



University of Agricultural Sciences, Bangalore Centre of Excellence on Watershed Management

Training Manual

Application of Scientific data Generated under REWARD for Planning and Management of Watershed Development and Line Departments Programs

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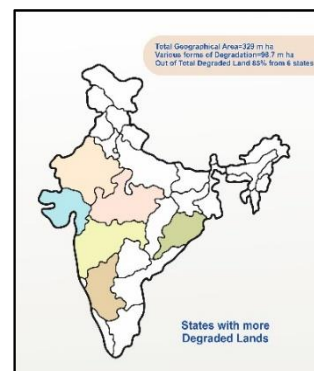
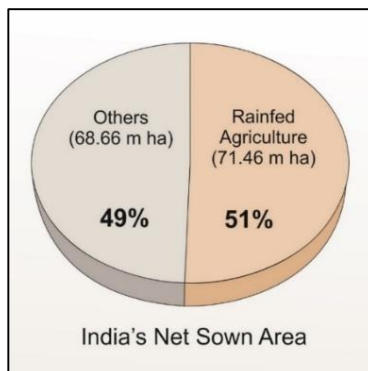
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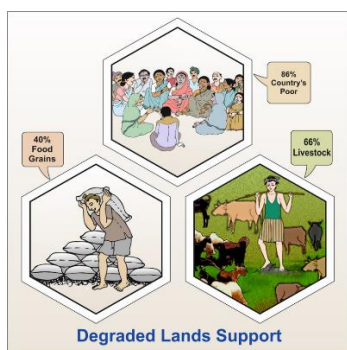
1. An overview of REWARD program

A. Watershed Development and its importance

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

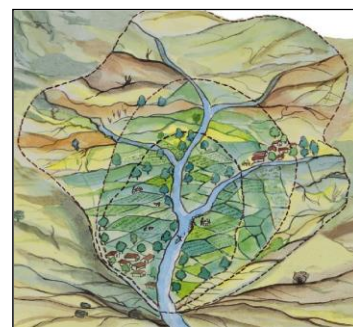


- 2.



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

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

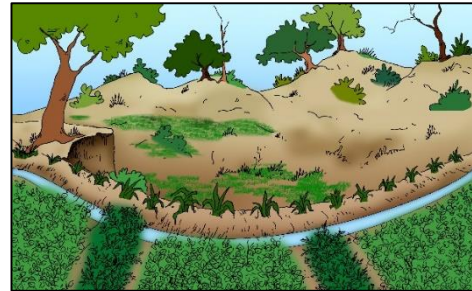
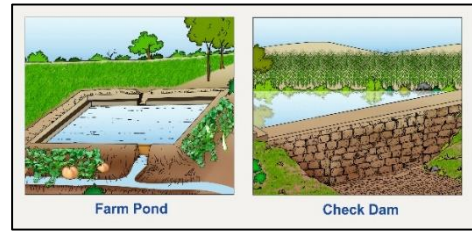


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Watershed Development in India has been a part of the national approach to improve agricultural production and alleviate poverty in rainfed regions since 1970s. Watershed development programs aim to restore degraded watersheds in rainfed regions to 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.

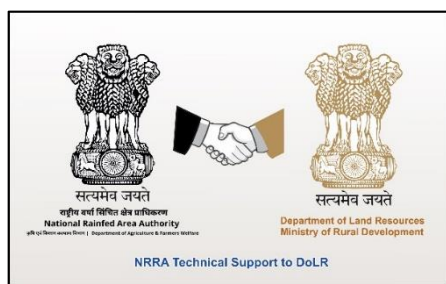
5. The objective of watershed development is maximizing the productivity and income per unit area, per unit time and per unit of water thereby improving the socio-economic status of the farmers. The objective of watershed development can be achieved through implementation of a series of systematic approaches,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



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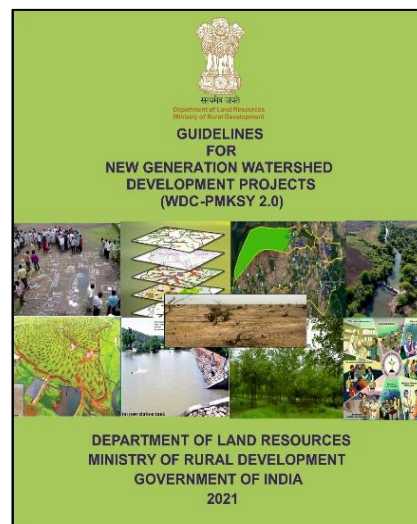


In 1970's Soil and water conservation was taken up with a focus on engineering structures mainly for protecting dams. In 1983, the Operation Research Projects (ORPs) were established in 47 watersheds spread over 16 states covering an area of 35739 ha under the technical guidance of Indian Council of 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.

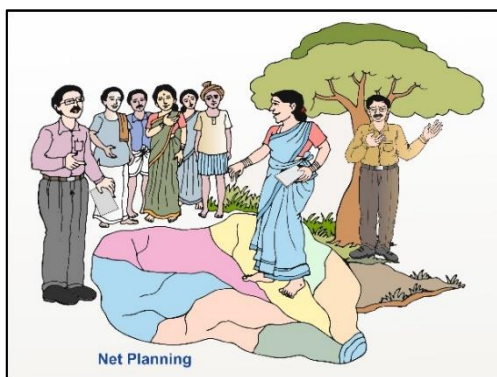


In 2006 National Rainfed Area Authority (NRAA) by the Planning Commission was established to provide technical support to Department of Land Resources (DoLR), GoI, and issued common guidelines for all watershed development programmes for the development of rainfed farming in India.

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.



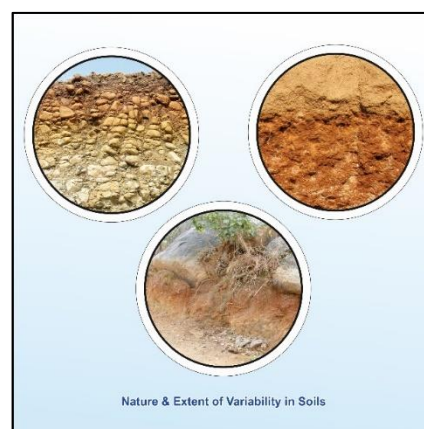
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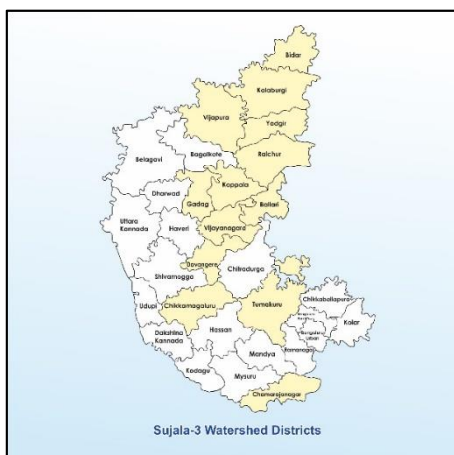
The common approach followed in watershed planning in earlier watershed development programmes was, net-planning which is an eyesight-based planning for each survey number. The designs of drainage line structure were standardized ones and do not take into account the run-off available at the site. Indiscriminately,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



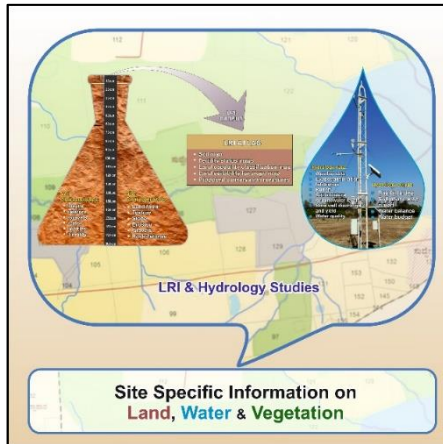
10. Realizing the importance of site-specific soil and other information for taking up targeted interventions, the World Bank supported Karnataka watershed Development Project-KWDP II, popularly known as Sujala-3 project, implemented from 2013 to 2019 in about



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 development 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.

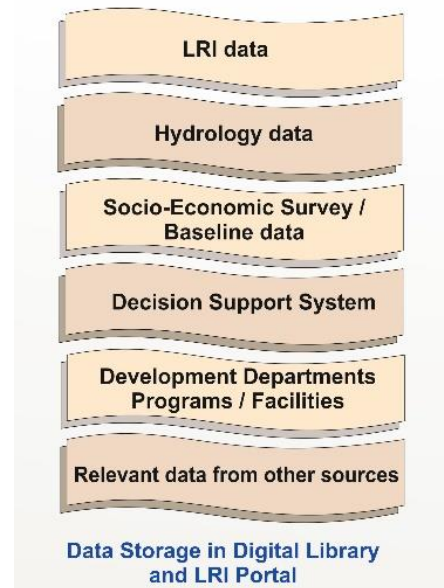
- The uniqueness Sujala-3 project was adoption of more advanced scientific approaches for capturing the data on status of land, water, and other resources at cadastral level through land resource inventory (LRI) and hydrological assessments for preparation of scientific Detailed Project Reports (DPR)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

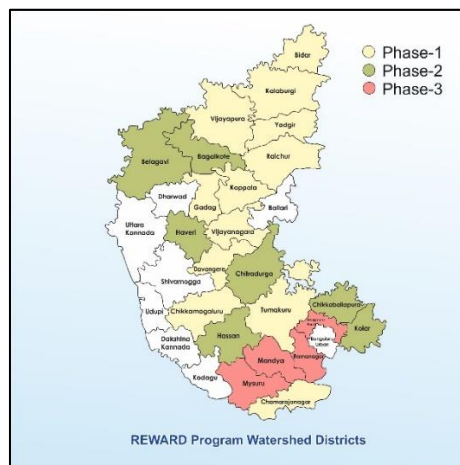
- To carryout LRI and hydrological studies under Sujala-3 project, 15 scientific consortium partners were involved. Development of Decision Support System (DSS), to improve watershed planning, by integrating the data base generated with decision criteria, models and algorithms is one of the noteworthy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



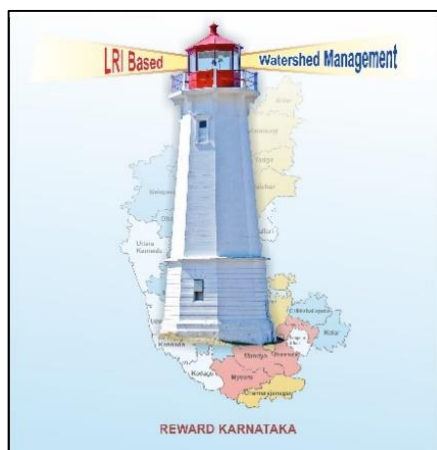
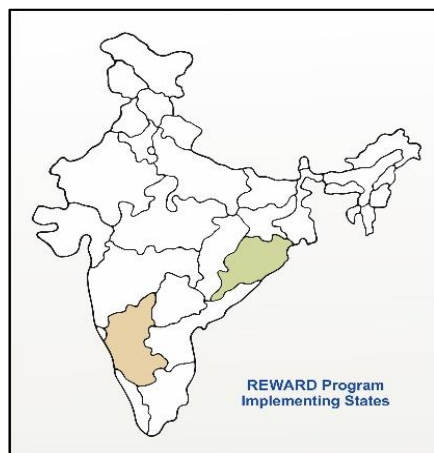
C. Emergence of REWARD program

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

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

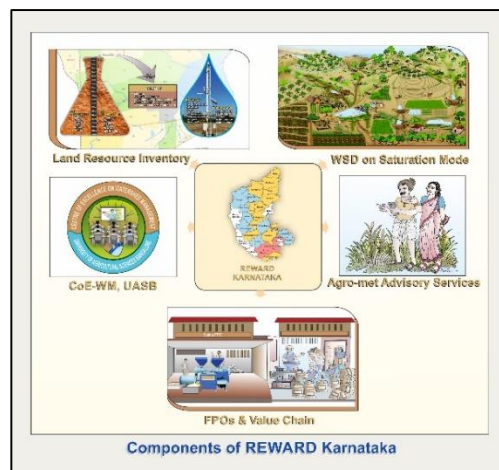


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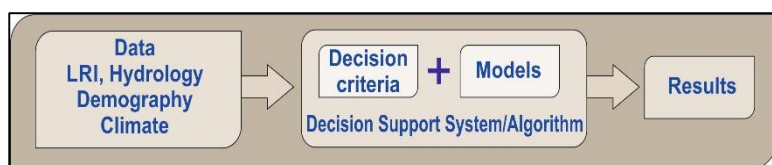


The REWARD-Rejuvenating Watersheds for Agricultural Resilience through Innovative Development program, will create a path for adoption of LRI (including hydrology) based scientific watershed management by all the States through WDC –PMKSY. Karnataka is identified as a light house partner to provide technical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

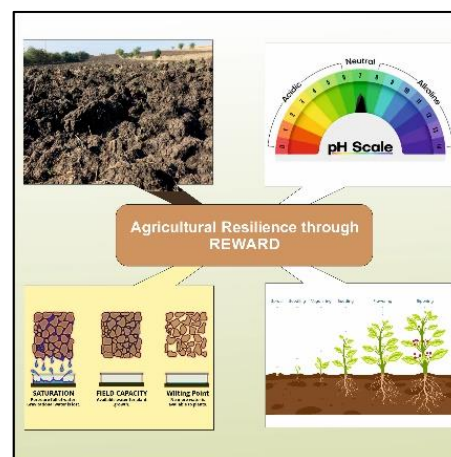
17. The major Components of REWARD program are (a) Land resource inventory (LRI) in 19 lakh ha of rainfed watershed areas spread over in 21 districts, (b) watershed development on Saturation mode covering an area of one lakh ha in 20 sub watersheds based on LRI & Hydrology recommendations, (c) FPO and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



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 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.



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



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

21. The committees for smooth implementation of the REWARD program

- a. National Level Steering Committee (NLSC): Headed by Secretary, DoLR, Senior Officers from: DoLR, NRAA & relevant national departments and research organizations; and State Watershed Departments of Karnataka and Odisha

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



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

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



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



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



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

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

22.

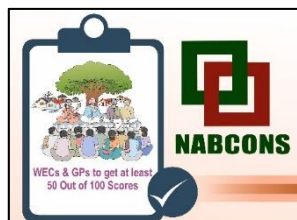


The REWARD program in Karnataka, covers 21 Districts with a budget outlay of Rs 600 Crores. Out of the total budget, the World Bank share is 70% and GoKs share is 30%. The duration of the program is for five years. The major Components of REWARD program are (a) Land resource inventory (LRI) in 19 lakh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

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

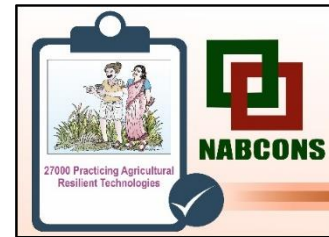


24. Disbursement of funds based on achievements of the results. For this purpose, Disbursement Linked Indicators are set for important components. The NABCONS (NABARD Consultancy Services) has been entrusted for verification of the indicators.



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

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



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

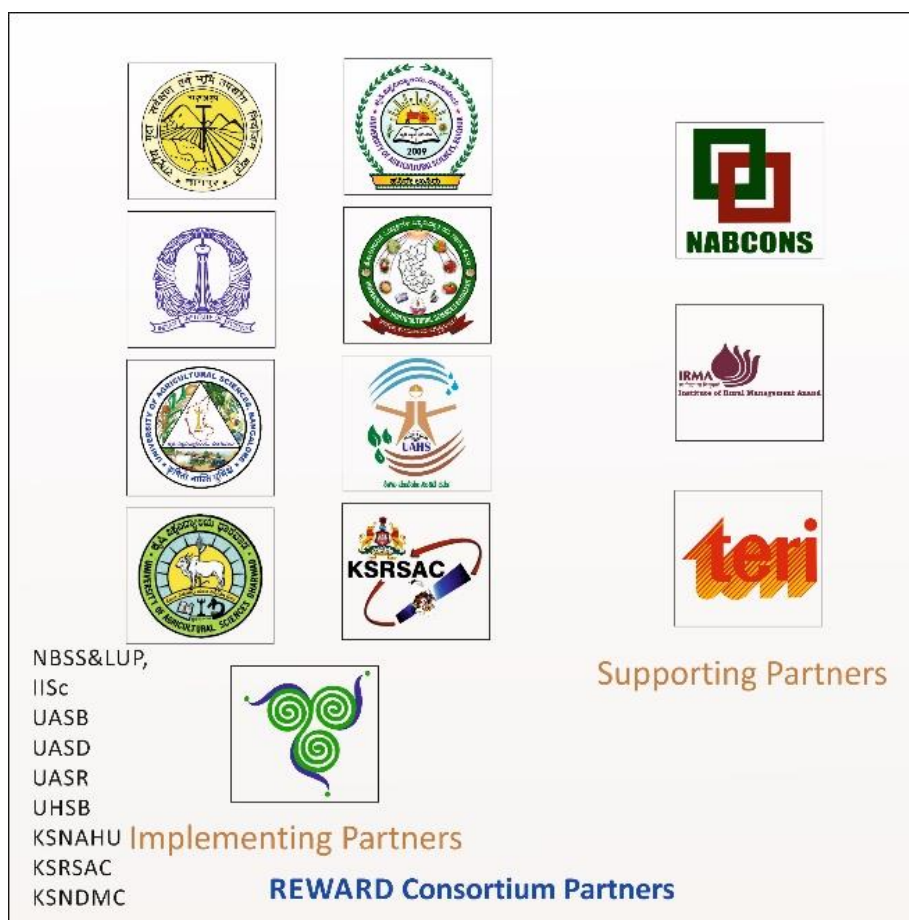
According to fourth indicator, there should be 25 per cent increase in business turnover relative to baseline among existing FPOs and additional 15 FPOs should be started.



