆ ಹೊದಿಕೆಯ ರೀತಿ ಹಾಕುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇದೆ	ಅಧಿಕ	ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಲ್ಲದಂತೆ ಬಸಿಯುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇಲ್ಲ		ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಂತಿದ್ದರೆ ಬಸಿಯುವುದು.	
		35–45	panicle initation (ತೆನೆಯೊಡೆಯುವಿಕೆ)	ವಾಡಿಕೆ	ಇದೆ			
				ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇದೆ		ಶೇ 1 ರಷ್ಟು (10ಗ್ರಾಂ ಪ್ರತಿ ಲೀ ನೀರಿಗೆ) ಪೊಟ್ಯಾಶಿಯಂ ಸಿಂಪಡಿಸುವುದು	
				ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇಲ್ಲ	ಕಡಿಮೆ	ಸಂರಕ್ಷಣಾ ನೀರಾವರಿ ಕೊಡುವುದು	

ಬಿತ್ತ ದಿನಾಂಕ	ತಳಿಗಳು	ಬಿತ್ತನೆ ನಂತರದ ದಿನಗಳ ಸಂಖ್ಯೆ	ಬೆಳೆಯ ಹಂತ	ಹಿಂದಿನ ವಾರದ ಹವಾಮಾನ: ಮಳೆ: ವಾಡಿಕೆ, ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ, ವಾಡಿಕೆಗಿಂತ ಹೆಚ್ಚು	ಮುಂದಿನ ವಾರದ ಮುನ್ಸೂಚನೆ: ಮಳೆ: ಇದೆ, ಇಲ್ಲ	ಮಣ್ಣಿನಲ್ಲಿ ನೀರನ್ನು ಹಿಡಿದಿಟ್ಟುಕೊಳ್ಳುವ ಸಾಮರ್ಥ್ಯ	ಸಲಹೆಗಳು	ಸಲಹೆಗಳು (ಸಸ್ಯ ಸಂರಕ್ಷಣೆ)
				ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇದೆ	ಅಧಿಕ	ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಲ್ಲದಂತೆ ಬಸಿಯುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇಲ್ಲ		ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಂತಿದ್ದರೆ ಬಸಿಯುವುದು.	
		45–90	Grain filling stage (ಕಾಳು ಕಟ್ಟುವ ಹಂತ)	ವಾಡಿಕೆ	ಇದೆ			
				ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇದೆ			
				ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇಲ್ಲ	ಕಡಿಮೆ	ಸಾಧ್ಯವಿದ್ದಲ್ಲಿ ಸಂರಕ್ಷಣಾ ನೀರಾವರಿ ಕೊಡುವುದು,	
				ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇದೆ	ಅಧಿಕ	ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಲ್ಲದಂತೆ ಬಸಿಯುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇಲ್ಲ		ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಂತಿದ್ದರೆ ಬಸಿಯುವುದು.	
		90–110	Maturity(ಕಾಳು ಮಾಗುವ ಹಂತ)	ವಾಡಿಕೆ	ಇದೆ			
				ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇದೆ			
				ವಾಡಿಕೆಗಿಂತ ಕಡಿಮೆ	ಇಲ್ಲ	ಕಡಿಮೆ	ಅತೀ ಬರ ಸ್ಥಿತಿಯಲ್ಲಿ ಬೆಳೆಯನ್ನು ಮೇವಿಗಾಗಿ ಕಟಾವು ಮಾಡುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇದೆ	ಅಧಿಕ	ಜಮೀನಿನಲ್ಲಿ ನೀರು ನಿಲ್ಲದಂತೆ ಬಸಿಯುವುದು. ಗಿಡಗಳು ನೆಲಕ್ಕುರುಳುವುದನ್ನು ತಡೆಯಲು ಕೂಡಿಸಿ ಕಟ್ಟುವುದು.	
				ವಾಡಿಕೆಗಿಂತ ಅಧಿಕ	ಇಲ್ಲ		ಗಿಡಗಳು ನೆಲಕ್ಕುರುಳುವುದನ್ನು ತಡೆಯಲು ಕೂಡಿಸಿ ಕಟ್ಟುವುದು.	
			Harvest (ಕೊಯ್ಲಿನ ಹಂತ)				ಕಾಳು ಮಾಗಿದ ನಂತರ, ಮಳೆಯ ಮುನ್ಸೂಚನೆಯಾಧಾರಿತ ಕಟಾವು ಮಾಡುವುದು	

References:

Borrowers Completion Report, 2020, Sujala-3 Project, KWDP-II, Watershed Development Department, Government of Karnataka

Desertification and Degradation Atlas of India, 2021, Ministry of Environment and Forests. Economics of Desertification, Land Degradation and Drought in India, 2018, TERI. GoI. 2022. Directorate of Economics and Statistics.

Handbook for Land Resource Inventory, REWARD Project, Karnataka, 2022, National Bureau of Soil Survey and Land Use Planning and Watershed Development Department, Government of Karnataka.

High level committee report on Wasteland Development, 1995, Ministry of Rural Development, Government of India. http://www.sujala3lri.karnataka.gov.in

SVAMITVA, 2020, Survey of Villages Abadi and Mapping with Improvised Technology in Village Areas, Ministry of Panchayat Raj, GoI.

Natarajan, A., 2006, Land Resources of Sivagangai Block, Soil Survey and Land Use Organisation, Department of Agriculture, Tamil Nadu

Natarajan, A., Land Resource Inventory for Climate Smart Agriculture, 2022, Dr S. V. Govindarajan Memorial Lecture, Nat. Seminar on Managing Soils in a Changing Climate, NBSS&LUP, Nagpur

Natarajan, A., Reddy R. S., Niranjana K. V., Rajendra Hegde, Srinivasan R., Dharumarajan S., Srinivas S., Dhanorkar B. A. and Vasundhara, R., 2016, Field Guide for Land Resource Inventory, Sujala III Project, Karnataka, National Bureau of Soil Survey and Land Use Planning, Nagpur, India.

National Mission for Sustainable Agriculture (NMSA-9) -Sub-Group -4 for Promoting Data Access of the NMSA under the National Action Plan on Climate Change (NAPCC), 2009, Department of Agriculture and Co-operation, GoI.

Operational Guidelines for implementation O&M Policy, 2019, Watershed Development Department, GoK

Our Farmers are toiling on decaying Soil, Coverage of Sujala-3 Project, 2018, The Hindu, dated Aug 6, 2018

Report of the working Group on Rainfed areas for formulation of 11th five-year plan, 2007, Planning Commission, Government of India.

Soil Survey Manual, Handbook No.18, 2019, United States Department of Agriculture, USA