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

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

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



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

2. Land Resources Inventory - Meaning and Importance

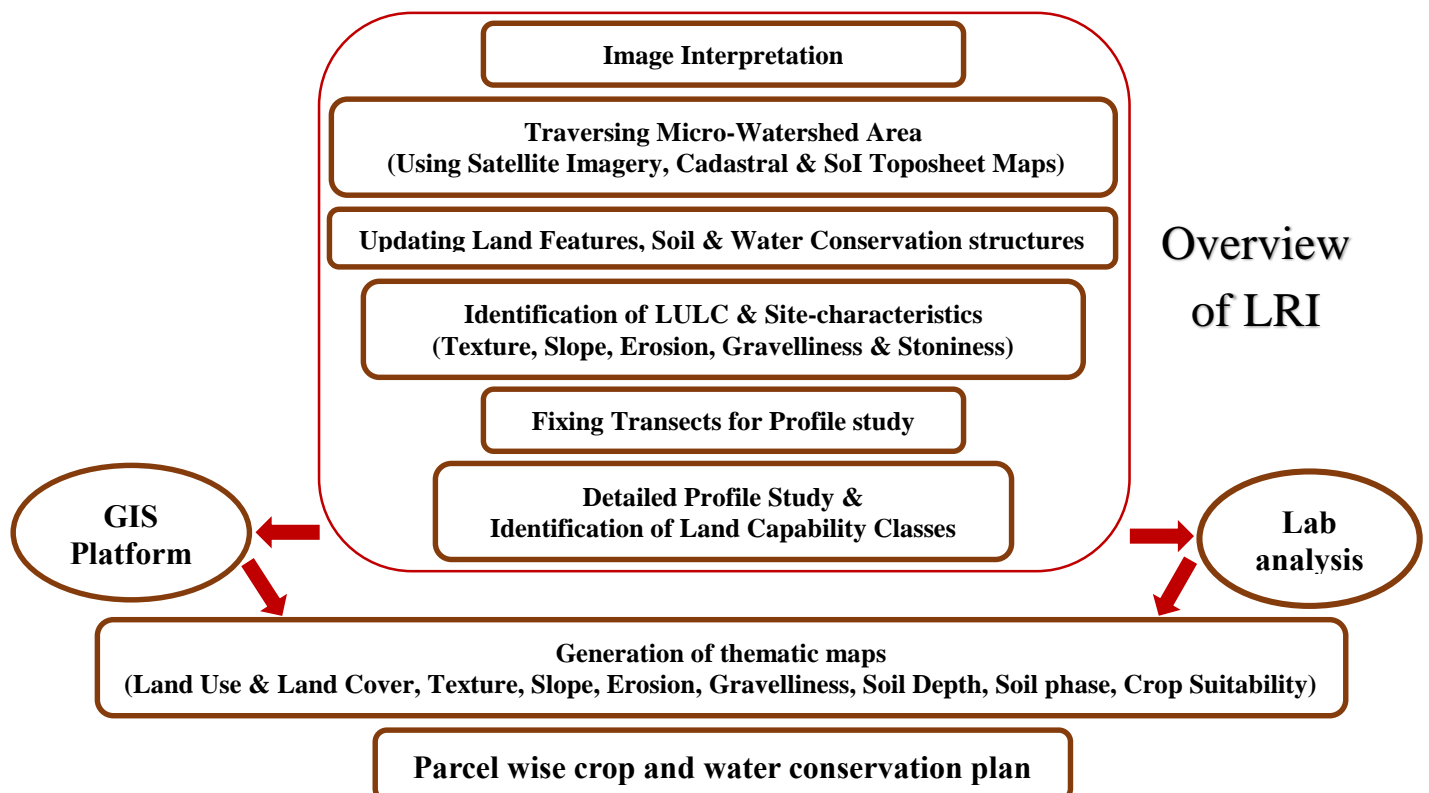
The Land Resource Inventory (LRI) is an assessment of the status and changing condition of soil, water and related resources at the field level. The LRI database is generated on a geo-referenced cadastral map, superimposed on satellite imagery. The land parcels are grouped into management units based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

Significance of LRI

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

Maps inputs needed for LRI

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



LRI approach - data generation process

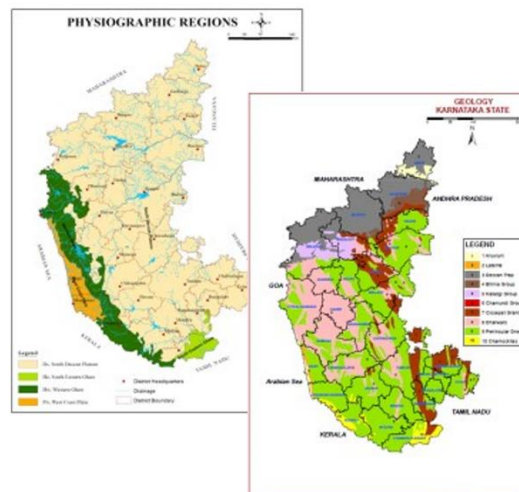
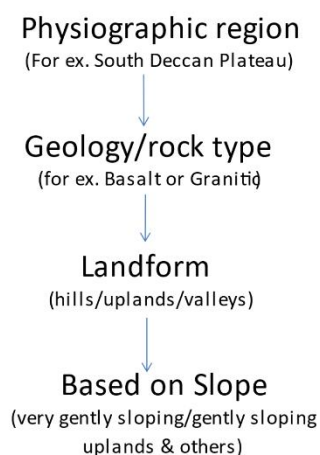
Pre-field activities: Image interpretation for various physiographic units and identification of transect for profile studies

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

Interpretation at Sub watershed level:

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

Sub watershed level



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

Interpretation at MWS level:

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

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

the uplands can be subdivided into rolling, undulating, gently sloping, very gently sloping and nearly level lands based on their extent and slope at the MWS level.



Red sand stone



Basalt Rock



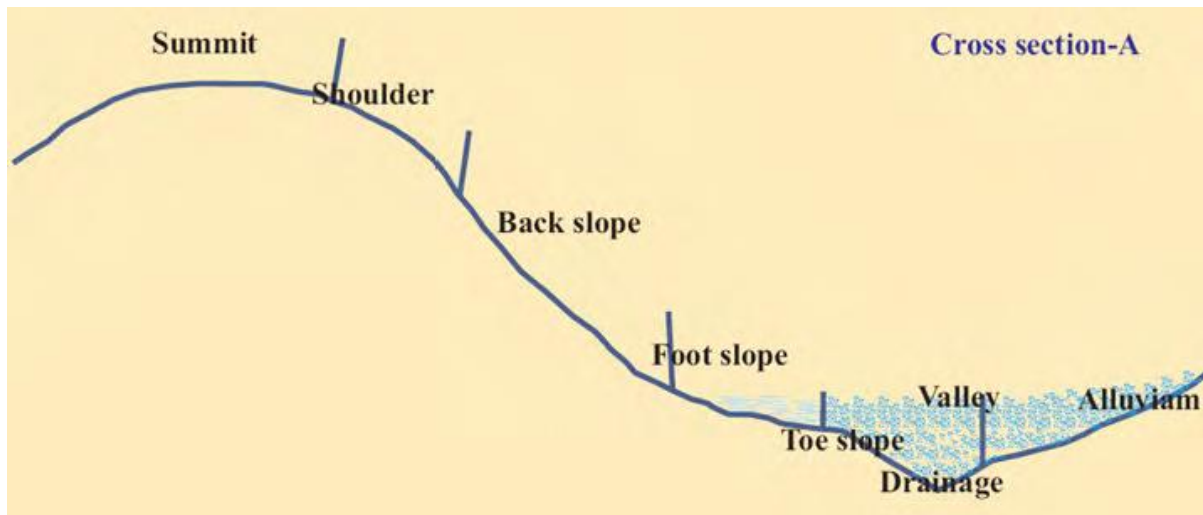
Granite



Laterite

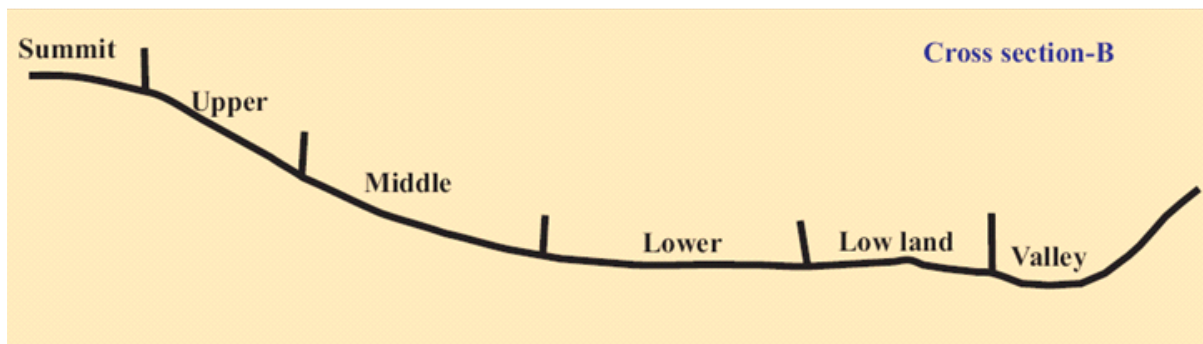


Schist



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

G221 Very gently sloping uplands, yellowish green

G222 Very gently sloping uplands, medium green and pink

G223 Very gently sloping uplands, pink and green (scrub land)

G224 Very gently sloping uplands, medium greenish grey

G225 Very gently sloping uplands, yellowish white (eroded)

G236 Very gently sloping uplands, dark green

G237 Very gently sloping uplands, medium pink (coconut garden)

G23 Gently sloping uplands

G231 Gently sloping uplands, yellowish green (eroded)

G232 Gently sloping uplands, yellowish white (severely eroded)

G24 Undulating uplands

G3 Valleys

G31 Interhill Valley

G32 Valley /Lowlands

A Alluvial landscape

A1 Nearly level Uplands

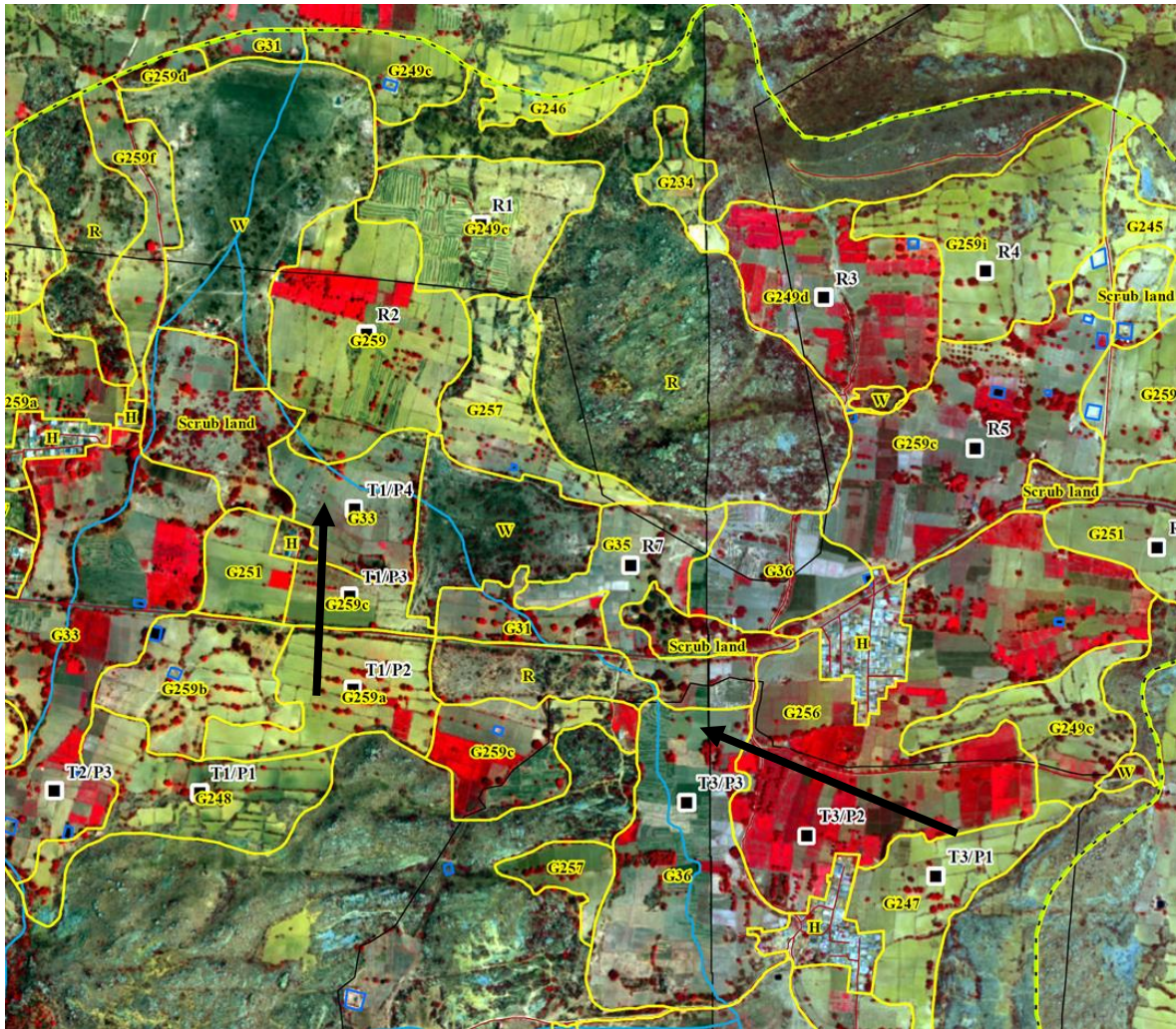
A2 Very gently sloping lands

Identification of transect for profile studies:

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

Criteria for transect identification:

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



Transects and randoms marked for profile study

Field activities: Traversing and validation of interpreted map

a) At Sub watershed level:

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

Differentiating Characteristics for identifying Soils at SWS level

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

b) At Micro watershed level:

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

Study of site characteristics (phases):

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

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

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

GHT - indicates the name of the soil series

c - indicates the texture of the surface soil

B - indicates the slope of the land

2 - indicates the degree of erosion

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

properties (like depth, texture, gravel, slope, salinity *etc.*) and their variations for each mapping unit.

Codification of soil samples (in master profiles):

Soil samples are collected from a representative pedon for each series for laboratory analysis. For labelling, the codification given below may be followed

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

Gg - indicates the name of the district, Gadag

Sht - indicates the name of the taluk, Shirahatti

Rtr - indicates the name of the village, Ranatur

T1 - Transect No.1 in Ranatur village

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

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

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

or

R1 Random profile No.1 from Ranatur village

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

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

Grid soil sampling:

Composite soil samples are to be collected from grids drawn on the cadastral map at every 320 m interval (10.24 ha) for rainfed/dry land areas and 160 m interval (2.56 ha) for irrigated/command areas respectively. On an average, about 50 to 70 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	0-1 % slope 1-3 % slope
Nearly Level	3-8 % slope
Undulating	8-16 % slope
Rolling	16-30 % slope
Hilly	30-60 % slope
Steep	>60 % slope
Very steep	0-1 % slope 1-3 % slope

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

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

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

<i>Major landscape areas</i>	<i>Landforms identified</i>
Basalt landscape	Plateau, Mesas, butte, summits, escarpments, side slopes, sloping uplands, plains, valleys

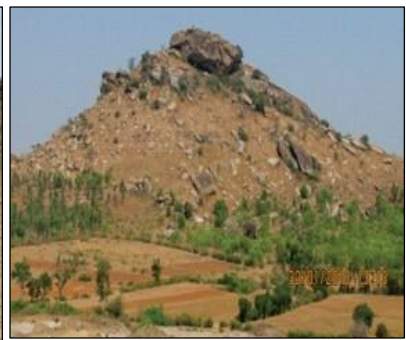
Granite and gneiss landscape	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, tors, inselbergs, foot slopes, sloping uplands, valleys
Schistose landscape	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, foot slopes, sloping uplands, valleys
Lateritic 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

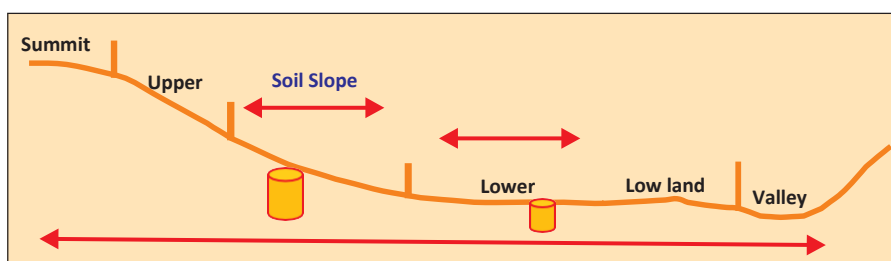
Micro-features - Any discrete, natural or artificial surface feature, occupying very small area on the land surface, which cannot be delineated at the scale of mapping are known as micro features. These small features individually cover less than 100 m² area and the height difference will be within few metres from the ground level. For example, small gullies or sand dunes if

they occur in a very small extent in the survey area are described as micro features and if the same occupy large areas, then they are delineated and described as a mapping unit.

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

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

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



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

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

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

Slope length - Indicates the distance up to which there is no break in the slope. For example, if the length of B slope is 100 m, then this indicates that the distance between the starting point

of the slope and the point where it breaks is about 100 m. Record the gradient and length in the proforma.

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

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



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.

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

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

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

Class 2 (moderate erosion) - This class consists of soils that have lost, on the average, 25 to 75 per cent of the surface soil (A horizon). In cultivated areas, the surface layer consists of a

mixture of the original A and/or horizons and material from below. Some areas may have intricate patterns, ranging from uneroded small areas to severely eroded small areas.

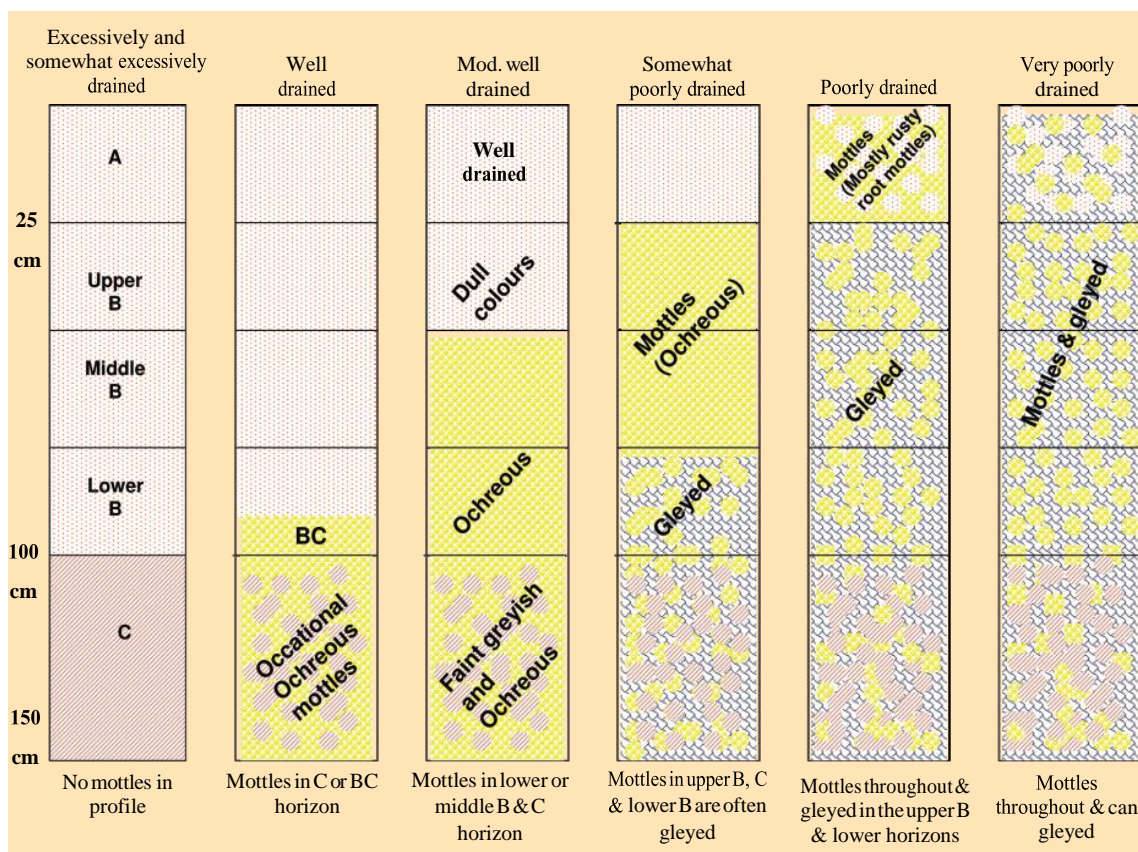
Class 3 (severe erosion) - This class consists of soils that have lost, on the average, 75 per cent or more of the original A horizon. In class 3 erosion, material below the A horizon is exposed at the surface in cultivated areas and some mixing with underlying material is also observed.

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

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

- a) **Ponded** - None of the water added to the soil as precipitation or by flow from surrounding areas escapes as runoff. This condition occurs normally in depressed areas.
- b) **Very slow** - Surface water flows away **very slowly** that free water lies on the surface for long periods or enters immediately into the soil. In very slow condition, most of the water either passes through the soil or evaporates into the air. This condition is observed normally in level to nearly level areas or in very porous sandy soils.
- c) **Slow** - Surface water flows away **slowly** that free water lies on the surface for significant periods or enters rapidly into the soil. This condition is observed normally in nearly level or very gently sloping areas or in sandy soils.
- d) **Medium** - Surface water flows away at such a rate that a moderate proportion of the water enters the soil and free water lies on the surface for only short periods.
- e) **Rapid** - A large part of the rainfall moves rapidly over the surface of the soil and a small part moves through the soil profile. In this condition, water runs off nearly as fast as it is added and occur in moderately steep to steep areas and in soils with low infiltration capacity.
- f) **Very rapid** - A very large part of the rainfall moves rapidly over the surface of the soil and a very small part moves through the soil profile. In this condition, water runs off as fast as it is added and are observed in steep to very steep areas and in soils with low infiltration capacity.

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



Morphological changes due to prolonged wetness and poor drainage

Description of various drainage classes of soil

<i>Drainage class</i>	<i>Characteristics</i>	<i>Water table (cm)</i>	<i>Mottles/gleying & other features</i>
Excessively drained	Water is removed from the soil very rapidly	>100	None in profile
Somewhat Excessively drained	Similar to excessively drained, but water table may not be as deep, and the soil may be slightly fine textured	>100	None in profile
Well drained	Water is removed from the soil readily but not rapidly.	at or nearer to 100	Mottles in C or BC horizon
Moderately well drained	Water is removed from the soil somewhat slowly. Soil is wet for a short time have a slowly pervious layer within one metre, periodically receive high rainfall, or both	75 - 100	Mottles in lower or middle B horizon and in C horizon
Somewhat poorly drained	The soil is wet at a shallow depth for significant periods and commonly have a pervious layer, high-water table, and/or nearly continuous rainfall	25-75	Mottles in upper B horizon; C and lower B horizons are often gleyed

Poorly drained	The soil is wet at shallow depths or remains wet for long periods. Needs proper drainage for cultivation.	< 25	Mottles throughout the profile; soil is in the upper B and lower horizons
Very poorly drained	Similar to poorly drained soils except that the soils occur on level or depressed areas and are frequently ponded	At surface or < 15	Entire profile has mottles and soil may be gleyed

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

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

<i>Frequency</i>	<i>Classes Criteria</i>
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, <i>ie</i> , 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

<i>Gravelliness class</i>	<i>% of area covered</i>
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

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

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

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

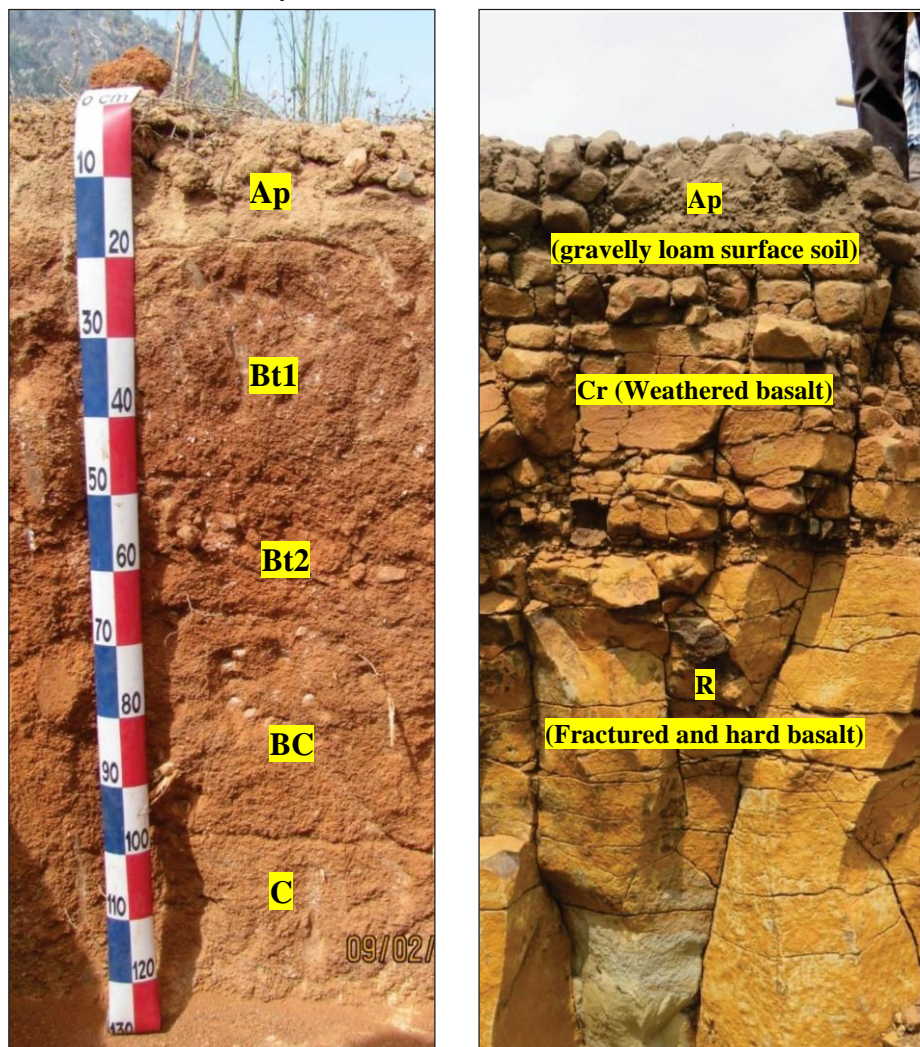
Elevation - Elevation refers to the height of a point on the earth's surface, relative to mean sea level. It can be determined from the contour maps or by using Global Positioning System (GPS). The elevation of the area is to be noted in the box based on the GPS measurement.

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

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

Soil characters

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



Typical horizon designations used to describe profile development

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

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

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

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

b. Master Horizons and Layers

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

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

E horizons - Mineral horizon in which the main feature is loss of silicate clay, iron, aluminium, or some combination of these, leaving a concentration of sand and silt particles. This horizon is usually lighter in 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

<i>Horizon suffix</i>	<i>Criteria</i>
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.

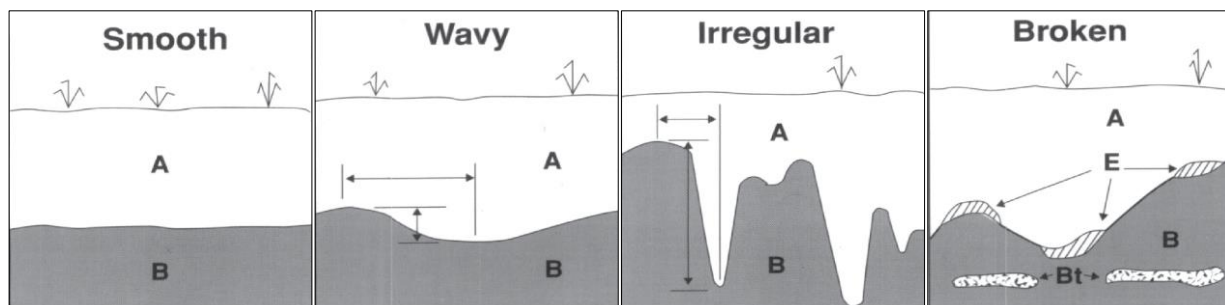
Boundaries of horizons and layers - A transitional area or layer present between two adjoining horizons or layers is known as the boundary. Boundaries vary in **distinctness** (contrast) and in **topography**.

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.

<i>Distinctness class</i>	<i>Criteria: transitional zone thickness</i>
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



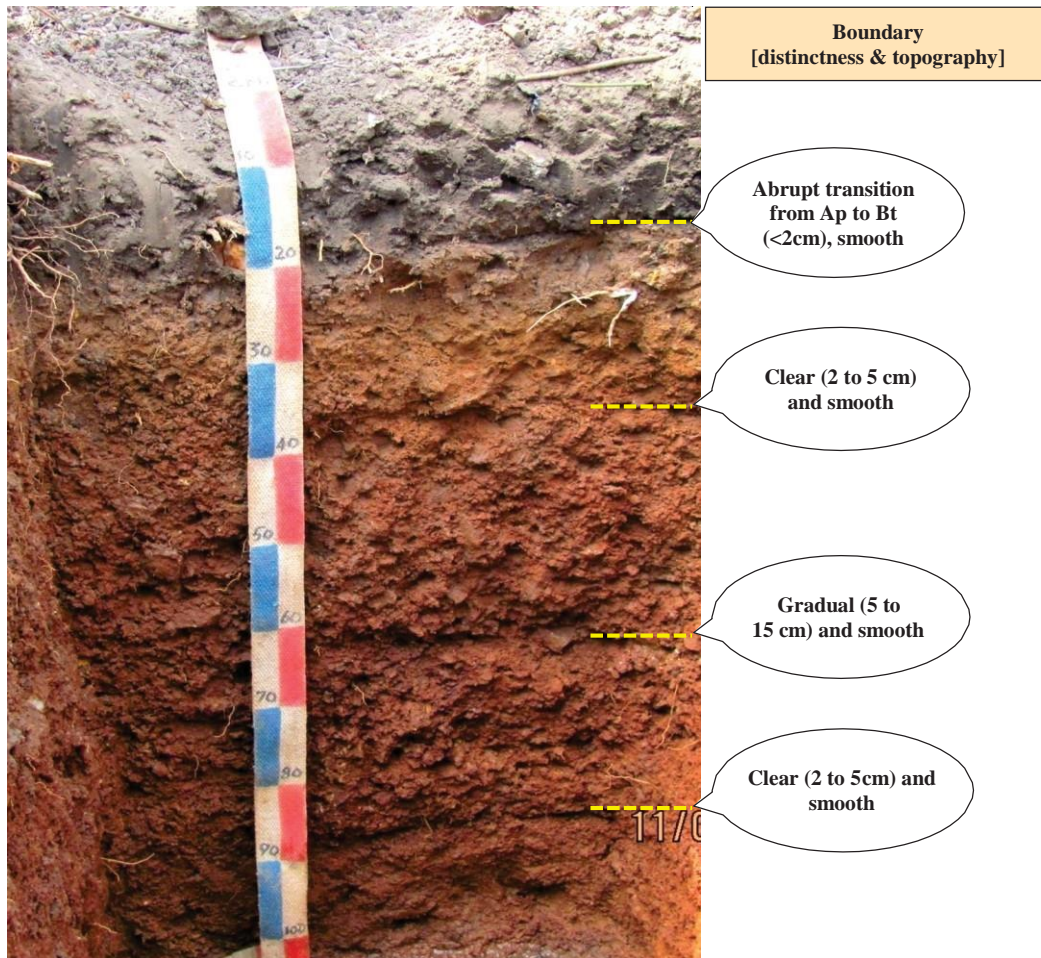
Topography of the soil boundaries as seen in the field

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.

- Hue** is a measure of the chromatic composition of light that reaches the eye.
- 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/.
- 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.

<i>Rock fragments % by volume</i>	<i>Modifier used for texture description</i>
< 15	No texture adjective is used (noun only; e.g., loam)
15 to < 35	Use adjective for appropriate size; e.g., gravelly

35 to < 60	Use “very” with the appropriate size adjective; e.g., very gravelly
60 to < 90	Use “extremely” with the appropriate size adjective; e.g., extremely gravelly
> 90	No adjective or modifier, If the soil contains < 10 % fine earth, use the appropriate noun for the dominant size class; e.g., gravel (used in lieu of texture)

Guide for assessment of soil texture in the field

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

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

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

Soil Structure - The arrangement of primary soil particles into aggregates is known as structure in soils. Clods and fragments in the soil are not considered as structural units. Soils

lacking structure are considered as structure less soils and described as single grain or massive. The structure is described based on the shape (type), size and grade of the structural units observed in the soil.

Based on shape (type)

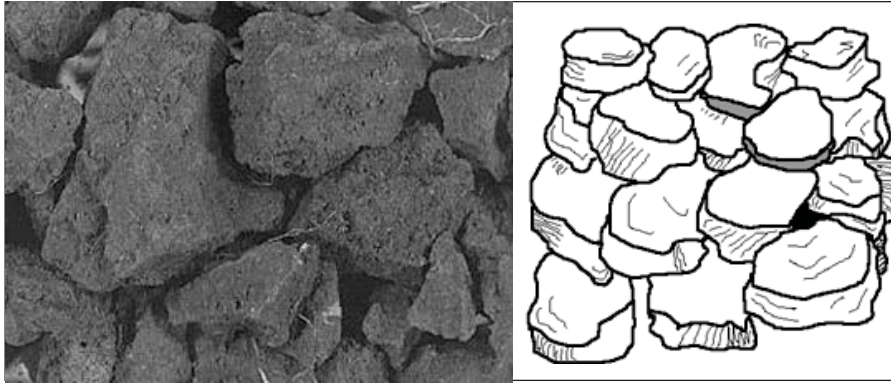
Platy	The units are flat and plate like and horizontally oriented
Prismatic	Vertically elongated units with flat tops, the individual units are bounded by flat to rounded vertical faces
Columnar	The units are like prisms and are bounded by flat or slightly rounded vertical faces and the top of columns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

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

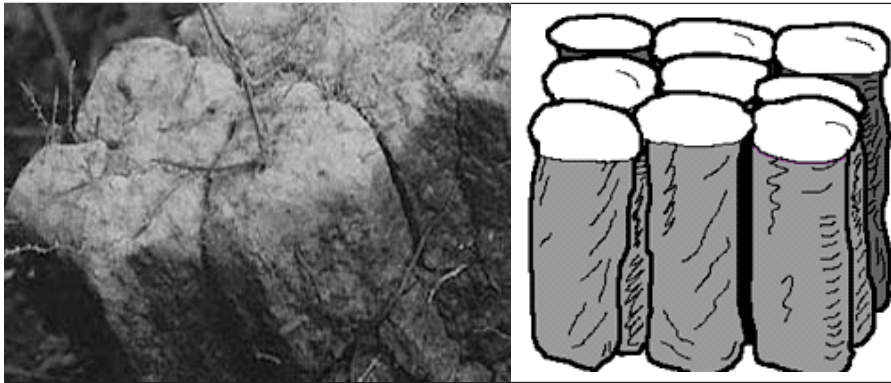
<i>Size classes</i>	<i>Grannular, Platy (mm)</i>	<i>Prismatic & Columnar (mm)</i>	<i>Blocky (mm)</i>
Very fine	< 1	< 10	< 5
Fine	1-2	10-20	5-10
Medium	2-5	20-50	10-20
Coarse	5-10	50-100	20-50
Very Coarse	> 10	> 100	> 50

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

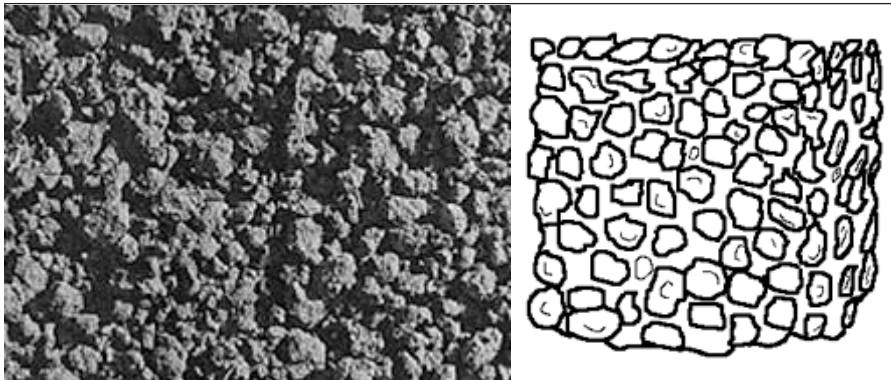
Structureless (0)	No discrete units observable in place or in hand sample
Weak (1)	Units are barely observable in place or in a hand sample
Moderate (2)	Units well-formed and evident in place or in a hand sample
Strong (3)	Units are distinct in place (undisturbed soil) and separate cleanly when disturbed



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.

<i>Dry Class</i>	<i>Moist Class</i>	<i>Specimen fails under</i>
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.

<i>Stickiness Class</i>	<i>Code</i>	<i>Criteria-Description</i>
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 Fe²⁺. 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 ($\text{chroma} \leq 2$) 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)

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

Size (Refer size class under mottles or concentrations)

<i>Size Class</i>	<i>Code</i>	<i>Criteria</i>
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

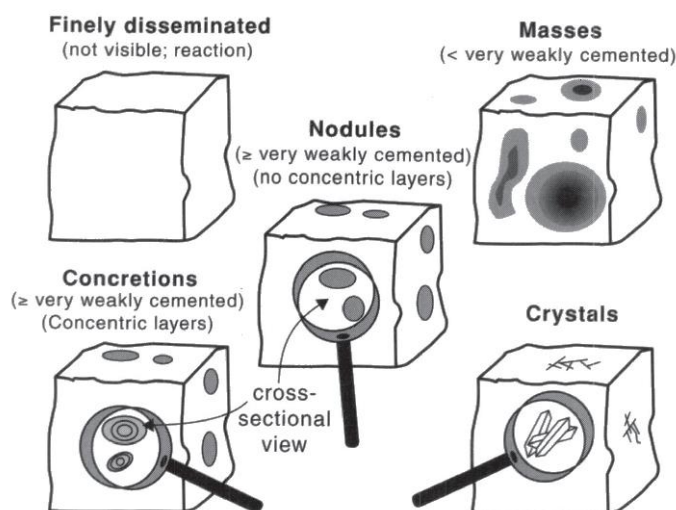
- a. **Finely Disseminated Materials** are patches of precipitates (e.g. salts, carbonates) dispersed throughout the matrix of a horizon and can be detected by a chemical reaction (e.g. effervescence of CaCO_3 by HCl).
- b. **Masses** are non-cemented accumulation that cannot be removed from the soil 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 - fecal 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 m² 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	1 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⁻¹cm² for very fine and fine pores, 1 dm² (10 x 10 cm) for medium and coarse pores, and 1 m² for very coarse. The quantity and size classes are similar to the classes used for roots.

Cracks - Are fissures primarily associated with clayey soils and are most pronounced in high shrink-swell soils. Record the Relative Frequency (estimated average number per m²) and Depth.

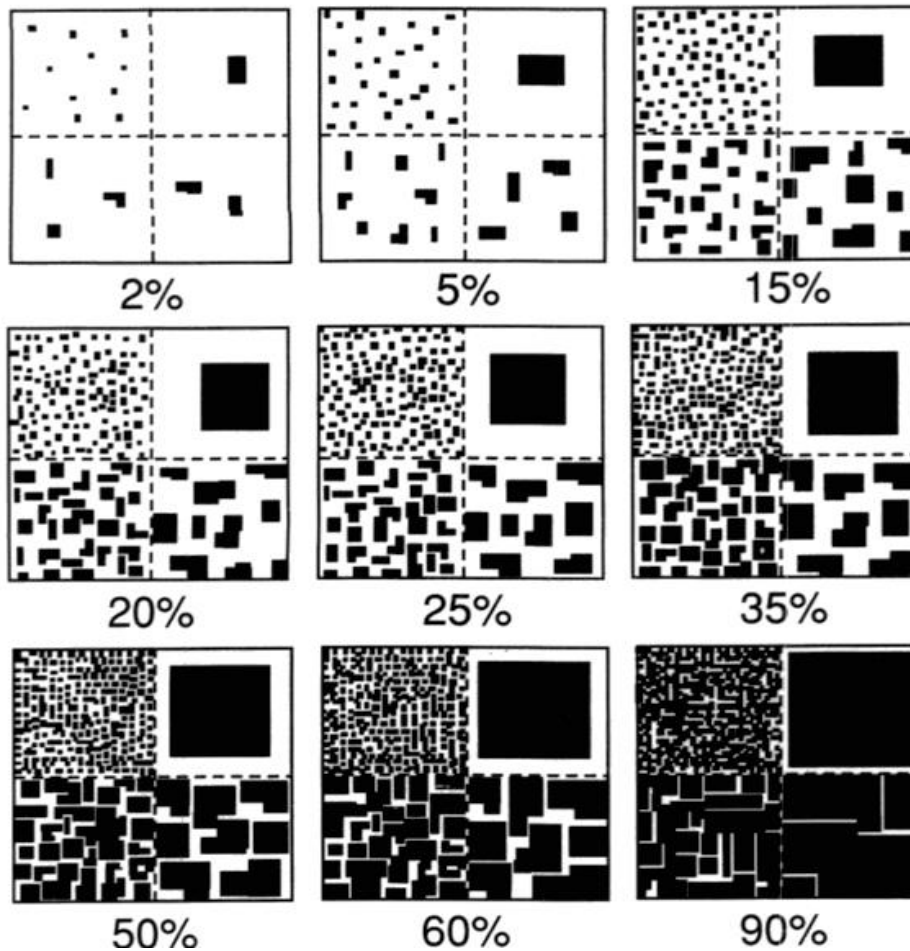
Soil crusts - A soil crust is a thin (e.g. <1 cm up to 10 cm thick) surface layer of soil particles bound together by living organisms and / or by minerals into a horizontal mat or small polygonal plates. Soil crusts form at the soil surface and have different physical and /or chemical characteristics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

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

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

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

For estimation of per cent of area covered in soil



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

PEDON DESCRIPTION FORM – SITE CHARACTERISTICS

NBSS & LUP		Agricultural University			Dept. of Agriculture					Author: Date :							
Series Name:				Map unit Symbol:				Soil Classification:									
Observation No.:					Topo sheet No.:		Imagery No.:		Base map: Scale:			Cadastral Sheet No.:					
Location:		Latitude: ° ' "			Longitude: ° ' "			Plot (Survey) No.:		Village:		Block:					
								Taluk:		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	1-3	3-5	5-10	10-15	15-25	25-33	>33	Erosion	Very slight	Slight	Mod.	Sev.	V. Sev		
	A	B	C	D	E	F	G	H									
	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		Occasional	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		Diag. Hori.	Matrix Colour		Textu re ²	% clay	Rock Frags ³			Structure ⁴		Consistence ⁵				
		D	T		Dry	Moist			Sz	Knd	Vol	Grade	Sz Type	Dry	Mst	Stk	Pls	
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

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

- D-Distinctness:** a-abrupt, c-clear, g-gradual, d-diffuse, **T-topography:** s-smooth, w-wavy, i -irregular, b-broken
- Texture:** s-sand, ls-loamy sand, sl -sandy loam, l -loam, sil -silt loam, si-silt, scl -sandy clay loam, cl -clay loam, silc -silty clay loam, sc-sandy clay, sic-silty clay, c-clay.
- Size:** fg-fine gravel(<2cm), cg-coarse gravel(2-7.5cm), cb-cobbles(7.5-25cm), st-stones(25-60cm), b-boulders(>60cm).
- 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.
- 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.
- 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.**
- 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
- 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.
- 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 establishment and phase map preparation

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

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

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

Output of LRI approach

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

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

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

Data products of LRI atlas

1. **Location and extent:** Indicate the location of watershed with latitude, longitude along with total area cover and area bounded.
2. **Agro Ecological Sub Region of watershed:** Represent the Agro Ecological Sub regions of watershed among different Agro Ecological Sub regions of India.
3. **Agro-climatic Zone of watershed:** Indicate the Agro-climatic Zone under which the watershed falls along with the total geographical area, total cultivable area under irrigation, mean sea level (MSL), average annual rainfall, major soil types and main cropping season of that particular Agro-climatic Zone.
4. **Base maps, satellite images and cadastral maps:** Before start of an inventory, there is a need for the data resources like base maps, satellite images and cadastral maps to study the location features and existing situation.
 - a. **Base map:** A base map is the graphic representation at a specified scale of selected fundamental map information; used as a framework upon which additional data of a specialized nature may be compiled (American Society of Photogrammetry, 1980).
 - b. **Satellite image:** Satellite images are images of earth collected by imaging satellites. At present for survey (inventory), we (Karnataka) are using maps in the False Colour

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

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

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

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

- 7. Geology:**

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

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

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

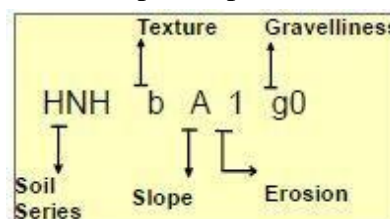
- 9. Location of wells map:** The total number of wells (open wells and bore wells) existing in the particular watershed area will be indicated in the maps along with their location.

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

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

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

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



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

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

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

Class I- Class IV: Suitable for cultivation

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

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

- 15. Land suitability for different crops:** Under this section we can assess the suitability of land/soils for cultivation of particular crops *viz.*, cereals (paddy, ragi, maize *etc.*), pulses (red gram, black gram, cowpea *etc.*), oilseeds (groundnut, sunflower *etc.*), plantations (tea, coffee, coconut, *etc.*) and commercial crops (sugarcane, cotton *etc.*).

- 16. Land management units (LMU):** It is the grouping of different soils into single management unit based on their similar characteristics features. It helps to propose similar management practices. The number LMUs we can get in a particular watershed area is based on the variability in management requirements of lands. If the variation in the land features is more, more the number land management units.

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

- 17. Proposed crop plan based on LMU:** After grouping of soils into LMUs, suitable crops for cultivation to that particular watershed area is to be proposed which helps to exploit the yield potentials of the crops. Along with suitable crop plan, suitable interventions like cultivation on raised beds with mulches and irrigation system with suitable soil and water conservation measures and application of amendments if needed is to be proposed.

- 18. Economic land evaluation of different land use types:** Economic evaluation of the land is very much important and it will be done based on benefit cost ratio (B:C ratio) and land suitability classes.

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

- 19. Runoff distribution:** Knowing runoff status of the particular watershed area is important to adopt the proper conservation measures.

- 20. Conservation plans:** After knowing all the variation in the particular watershed area, suitable conservation plans will be proposed.

21. Conclusion: Correction of variation in the particular watershed area with suitable technologies helps to conserve the natural resources effectively and exploit the potentials of the area economically.

For more details, refer the soft copy of the LRI manual and sample atlas loaded in the pen drive supplied as part of training kit.

Exercise - 1

LRI atlas

1. What criteria are followed in coding the soil phases in the Atlas?
2. Study land suitability for two commercial crops suggested for a micro watershed. If a farmer wants to cultivate S2 or S3 crops, what are your suggestions to the farmer?

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

Importance of Agro-hydrological Monitoring

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

Hydrological Field Measurements in the Selected Micro Watersheds

Installation of the equipment's

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

In an experimental watershed, the following agro-hydrology components are monitored or measured:

Soil Moisture

Surface Soil Moisture (SSM) plays a vital role in various processes occurring on the soil atmosphere interface. The evaporation is controlled directly by the surface soil moisture; the

transpiration is controlled by the soil moisture present in the root zone. The precipitation passes through surface soil moisture to reach the root zone. Hence, surface soil moisture could be able to provide some insight into the root zone soil moisture. This means that surface soil moisture may be a useful variable to predict the hydrological cycle over land. Apart from hydrology, it is also useful in various other applications e.g., agronomy, drought management and in the improvement of disaggregation/downscaling of precipitation etc.

Surface soil moisture

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

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

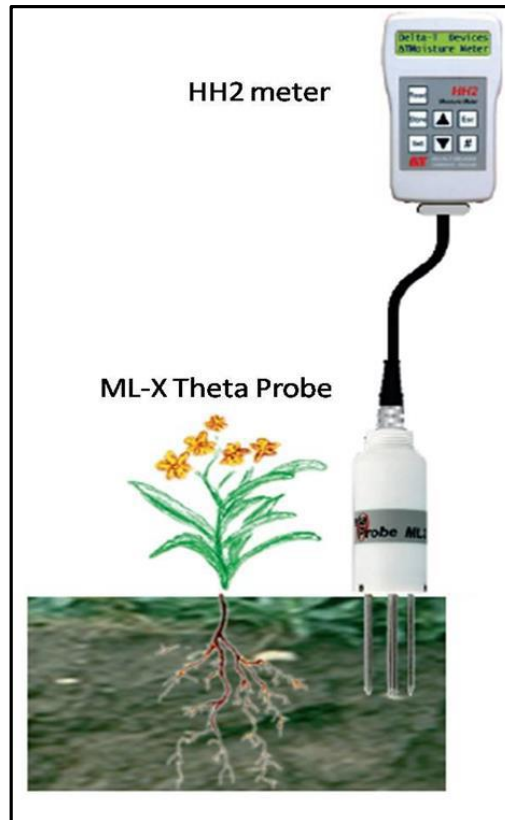
The two methods for measuring the surface soil moisture are detailed in the following two subsections:

Volumetric Soil moisture measurement (Theta Probe)

Surface soil moisture is measured using ML2x theta probe (Delta-T devices, Delta-T Devices Ltd, Cambridge, UK), which measures soil moisture averaged over 0 to 5 cm depth and equipped with a HH2 meter for spot measurements and display. Accuracy of measurements is $\pm 1\%$. 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, ($\sqrt{\epsilon}$), and volumetric moisture content, (θ), which is used to convert the measured dielectric constant to soil moisture.



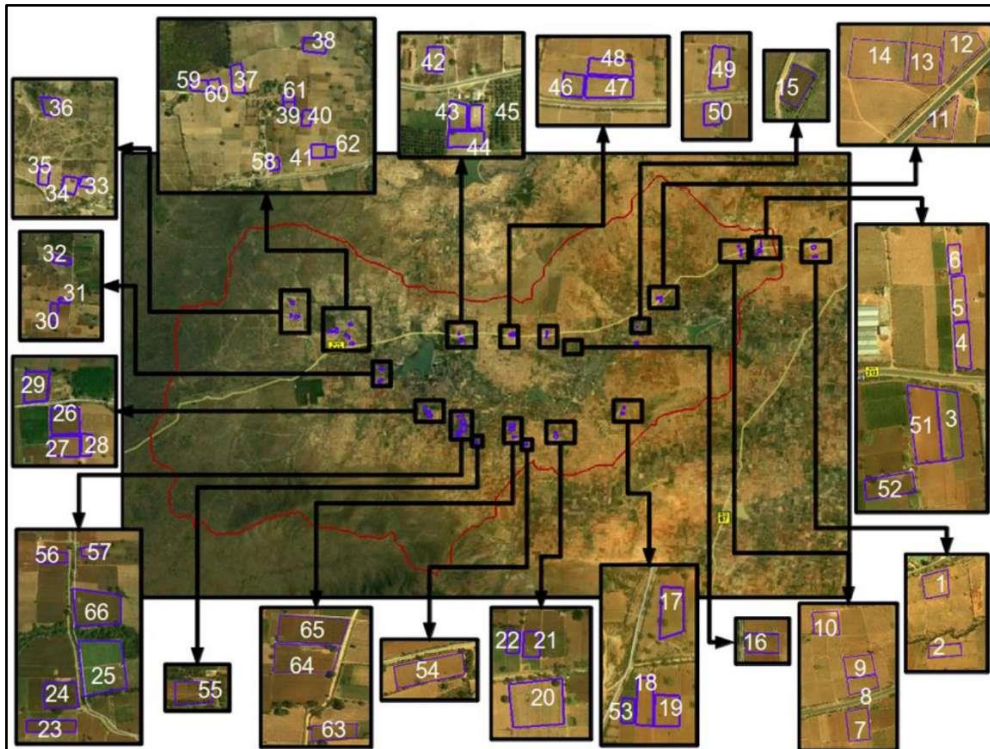
Theta probe and HH2 meter (Delta T Devices)

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 $\pm 2\%$. Measuring volume: The effective penetration depth of the probe T3 is about 15 cm with the highest sensitivity in the immediate vicinity of the access tube, and decreases exponentially as distance increases.

Installation of Access Tubes

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

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



TRIMEPICO IPH for Profile Soil Moisture Measurements

How to Measure

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

Continuous Soil Moisture Monitoring

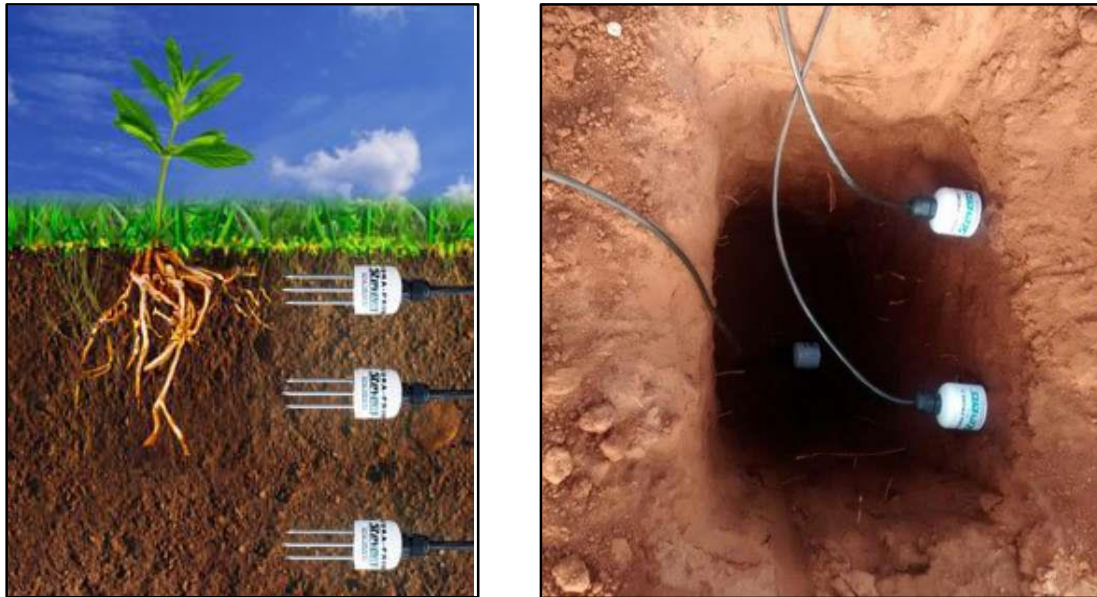
Continuous monitoring of surface and profile soil moisture is essential to understand the controls of soil moisture in the watershed. Such data can help in irrigation scheduling, calibration, and validation of satellite soil moisture products and in predicting drought.

HYDRA Probe Soil Moisture Sensor

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

Installation and Calibration

- ✓ Excavate a hole no larger than 25" x 25" square and 25" deep for the sensor installation pit. To best re-create the original soil horizons, these soil layers should be replaced in the pit in the same order they were removed.
- ✓ Trench from the location of the power source and data logger to the sensor installation pit. Assemble rigid or flexible PVC conduit to protect the sensor wires.
- ✓ Check that there is enough cable length to reach up through the soil pit and through the conduit to the data logger. Label sensor wires with sensor depth or position at both ends – the sensor end and the end that will be hooked up to the data logger.
- ✓ Before installing sensors into the soil, connect the wires to the data logger and power source. Test each sensor separately in moist soil to make sure that it is working as expected. A small cup with moistened soil works well for testing because each sensor should give very close to the same reading for soil moisture and temperature.
- ✓ Install the 50cm, 5cm, and 5cm sensors along the pit face in a staggered pattern, carefully backfill the soil in the rest of the pit and leave drip loops in all the wires.
- ✓ Gather all the wires together at the surface and seal the end of the conduit with duct seal putty. When all the sensors are in place and the installation is complete, bury the conduit in the trench

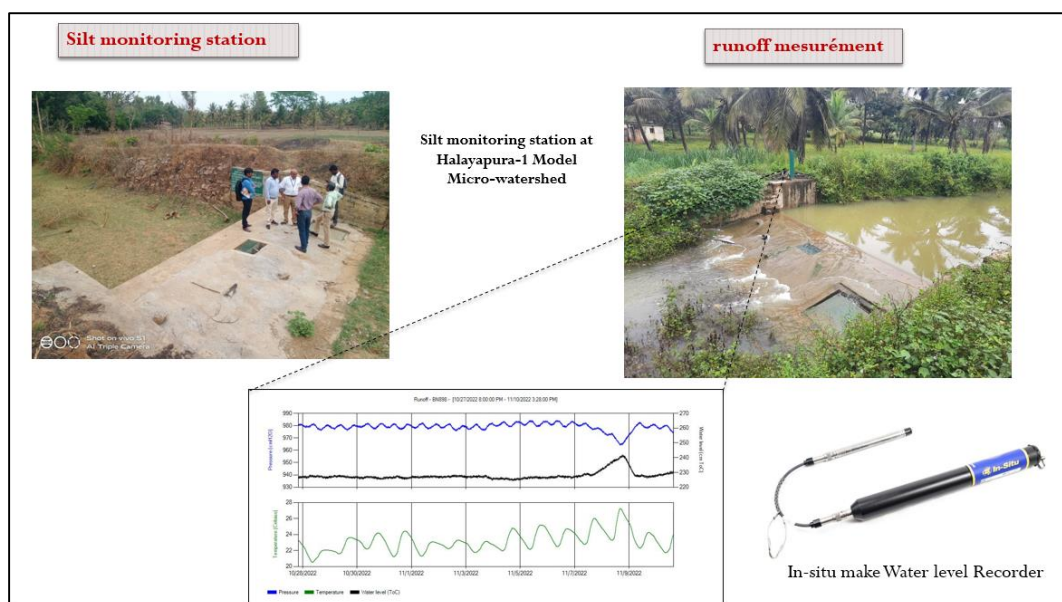


Schematic of HYDRA Probe Soil Moisture Sensor

Measurement of Runoff

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

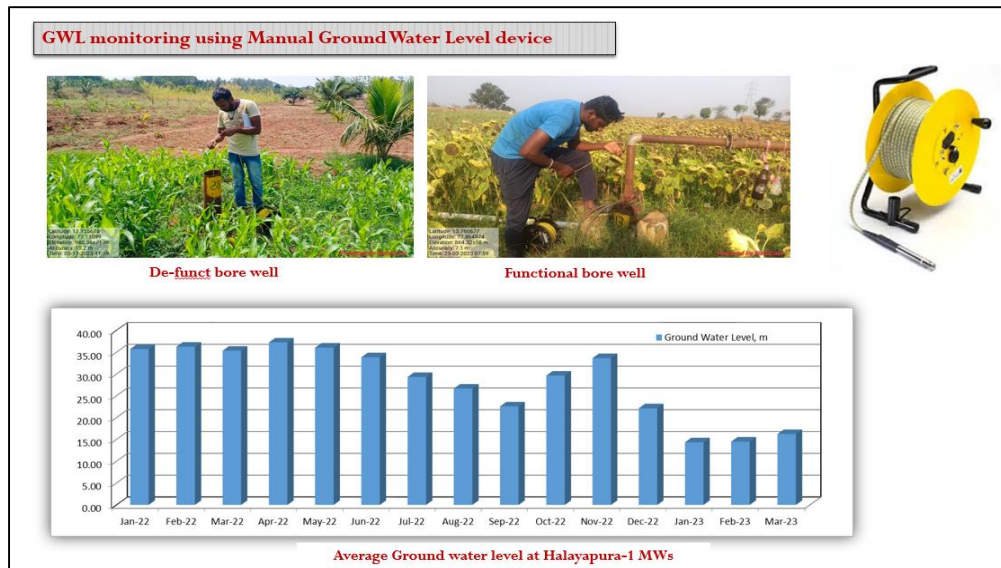
An in-situ water level recorder is a device designed to measure and record changes in water level within natural water bodies such as rivers, lakes, and wells. It is typically placed directly in the water or in a well, allowing it to accurately monitor fluctuations in water levels over time. This instrument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



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

Groundwater studies

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



GWL monitoring using manual ground water level device and readings

Evapotranspiration

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

vapor (vaporization) and removed from the evaporating surface (vapor removal). Transpiration consists of the vaporization of liquid water contained in plant tissues and the vapor removal to the atmosphere

ET Measurement using Agro-Meteorological Stations

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

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

Sl. No.	Observed parameter	Instrument	Height(s) of installation
1	Air temperature	Platinum resistance thermometer	2 m, 4 m and 6 m
2	Relative Humidity	Capacitor Type	2 m, 4 m and 6 m
3	Wind speed and wind direction	Cup Anemometer	2.5 m, 5 m and 10 m
4	Atmospheric pressure	Transducer	2 m
5	Rainfall	Tipping Bucket rain gauge	1 m
6	Net radiation <ul style="list-style-type: none"> • Shortwave incoming • Shortwave outgoing • Longwave incoming • Longwave outgoing 	Four component net radiometer	3 m
7	Diffuse radiation	Shaded pyranometer	3 m
8	Soil heat flux	Flux plate	-0.05 m, -0.2 m
9	Soil temperature	Soil Thermometer	-0.05 m, -0.15 m and -0.3 m



A typical 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.

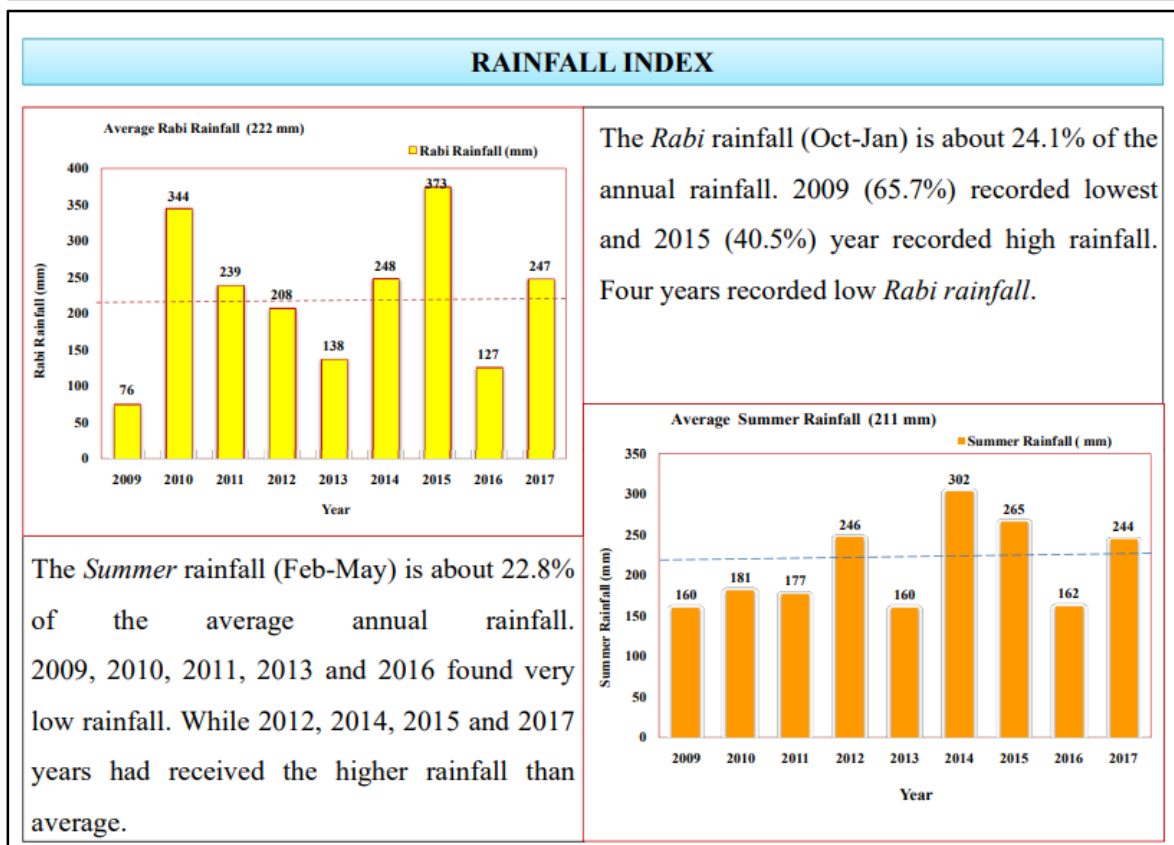
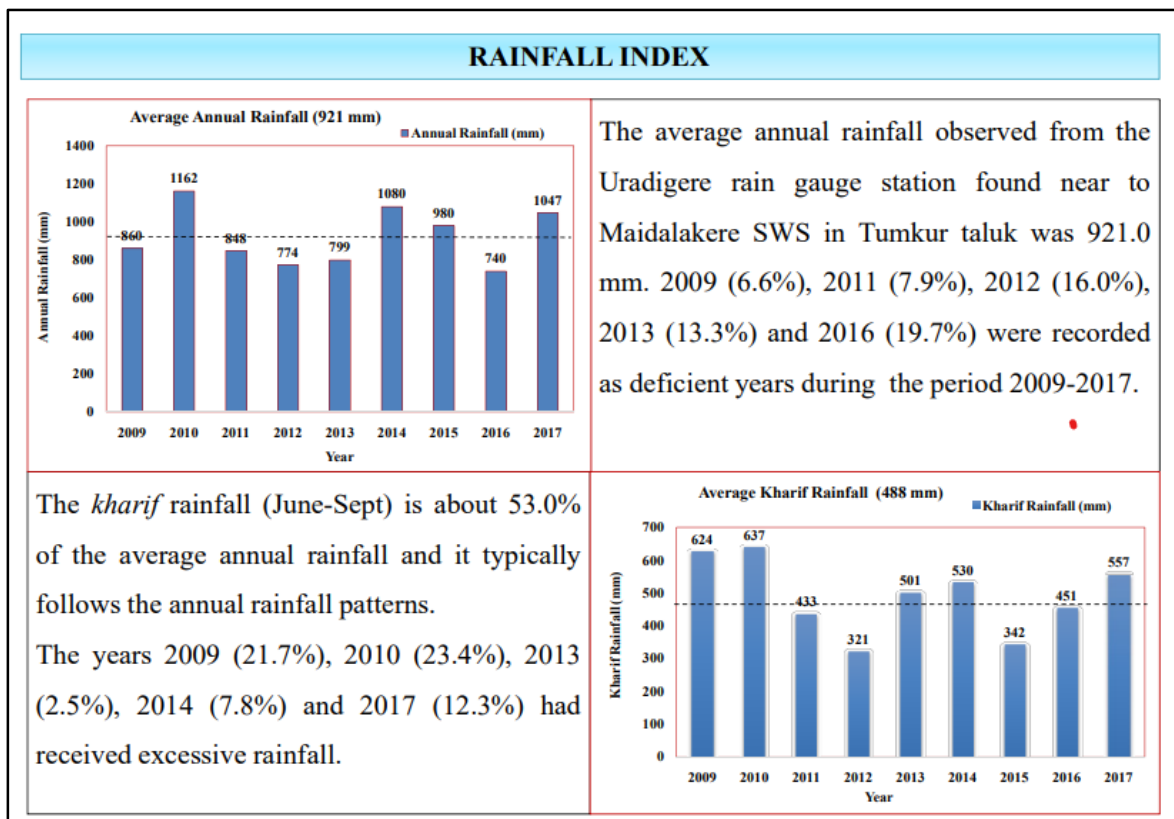
Rainfall indices

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 as that of



Summary Time Series Plots for Rainfall

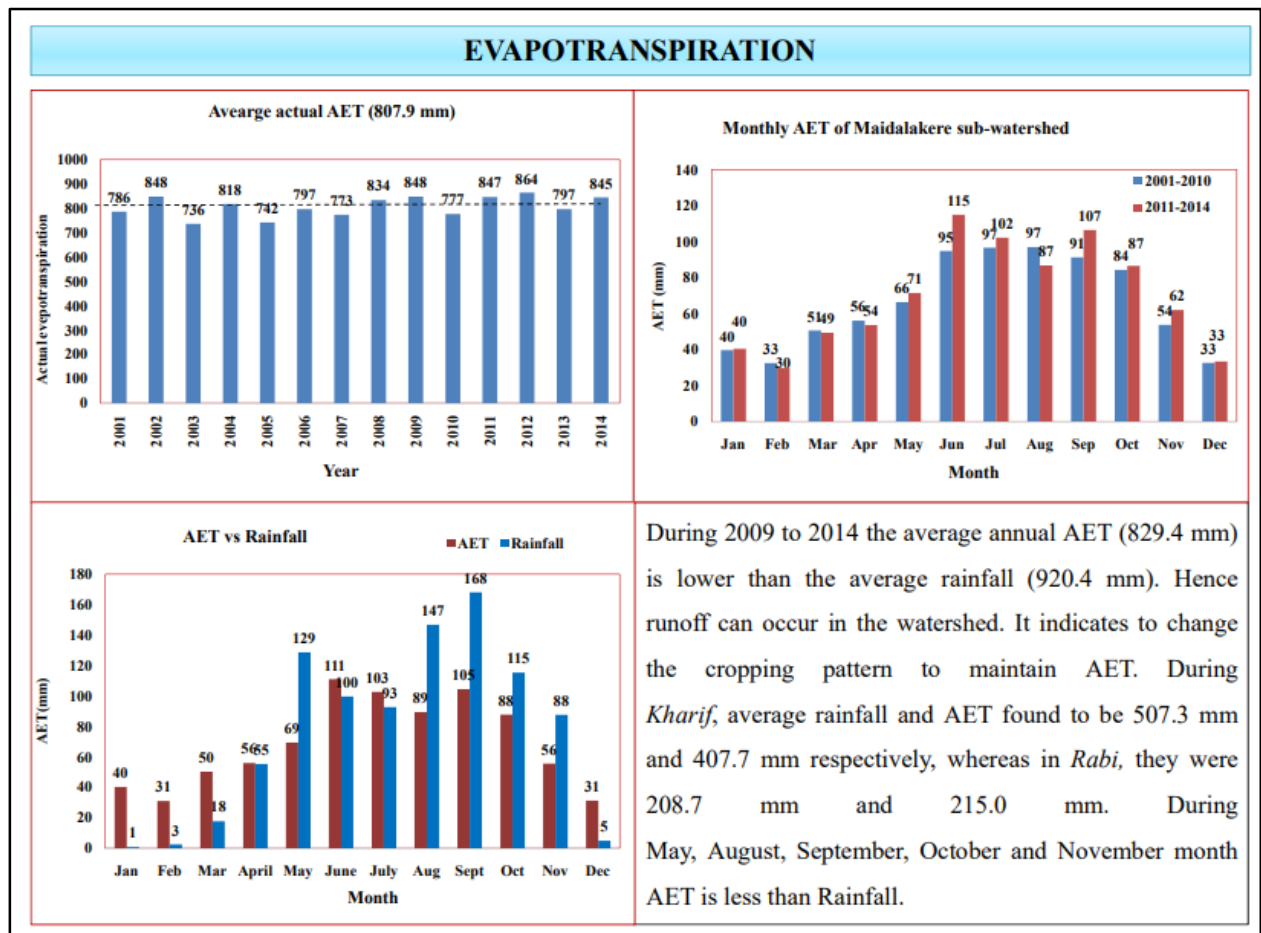
Evapotranspiration and Associated Indices

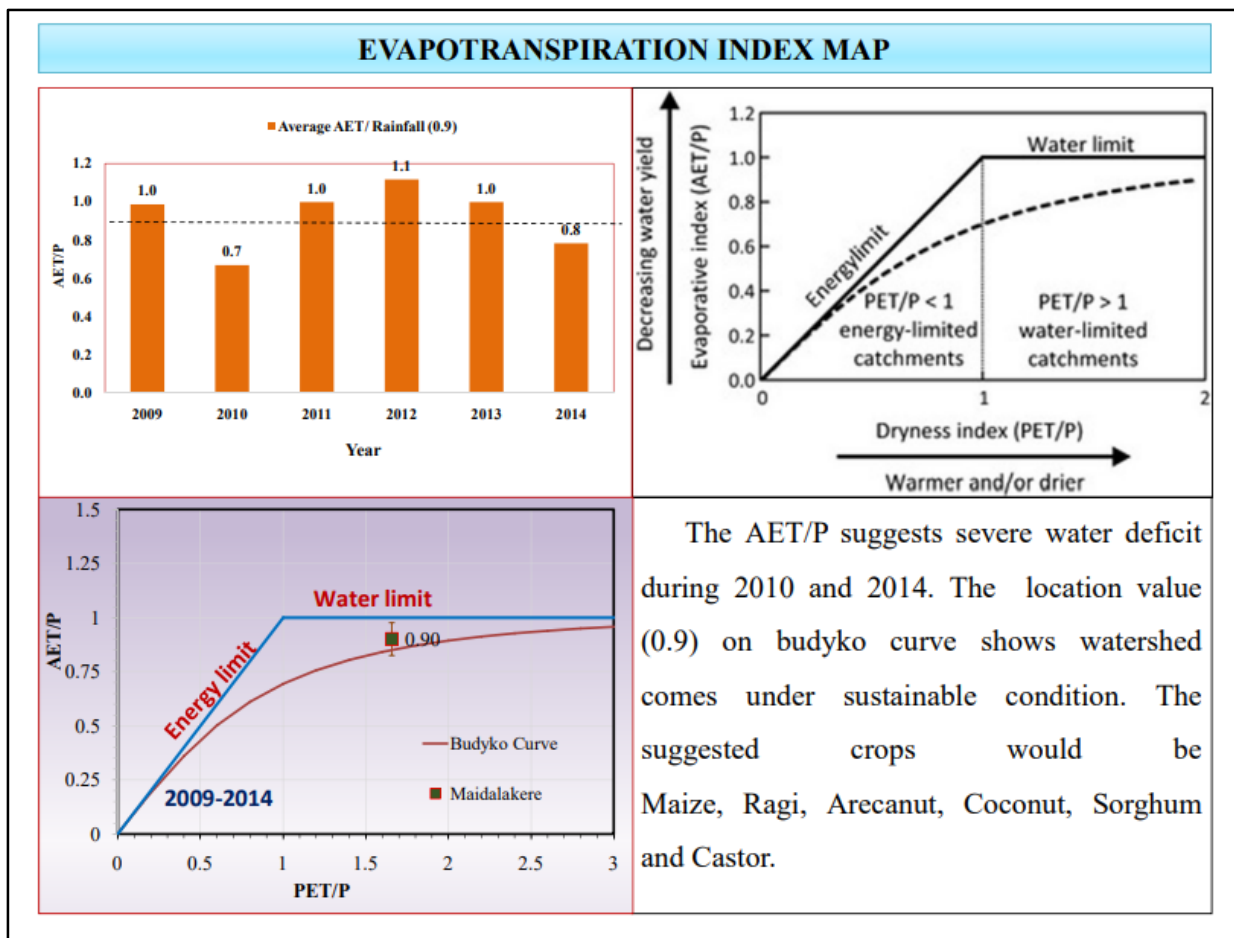
Several types of indices are developed using available time series of Actual Evapotranspiration (AET). Generally, AET time series are compiled at daily time step and with catchment-

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 and associated indices of Moidalakere 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

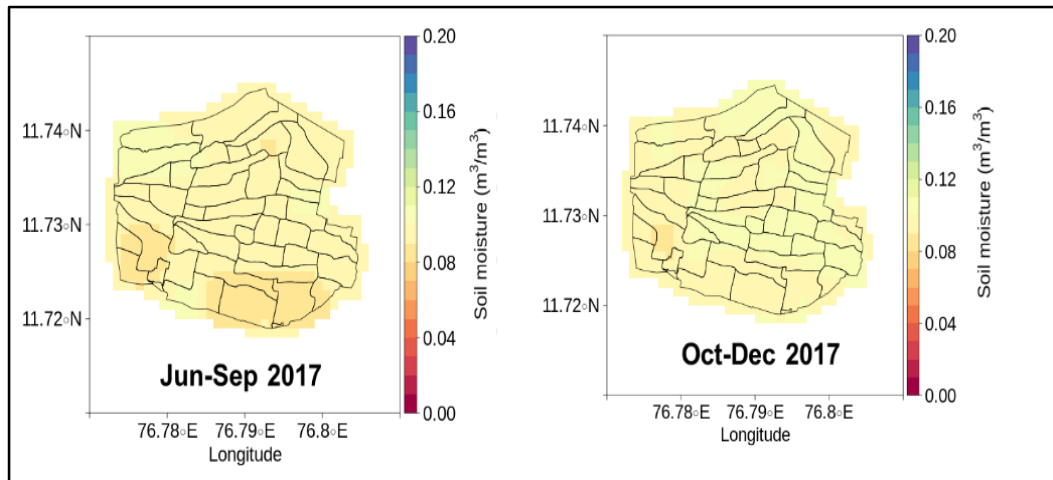
Surface soil moisture maps over a given micro-watershed for Kharif and Rabi Seasons is given below. These maps are prepared using satellite remote sensing products. The following facts are to be noted:

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

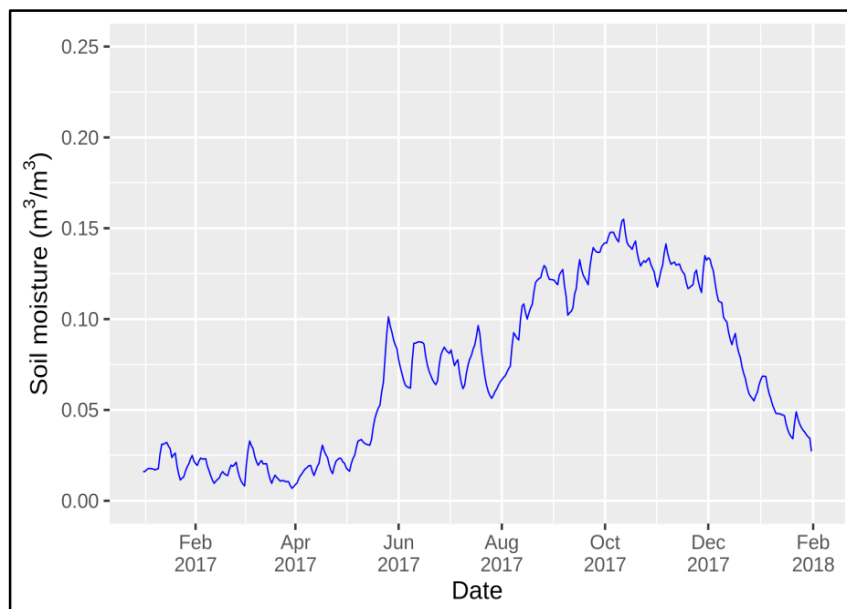
Time Series Plots

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

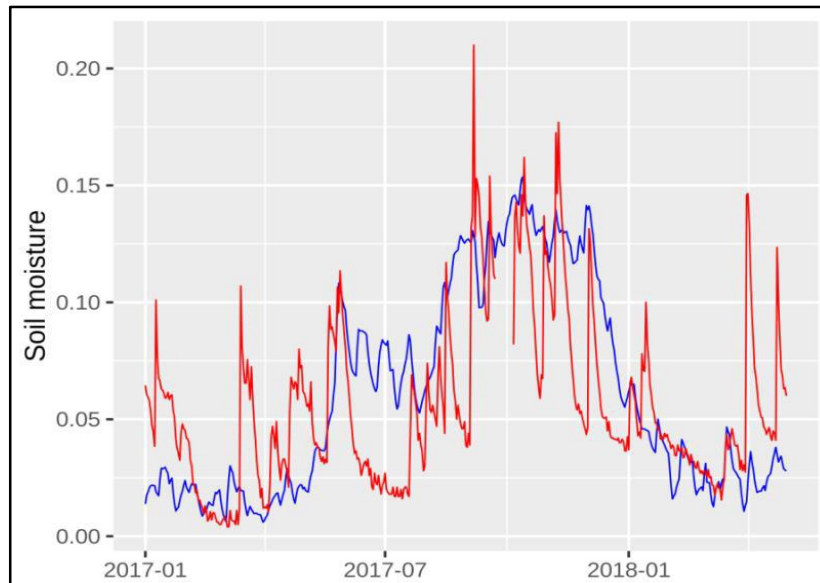


Satellite-derived Surface Soil Moisture Maps over a Study Watershed for Kharif and Rabi Seasons

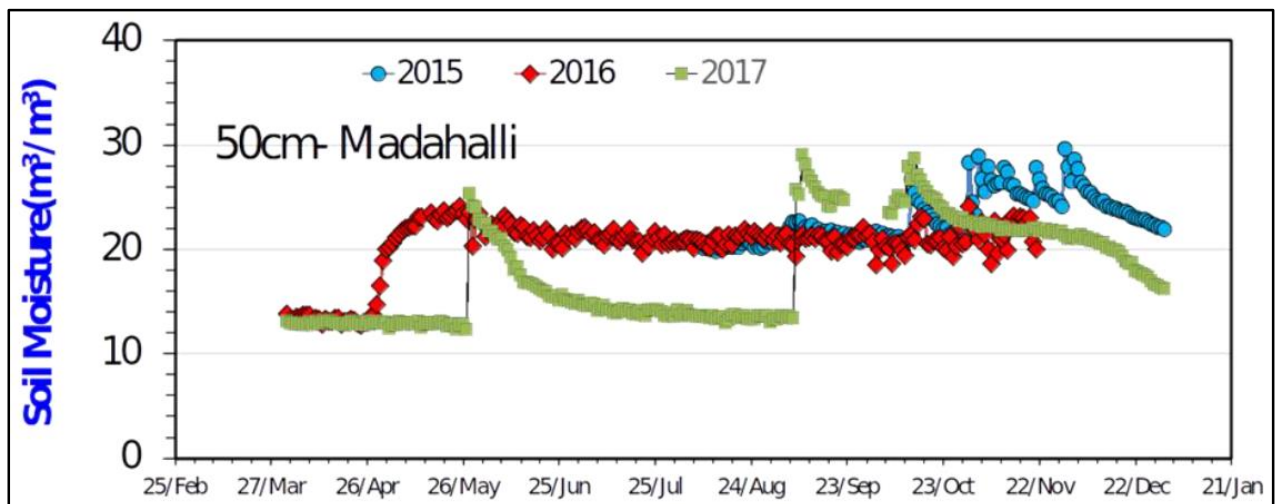


Time Series Plot of Surface Soil Moisture over a Study Watershed

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

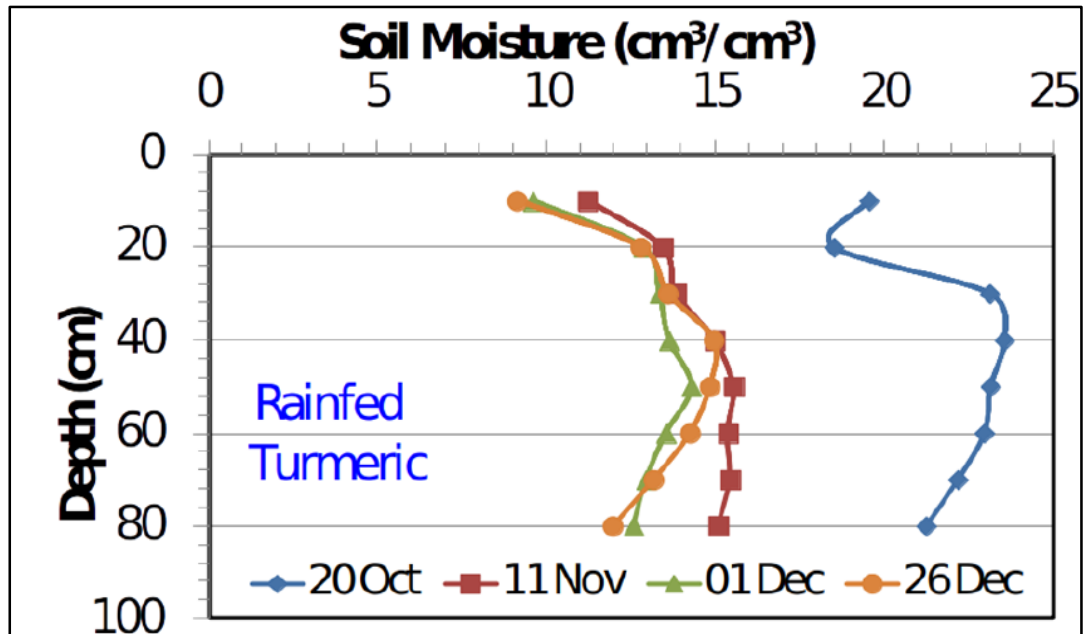


Root Zone Soil Moisture Time Series Plot at the location in the study watershed

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:

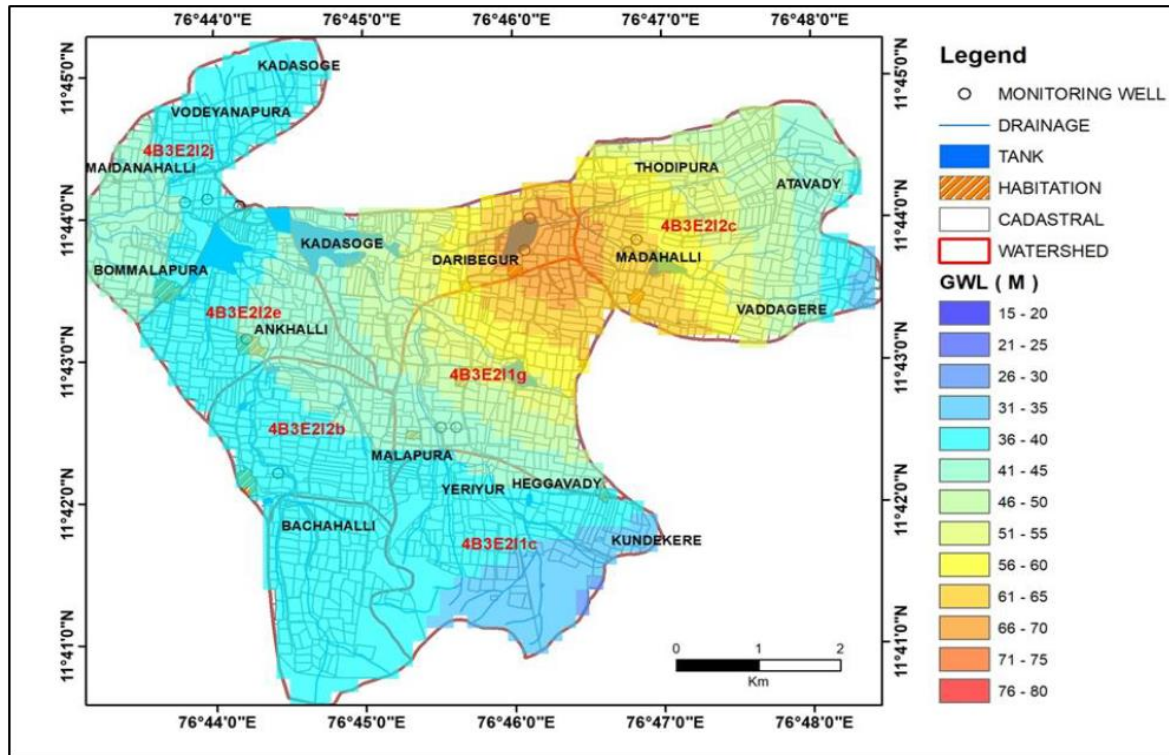
- Inverse Distance Weighted (IDW) Approach: In IDW, the value at an unknown point is estimated by giving weights proportional to the inverse of the distance (between the known locations and the unknown location) raised to the power value p . Typically, a value of $p=2$ is used; however, care should be 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

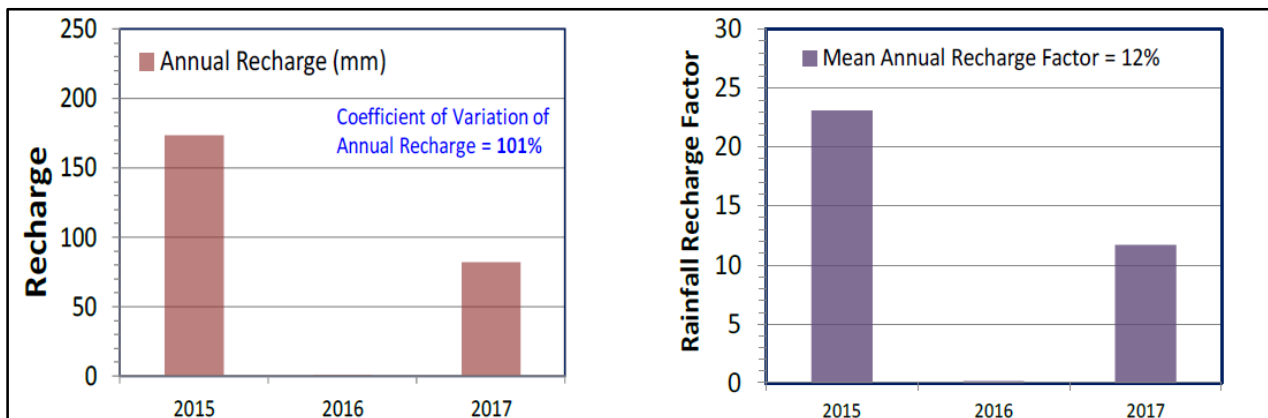
Figure shown below depicts Annual Recharge and Mean Annual Recharge Factor computed for Madahalli Micro-Watershed.

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.

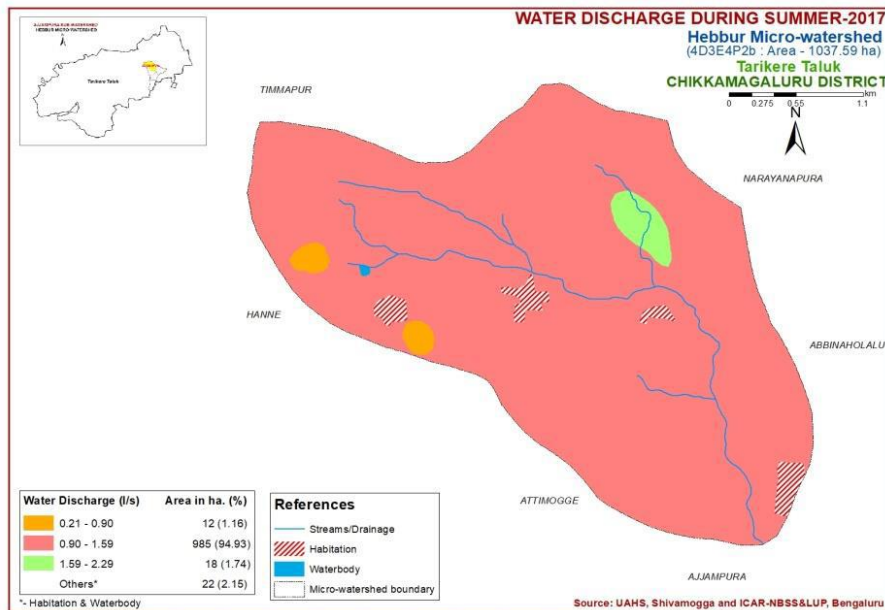


Spatially interpolated map of DGW values over the Madahalli micro-watershed

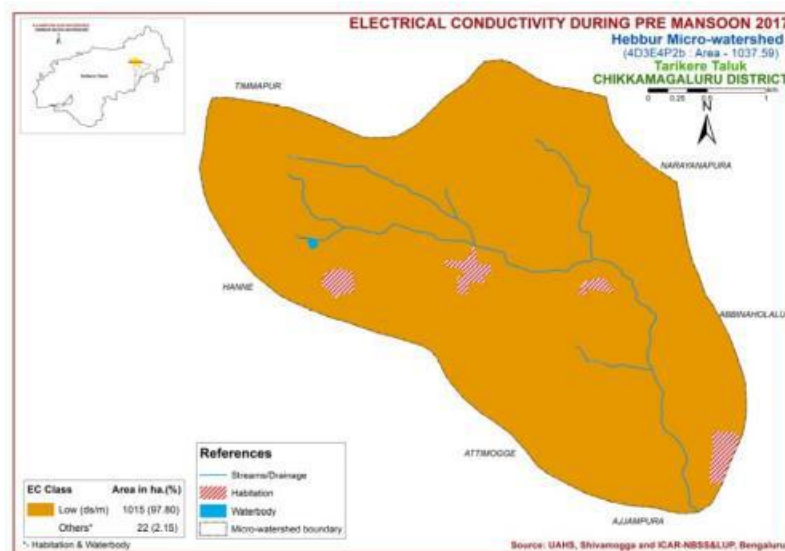


Sample Plot showing Annual Recharge and Mean Annual Recharge Factor for Madahalli Micro-Watershed

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



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

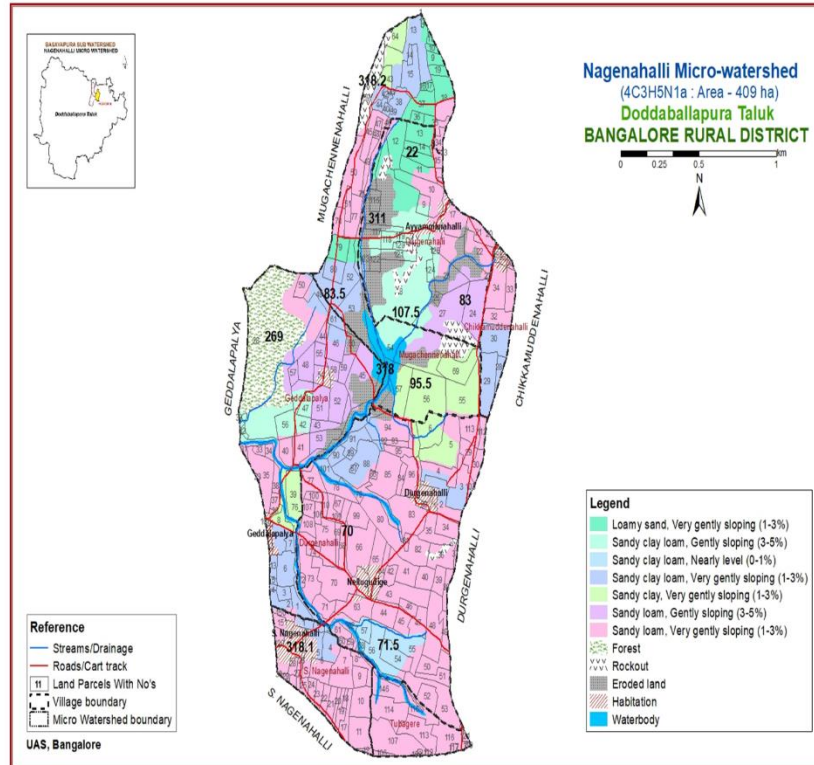


Sample Plot showing Spatially Interpolated Electrical Conductivity Values for the Hebbur Micro-Watershed

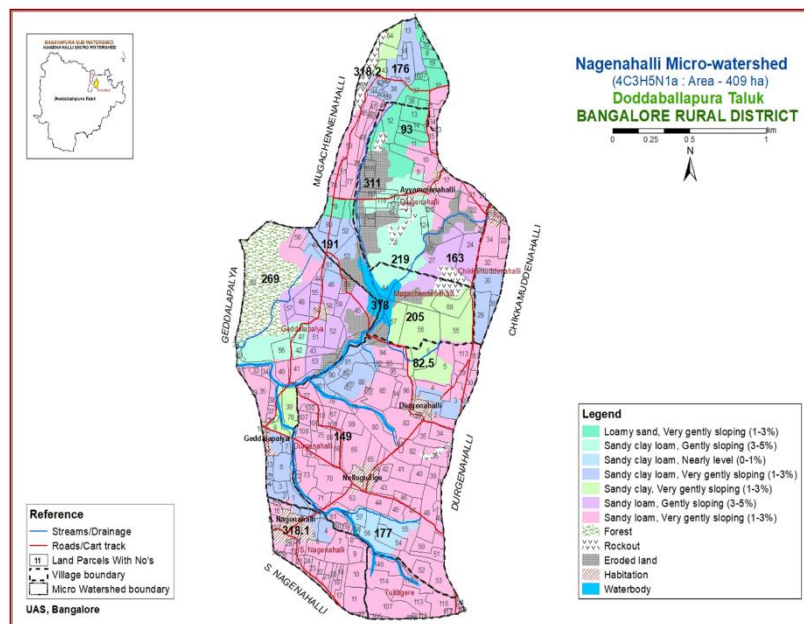
Runoff Potential

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

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



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



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

Water Budgeting

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

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

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

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

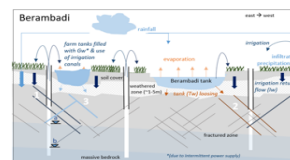
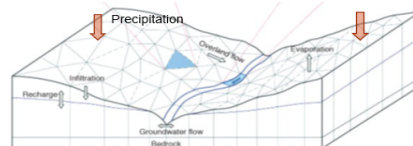
where all the variables are expressed in mm unit. Inserting following known values, $P=501$, $Q=44$, $AET=540$, $R=85$ into this equation, we get, $S=-168$ mm. This implies that over the considered time period, precipitation was lower than evapotranspiration. This negative balance when combined with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

Water Budget for the watershed

$$P = Q + E + R$$

$$P = Q + E + R + \Delta \theta$$

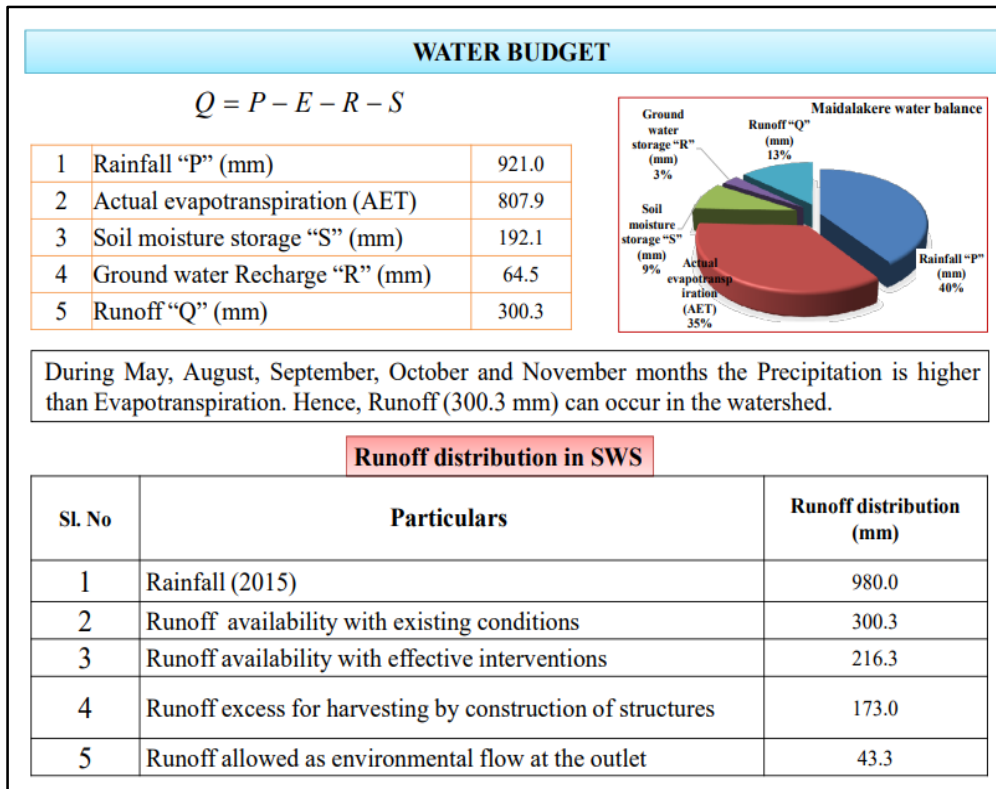
- P = Precipitation
- Q = Runoff
- E = Evapotranspiration
- R = Groundwater recharge
- $\Delta\theta$ = Change in soil moisture



Brauns et al. 2022

➔ **Models (customized) are required for estimating the hydrological components in micro-watersheds.**

➔ **Sensors/ monitoring installed in pilot micro-watersheds will help calibrate/ validate the models.**



Water budget of Maidalakere sub-watershed

Exercise - 2

DSS for estimating runoff and designing of water harvesting protocol

1. In the hydrology atlas, soil phase wise runoff figures are indicated. Correlate the contributing soil characteristics of different phases to understand the extent of runoff. Refer given atlas.

4. Digital library and LRI portal for accessing information

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

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

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

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

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

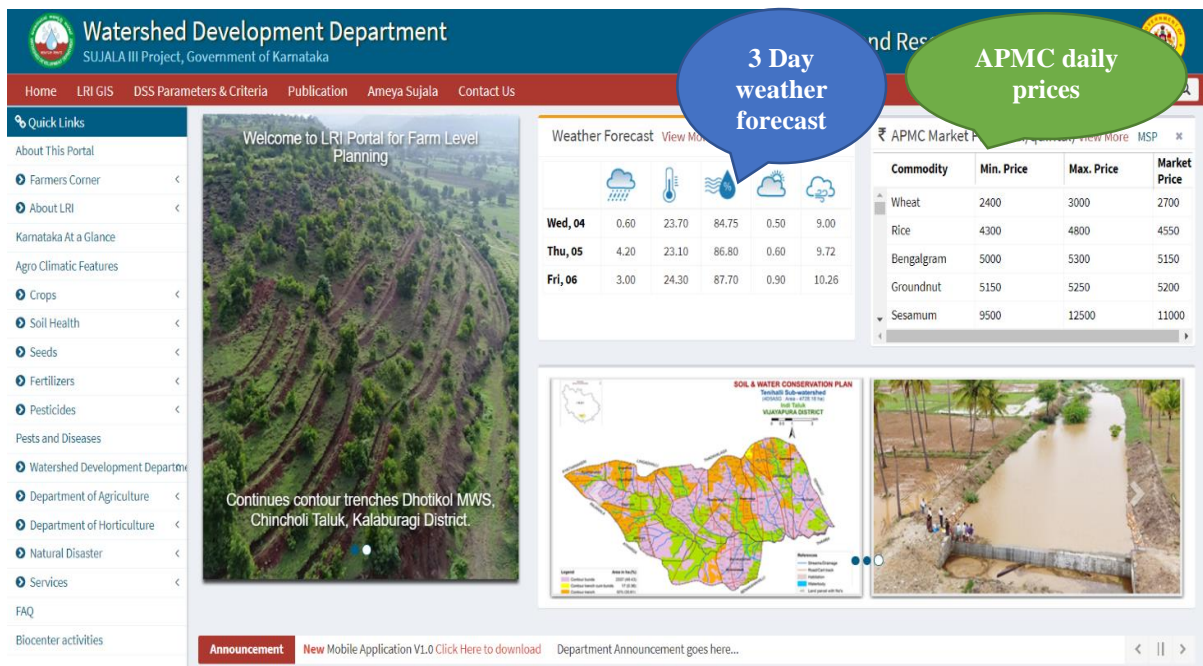
LRI portal

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

LRI Digital Library

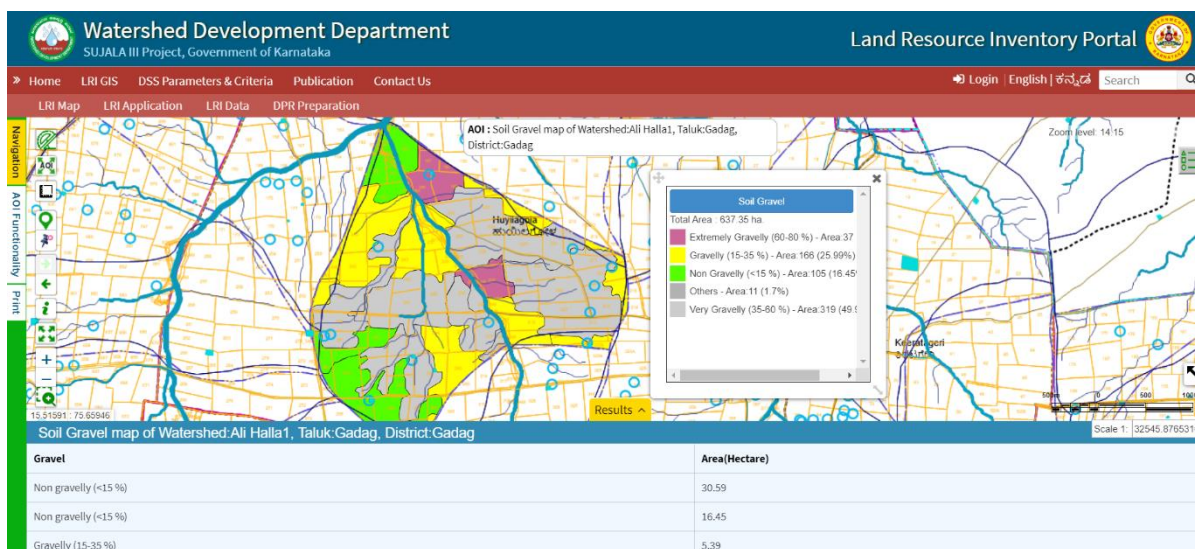
LRI Digital Library is centralized database comprising various thematic maps pertaining to natural resource and project component required for Decision Support System. This is hosted at Karnataka State Data Center which is being equipped with modern IT infrastructure enabling data sharing and collaboration.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

The user can view weather, market prices on real time basis and, select the area of his interest and get the required data/map/information from the Portal. Apart from this, there is a log in facility for the farmers and other users, through which the farmer can register himself and access a host of benefits including advisories on crop selection, 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.



Home page of the LRI Portal

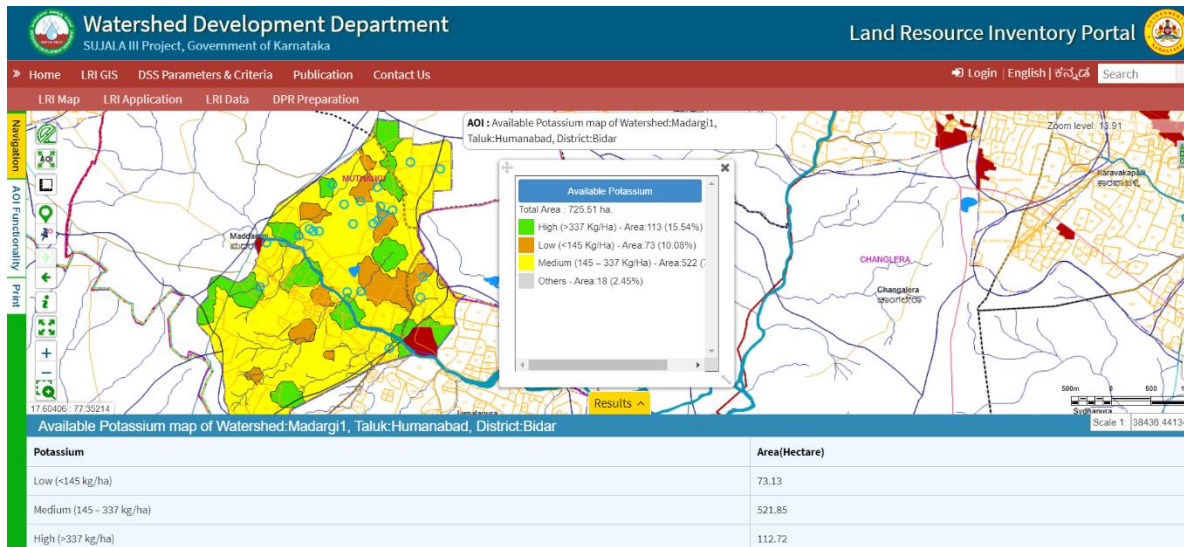
Generation of thematic maps: From the LRI database migrated and stored in the Portal, thematic maps on the constraints, potentials, status of soil nutrients, suitability for various crops and other land uses, hydrological parameters, and various other themes can be generated with the help of the interactive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



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

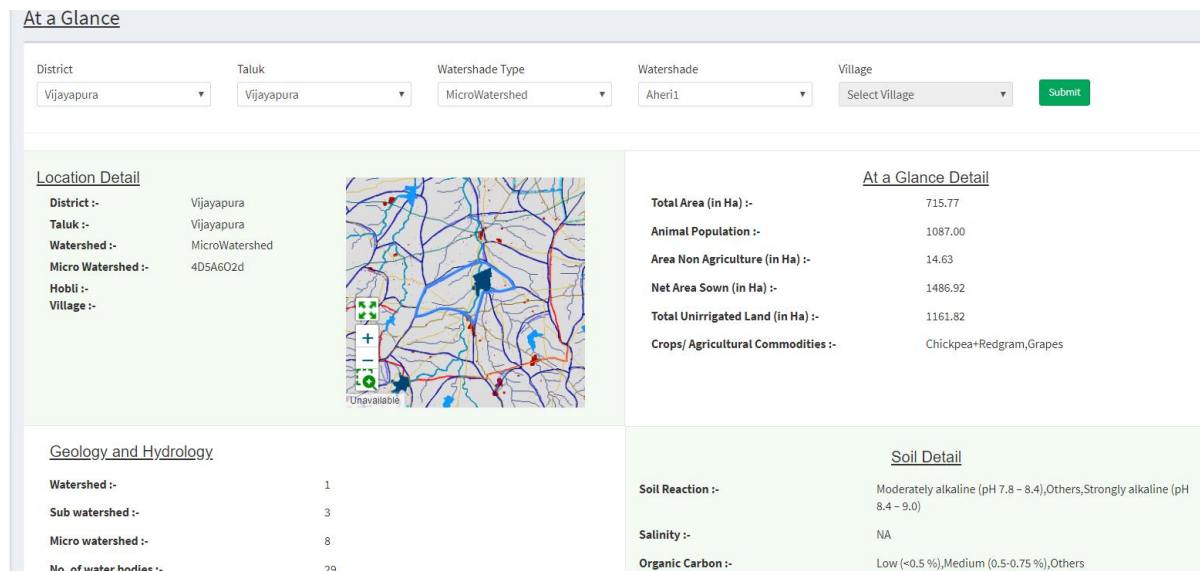
Similarly, the user can generate maps on erosion, slope, soil texture, soil depth, soil moisture, macro and micronutrients, suitability for various crops etc. from the Portal. The map on the status of the available potassium in the soils of Mandargi 1 watershed, shows that it is high in about 15 per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

cent of the area. Similar maps on the status of organic carbon, macro and micronutrients present in the soil can be generated for any area covered by LRI in the state.



Distribution of available Potassium in Mandargi 1 watershed, Humanabad Taluk

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



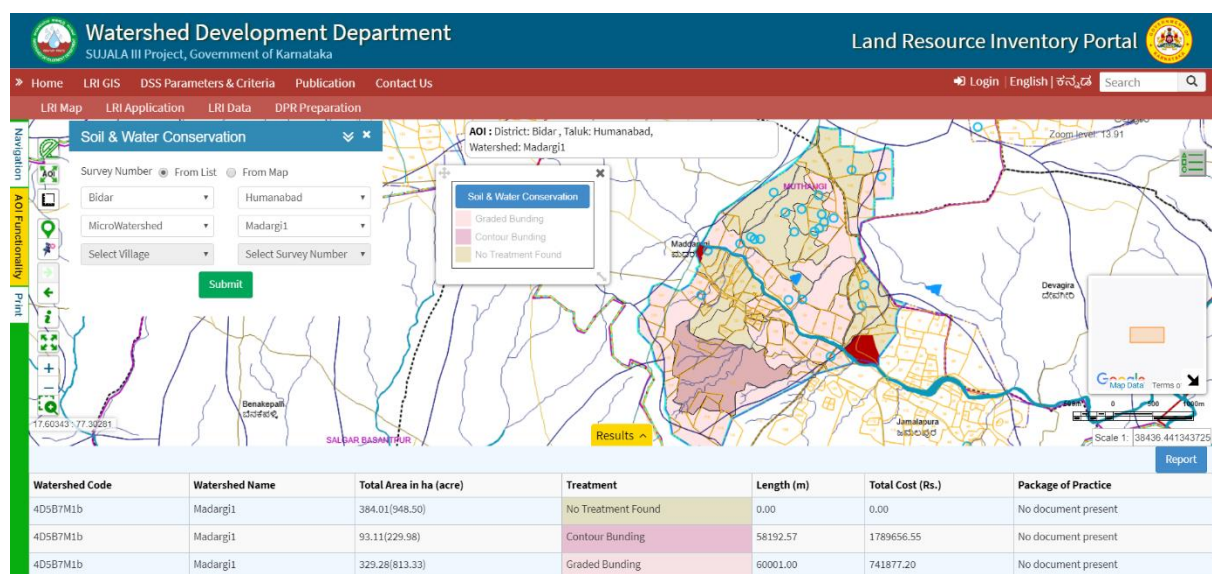
Dashboard for Department Users

Role of Decision Support System (DSS) in Program convergence

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

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

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



Conservation map of Mandargi 1 watershed

Similarly, the DSS on **Crop suitability** compares the bio physical characteristics of the land like the soil-site characteristics, climate etc., with the requirements of the crop and generates

the suitability map. The suitability map will show the degree of suitability like highly, moderately, or marginally suitable or not suitable for the crop with their limitations and extent. The DSS model can also be run at the field or at any higher levels as per the needs of the users. This model is available for about 73 different crops that are under cultivation in the state at present.

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

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

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

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

- For example, due to the availability of site-specific LRI database on real time basis through the Portal, the interventions have become more 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 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 (m³/year)
and ground water recharge (m³/year)

Select if there is any home cottage industry and provide water requirement for irrigation
(m³/year)

Select per cent vegetative cover and bund length manually or automated

Submit

To know the LRI Census Data

Go to “LRI GIS”

Select “LRI Map”

Select “Data”

Select “Census Data”

Select required District, Taluk, Watershed type and Watershed

Uncheck Watershed type to get the information by village wise

Select “Aggregate”

Submit

To get the report on individual nutrient for a MWS

Go to “LRI GIS”

Select “LRI Map”

Select “Custom report”

Select fertility parameter required

Select required District, Taluk, Watershed and fertility rating

Click “Execute”

5. Decision support systems for selection of WSD interventions

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. (Note: Under Sujala III project, land capability assessment is done only up to land capability subclass and not up to land capability unit levels)

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

Source:

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

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

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

	Black soils								
		A (<1%)	√						
	B (1-3%)		√						
	C (3-5%)			√					
	D (5-10%)				√				
Erosion	Slight (e ₁)	√							
	Moderate (e ₂)		√						
	Severe (e ₃)			√					
	Very Severe (e ₄)				√				
Drainage	Excessive						√		
	Well drained	√							
	Mod.WD		√						
	Imperfect			√					
	Poor				√				
	Very Poor					√			
Soil depth	> 100 cm	√							
	50 –100 cm		√						
	25-50 cm			√					
	10-25 cm				√				
	< 10 cm						√		
Texture	sl, scl, cl, loam, silty clay loam	√							
	sandy clay, silty clay		√						
	clay			√					
	loamy sand				√				
	sand						√		
Gravels	< 15 %	√							
	15-35 %		√						
	35-60 %			√					
	> 60 %				√				
Rockout crops (%)	<2		√						
	2-10			√					
	10-50				√				
	50-90					√			
	>90						√		
Salinity	<2	√							√

Reference material, CoE-WM

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							√	

Exercise - 3

Delineation of arable and prime lands based on land capability assessment

1. Based on the land capability classification presented in the sample atlas, group each soil phase into various land capability classes and sub classes.
2. The parameters to be considered and the ratings to be used in grouping the land parcels into land capability units are given in Page No 90.
3. To understand soil characteristics soil-sight characteristics criteria refer Annexure at last of the book.

Parameters	Depth	Drainage	e		w	s			LCC
			Slope	Erosion	Drainage	Soil depth	Texture	Gravels	
BNHhA2g1	100-150	Well							
BNKaB1g1	>150	Imperfect							
CKHcE2g2	25-50	Well							
KBTmB3g1	100-150	M. well							
YARhA1	>150	Well							

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 from Sujala III project 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. This chapter elaborates the criteria used for the development of the DSS, look up table for deciding the type of structures, cost norms followed, flow charts and expected outputs (maps, tables etc.) from the DSS.

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. The sequence of activities involved in the selection of different structures and preparation of Soil and Water conservation plan for a given watershed is elaborated in the Implementation Manual for Sujala III project (WDD, 2016).

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

Sl. No.	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

Reference material, CoE-WM

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
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

Reference material, CoE-WM

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

Reference material, CoE-WM

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
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

Reference material, CoE-WM

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
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

Reference material, CoE-WM

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

Reference material, CoE-WM

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
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: ¹As 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.

²If 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

Sl. No.	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Sub surface			
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)
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
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)
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: ¹As 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

Sl. No.	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Sub surface			
1	<5	<25	Loam	Clay	<35%	<=750	Contour trenching (continuous/staggered contour trench)
2	<5	<25	Loam	Clay	<35%	750-950	Graded trenching

Reference material, CoE-WM

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

Reference material, CoE-WM

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
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
Terracing	<p>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</p>				

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

<i>Texture</i>	<i>Gravel</i>	<i>Depth</i>	<i>Top width</i>	<i>Base width</i>	<i>Height</i>	<i>Side slope</i>	<i>Cross section</i>
<i>Contour bunding</i>							
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
<i>Graded bunding</i>							
Clay	<35	50-100	0.3	1.2	0.5	0.9:1.0	0.375
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
<i>For Plantation crops</i>							
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]							
			0.375	0.45	0.54	0.72	0.92	1.07	1.29	1.49
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
<i>a) Black Soils/Red Soils</i>										
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
<i>b) Lateritic Soils</i>										
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
	Total		62.74	71.96	81.98	105.00	137.96	156.13	187.97	213.46
<i>a) Black Soils/Red Soils</i>										
		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									
	<i>b) Lateritic Soils</i>									
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
<i>a) Black Soils/Red Sandy Soils</i>										
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

<i>b) Lateritic Soils</i>										
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)

<i>Slope (%)</i>	<i>Cost (Rs./ha)</i>			
	<i>Bund Section (m²)</i>			
	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

<i>Soil type</i>	<i>Gravel</i>	<i>Soil texture</i>	<i>Mode of execution</i>	<i>SoR</i>	<i>Cost of earth work per metre bund length (Rs.) as per bund sections (m²) given below</i>			
					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

<i>Bund section m²</i>	<i>Average cost/ channel weir</i>	<i>Average cost/ channel weir</i>
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)

<i>Sl. No.</i>	<i>Land slope (%)</i>	<i>Profile depth (cm)</i>	<i>Total cost of terracing (Rs./ha)</i>
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 0.06m² 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

<i>Sl. No.</i>	<i>Land Slope (%)</i>	<i>Profile depth (cm)</i>	<i>Total cost of terracing (Rs./ha)</i>
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 0.06m² 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

<i>Sl. No.</i>	<i>Land Slope (%)</i>	<i>Profile Depth (cm)</i>	<i>Total cost of terracing (Rs./ha)</i>
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 m² 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

<i>Sl. No.</i>	<i>Land slope (%)</i>	<i>Profile depth (cm)</i>	<i>Total cost of terracing (Rs./ha)</i>
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 m² 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

<i>Contour trench</i>		<i>Staggered trench</i>					
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

<i>Sl. No.</i>	<i>Slope (%)</i>	<i>Horizontal interval (m)</i>	<i>Volume of earth excavation (m³) per ha</i>	
			<i>Continuous contour trenches</i>	<i>Staggered contour trenches</i>
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

<i>Soil type</i>	<i>Gravel</i>	<i>Soil</i>	<i>Mode of execution</i>	<i>SoR</i>	<i>Cost of earth work per metre length of trench (Rs.) Trench section: 0.27m²</i>
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

Exercise - 4

Soil and Water conservation for arable and non-arable lands

<i>Steps</i>	<i>Description</i>
1	Select two distinct soil phases and study their land characteristics
2	Select treatment for land characteristics based on decision rules (Page No. 95 or 102)
3	Select vertical and horizontal interval based on decision rules (Page No. 110)
4	Select cross-section of structure based on the decision rules (Page No. 111)
5	Estimate length of Bunding per hectare (m) = $10000 \times S / (VI \times 100)$
6	Estimate cost of conservation structure based on decision rules (Page No. 112 for Contour Bunding and TCB and Page No. 114 for Graded bunds.

DSS-2 (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

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

B. Quantitative evaluation

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

Land Suitability Evaluation

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

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

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

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

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

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

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

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

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

Order S (Suitable)

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

Order N (Not Suitable)

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

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

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

Drainage problem	w
Moisture availability	m
calcareousness	z
Topography	l

Limitations are indicated in lower case letters after the suitability class symbol. For example, marginally suitable land with low rainfall or short growing period as a limitation is designated as S3c. Normally two and sometimes three limitations are included at subclass level. Land suitability units are indicated by the Arabic numbers after the limitation symbol.

Based on the suitability classification, land resources of any watershed or area can be evaluated to find out their suitability for various crops, like cereals and millets, oil seeds, pulses, commercial crops like cotton, sugarcane, spices and horticultural crops. The assessment can be done for the existing crops that are under cultivation at present or for some of the promising crops and varieties from other places before they are recommended for cultivation in the area.

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

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

Example:

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

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

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

Benefit cost ratio: is decided based on standard cost of cultivation, yield and dynamic market prices. The standard cost of cultivation for any crop is available with the Department of Agriculture. Market prices can be obtained from Agmarketnet web API. Using the above the B:C Ratio can be calculated as (Yield X Market Price) / Cost of Cultivation.

The Crop suitability choices arrived for an area need to be shared to the concerned agricultural office/stakeholders and vetted before the same is recommended to the farmer. This assessment can help greatly in identifying the best suited areas and the areas having limitations in the watershed area. Similar assessments can be made for other areas and for other crops for the same area.

Exercise - 5

Crop wise soil characteristics for deciding suitability of crops

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

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

Soil Phase	Characters					<i>r</i>	<i>t</i>	<i>g</i>	<i>l</i>	<i>w</i>	Suitability class
	Depth	SSG	SST	Slope	Drainage	Depth	Texture	Gravels	Slope	Drainage	
Ragi											
TDHhB1	50-75	0	sc	1-3%	mod. well						
APHiA1St1	<25	33	sl	0-1%	well						
CKMiC1g1	75-100	0	ls	3-5%	poor						
Redgram											
KMHbB1g1	100-150	23	c(r)	1-3%	well						
BPRiB1	25-50	32	scl	1-3%	poor						
JDGcA1	50-75	8	sc	0-1%	mod. well						
Arecanut											
GLRiD1	100-150	40	c(r)	5-10%	well						
NDLhC1	>150	50	s	3-5%	well						
BDKcB1	25-50	14	c(b)	1-3%	very poor						
Mango											
RTRiB2g1	25-50	10	c(b)	1-3%	well						
TSDiA1	75-100	17	scl	0-1%	poor						
TDGiC1	>150	37	s	3-5%	well						

DSS-4 (nutrient management and soil health)

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

In the recent past, concept of watershed based holistic development has emerged as one of the potential approach 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)

<i>Nutrient</i>	<i>Very Low</i>	<i>Low</i>	<i>Medium</i>	<i>High</i>	<i>Very High</i>
Nitrogen	Recommended dose x 1.67	Recommended dose x 1.33	Recommended dose x 1.00	Recommended dose x 0.67	Recommended dose x 0.33
P ₂ O ₅					
K ₂ O					

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 x 1.33), 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

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

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

Exercise - 6

Nutrient Management Plan

1	Select a micro watershed
2	Select two crops suggested for a particular survey number in a soil phase
3	Study the soil fertility status for major nutrients of the survey number in a soil phase
4	Select nutrient recommendation for the selected crops
5	Adjust nutrient recommendation considering soil fertility status and RDF of selected crop
6	Select the suitable combination of fertilizers and estimate the quantity of fertilizers required for the crop
7	Estimate the dose at different stages of plant growth (Basal dose and top dressing)
8	Workout the cost per hectare

Status of nutrients for a particular survey number in a soil phase (refer the atlas)

Soil phase	Survey number	Nutrient status (low/medium/high)		
		N	P	K

Select Two crops and Two combinations of fertilizers, workout the per hectare nutrient requirement and the cost

Item	Crops	
	1.	2.
Nutrients recommendation (RDF) (as per standard PoP)		
Adjusted nutrient as per soil nutrient status (Page No. 129)		
Type and quantity of fertilizers recommended		
Combination 1		
Urea		
SSP		
MOP		
Combination 2		
DAP		
17-17-17		
Urea		
MOP		
Cost of fertilizers (Rs.)		

6. Decision support systems for selection of WSD interventions:

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

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

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

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

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

Multiplication factor for converting AMC II to AMC I or III

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

Rational method (Ramser’s method)

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

Recurrence interval for different conservation structures

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

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

Rational Formula $Q = CIA/360$,

Where,

‘Q’ is peak rate of runoff (Cubic meters per second)

‘C’ is runoff coefficient (Table 6.6)

‘A’ is area of catchment (hectares)

‘I’ is intensity of rainfall for the design frequency and for duration equal to time of concentration of the watershed/catchment. (mm/hr.). Highest rainfall intensity of a day observed in about 10 years’ time period or whatever years data is available from KSNDMC.

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

$$C_w = A_1C_1 + A_2 C_2 + \dots A_n C_n/A$$

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

‘C’ Values for use in Rational formula

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

Rainfall Intensity

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

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

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

Where ΔH is difference in elevation in meters

L is maximum length of the flow in meters

Rainfall intensity – duration – return period relationship & Empirical constants

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

Infiltration Method

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

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

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

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

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

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

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

4. If Slope and Soil Texture are not available, Infiltration rate is considered as 8 for clay bound and 13 for red and lateritic soils.
5. If the selected survey number has different slopes or soil type, then Weighted Average of Infiltration Rate will be considered for the further calculations.
6. **Net instantaneous runoff** is estimated by subtracting Infiltration rate due to Slope and Vegetation (mm/hr) from Average Rainfall Intensity (mm/hr).

$$\text{Net Instantaneous Runoff Rate} = (\text{Average Rainfall Intensity}) - (\text{Infiltration rate})$$
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 (R_r) (mm) is calculated by multiplying Minimum Length of the Bund (m) and Anticipated Water Spread Area (m^2).

$$\text{Design Runoff Retained} = (\text{min length of the bund}) * (\text{Anticipated Water Spread Area}) / 10$$

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 $R_d > R_r$,

$$\text{Design Runoff Excess} = \text{Design Runoff Depth} - \text{Design Runoff Retained}$$

Else,

$$\text{Design Runoff Excess} = 0$$

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

DSS-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. /m³)

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

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

For Black Soil: 1.5:1

For Red Soil: 1:1

Depth needs to be considered as 3 m.

Top Width = $\sqrt{(\text{Runoff Volume}/3) + 4.5}$ for Black soil

Top Width = $\sqrt{(\text{Runoff Volume}/3) + 3}$ for Red Soil

$$\text{Bottom Width} = \sqrt{(\text{Runoff Volume}/3) - 4.5} \text{ for Black soil}$$

$$\text{Bottom Width} = \sqrt{(\text{Runoff Volume}/3) - 3} \text{ for Red Soil}$$

$$\text{Top Area} = \text{Top Width} * \text{Top Length}$$

$$\text{Since its square Top width} = \text{Top Length}$$

$$\text{Bottom Area} = \text{Bottom Width} * \text{Bottom Length}$$

$$\text{Since its square Bottom width} = \text{bottom Length}$$

$$\text{Volume} = (\text{Top Area} + \text{Bottom Area})/2 * \text{Depth}$$

Example:

$$\text{Depth of Farm Pond} : 3 \text{ m}$$

$$70\% \text{ Surface Runoff} : 1500 \text{ m}^3$$

$$\text{Soil Type} : \text{Black Soil, Slide Slope consider as } 1.5:1$$

$$\text{Top Width} = \sqrt{(1500/3) + 4.5} = 26.8608 \text{ (Round off the Top width to } = 27 \text{ m)}$$

$$\text{Top Area} = \text{Top Width} * \text{Top Length} = 27 * 27 = 729 \text{ m}^2$$

$$\text{Bottom Width} = \sqrt{(1500/3) - 4.5} = 17.8608 \text{ (Round off the Bottom width to } = 18 \text{ m)}$$

$$\text{Bottom Area} = \text{Bottom Width} * \text{Bottom Length} = 18 * 18 = 324 \text{ m}^2$$

$$\begin{aligned} \text{Volume of Farm Pond} &= (\text{Top Area} + \text{Bottom Area}) / 2 * \text{Depth} \\ &= (729 + 324)/2 * 3 = 1579.5 \text{ m}^3 \end{aligned}$$

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

- Further, the application will check for the Storage Capacity (m³) by considering the 70% Runoff for the purpose of harvesting (from DSS 5.2 – Infiltration method)
- Depending on the standard rates of farm pond construction, cost of construction (rupees) is estimated
- Total Surface runoff (mm/year) is displayed in the final output table along with the farm pond size and the cost of construction. Display the Farm owner details based on the data fetched for cadastral from Bhoomi data
- Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyze DSS results based on these temporary changes

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

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

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 m³) 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 0.6 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

<i>Sl. No.</i>	<i>Storage capacity (m³)</i>	<i>Cost (Rs.)</i>	<i>Check dam-apron type</i>	<i>Catchment area (ha)</i>	<i>Gully depth (m)</i>	<i>Crest height (h) (m)</i>
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

Reference material, CoE-WM

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
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
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
<p>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)</p>						

Type of check dam

<i>Shape of Nala banks</i>	<i>Stone availability</i>	<i>Nala bed Condition</i>	<i>Type of check dam</i>
'V' Shape Nala bank with side slope milder 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 milder than 1:1	Available at more than 5km distance	Clayey/ lateritic soil	Solid Apron Type
'U' Shape Nala bank with side slope steeper than 1:1		Hard strata at a depth more than 1.0m	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.

Exercise - 7

Designing the size of Farm Ponds and Check Dams based on Runoff Calculation

Suggest the size of the farm pond for a given condition with cost estimates – Refer Page No.

138 & 139 for details

Catchment area - 1ha

Runoff - 30 mm

Soil type - Red

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 (ET_c). Crop water requirement is estimated using FAO 56 method. The common approach to calculate ET_c is to estimate a reference crop Evapotranspiration (ET_o) using weather variables from nearby weather station and multiplying it by an appropriate crop coefficient (K_c). Inputs required for estimating the crop water requirement is mentioned in Table 4. Steps for estimating the crop water requirement given in Table 5.

Inputs required for estimating Crop Water requirement

Inputs	Input parameter	Master table	Note
Location information	Geo-coordinates, land area	Micro-watersheds, management units, parcel numbers,	
Weather	Maximum, Minimum Temperature, Relative humidity, solar radiation or Sunshine Hours, wind speed, etc.	Estimate Potential evapotranspiration at daily scale	ET _o 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	K _c values to be compiled for different crops and for root growth characteristics like very shallow, shallow, medium, deep and very deep

Steps involved in the estimation of Crop Water requirements

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

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

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

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

	Crop	Initial stage Kc	Midseason Kc	End season Kc	Remarks
All Small Vegetables		0.7	1.05	0.95	
1	Cabbage		1.05	0.95	
2	Cauliflower		1.05	0.95	
3	Carrots		1.05	0.95	
4	Lettuce		1.00	0.95	
5	Garlic		1.00	0.70	
6	Onions		1.05	0.75	
7	Radish		0.90	0.85	
8	Spinach		1.00	0.95	
9	Broccoli		1.05	0.95	
Vegetables	All Solanaceous crops	0.6	1.15	0.80	
1	Tomato		1.15	0.70-0.90	
2	Egg Plant		1.05	0.90	
3	Capsicum (bell)		1.05	0.90	
Vegetables	All Cucumber family crops	0.5	1.00	0.80	
1	Cucumber	0.6	1.00	0.75	
2	Pumpkin		1.00	0.80	
3	Watermelon	0.4	1.00	0.75	
4	Sweet Melons		1.05	0.75	
5					
Tuber crops	All tuber crops	0.5	1.10	0.95	
1	Cassava	0.3	0.80	0.30	
2	Potato		1.15	0.75	
3	Sweet Potato		1.15	0.65	
4	Turnip		1.15	0.95	
Legumes	All Legumes	0.4	1.15	0.55	

Reference material, CoE-WM

1	Green Gram & Cowpeas		1.05	0.60 (Harvested fresh)	
2	Green Gram & Cowpeas		1.05	0.35 (Harvested dry)	
3	Groundnut		1.15	0.60	
4	Chickpea		1.00	0.35	
5	Soybeans		1.15	0.50	
6	Beans (green)	0.5	1.05	0.90	
Fibre Crops		0.35			
	Cotton		1.15-1.20	0 0.70-0.50	
Oilseeds	All oilseeds	0.35	1.15	0.35	
1	Castor		1.15	0.55	
2	Rapeseed		1.0-1.15	0.35	
3	Safflower		1.0-1.15	0.25	
4	Sesame		1.10	0.25	
5	Sunflower		1.0-1.15	0.35	
Cereals	All cereal crops	0.3	1.15	0.4	
1	Maize		1.20	0.60	
2	Sorghum-grain		1.00-1.10	0.55	
3	Rice	1.05	1.20	0.90-0.60	
4	Millet		1.00	0.30	
5	Bajra				
Sugarcane		0.40	1.25	0.75	
Banana	1st year	0.50	1.10	1.00	
	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	70% canopy	0.75	0.70	0.75	
	50% canopy	0.80	0.80	0.80	

Exercise - 8

Estimation of crop water requirement

Steps in estimation of crop water requirement

#	Description of the steps involved
1	Define land use class/ cropping system and its management details
2	Estimate day after sowing
3	Estimate crop coefficient based on days after sowing and crop growth parameters
4	Estimate potential evapotranspiration requirement using measured weather parameters on daily time scale
5	Estimate crop water requirement using crop coefficient (Page No. 147) and potential evapotranspiration (Multiply crop coefficient with PET)
6	Display crop-wise water requirement at parcel level. (Aggregate crop water requirement at soil unit, MWS and SWS levels based on the crop cultivated)
7	Display crop-wise water requirement to the farmer/other stakeholders

Calculate the crop water requirement for the following crops in one soil phase

Place: Hodekallu micro watershed in Tumkur Taluk

Daily average PET during south-west monsoon is 4.33

Daily average PET during north-east monsoon is 4.49

Refer table-13 page: 17 for crop coefficient (Kc) values compiled for major crops (FAO, 1998)

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

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:

$$\text{Change in soil moisture storage} = \text{Rainfall} + \text{Irrigation} - \text{Surface runoff} - \text{Evapotranspiration} - \text{Deep percolation}$$

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 <i>pedo-transfer</i> 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 (Table 8.3) 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

S. No	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, E_t , 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	

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

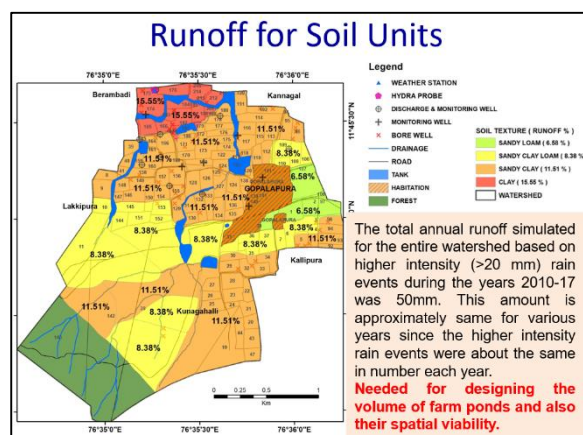
Sl. No.	Steps	Data requirement
1	Estimate Soil water balance component for selected micro-watershed	Based on the DSS already executed-Soil moisture/water
2	Estimate water availability in micro-watershed using 1. Measured capacities of surface water bodies	

	<p>2. Runoff generated through watershed based on runoff from Infiltration method</p> <p>3. Amount of water percolation in soil-ground water (deep percolation component in water balance)</p>	
3	Estimate water required for irrigation based on the crop water requirement and irrigation 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	

7. Demystifying science-based approaches in watershed management to 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 are 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.



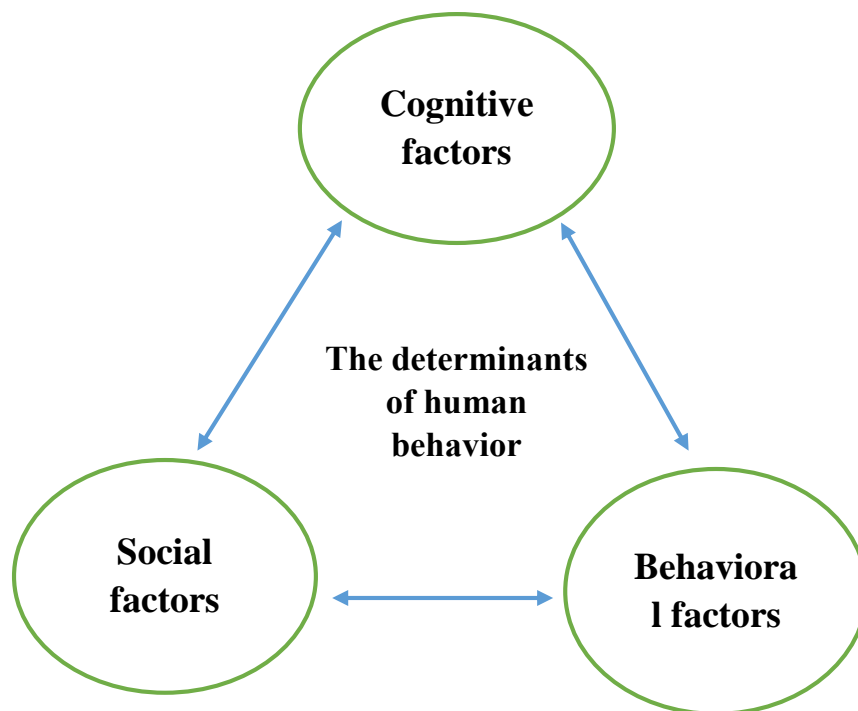
Approach to demystify science to communities

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

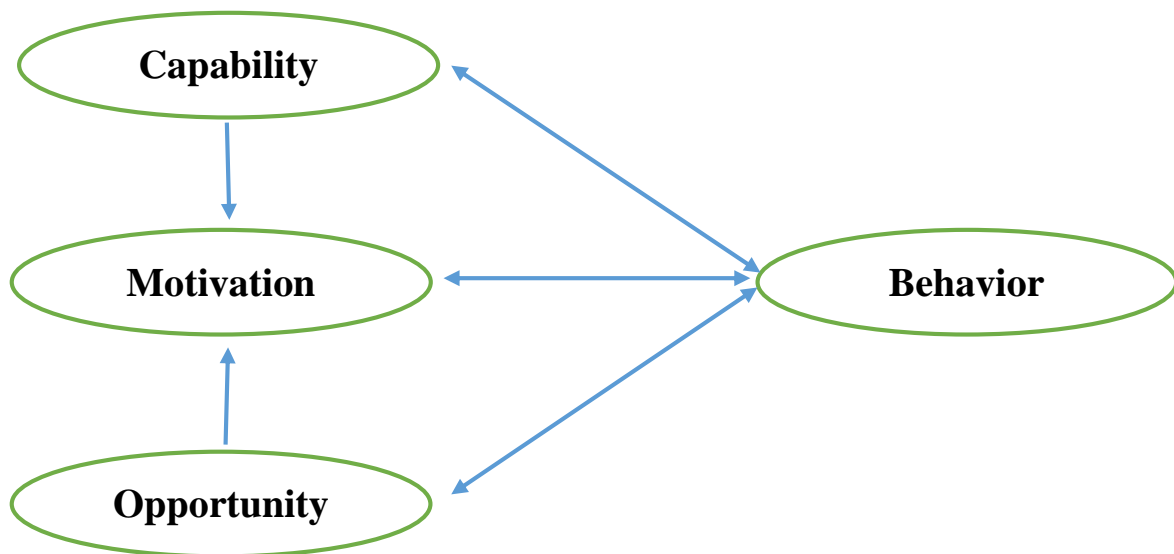
It is important to provide clarity regarding what to change and to specify target behaviors in terms of:

- 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 behavior 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.

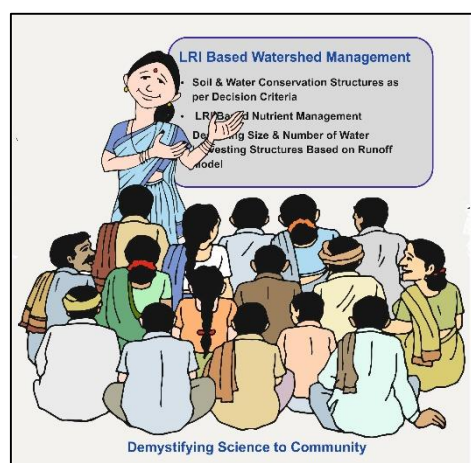
Opportunity can be achieved through by educating on the alternate approaches to improve or solve the problems over the existing approaches or relative advantages of all those alternatives compared to the existing ones.

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:

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)

Exercise - 9

Develop a strategy to demystify science - to convince the villagers in a micro-watershed to change the interventions as per scientific studies (LRI/ Hydrology)

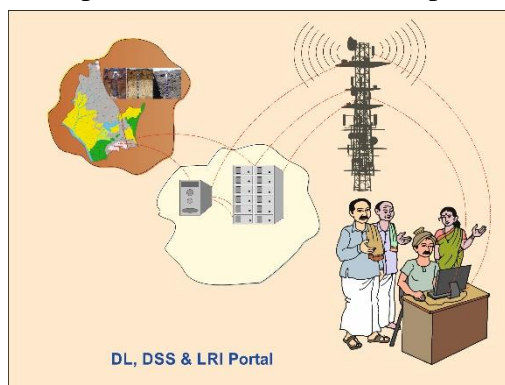
<i>Sl. No.</i>	<i>Intervention</i>		<i>Strategy</i>
	<i>Present</i>	<i>As per scientific study</i>	
1	Contour bund with cross section of 0.72 (Clay soil)	Contour bund with cross section of 0.54 (Clay soil) Refer page No: 30 DSS	
2	Farmer want to establish mango orchard in a soil with following characteristics: Mango in TSDiA1	Suitability class: S3rw Soil depth: 75-100 (S3) SSG: 17% (S1) SST: scl (S1) Slope: 0-1% (S1) Drainage: poor (S3)	
3	Farmers want a check dam at a particular location in the drainage line.	Based on the runoff estimation the harvestable runoff is 800 cubic meters	

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), Pradhanmantri Kissan Samman Nidhi, Organic farming, Millets promotion, etc. The production potential of crops from these programs can be improved by utilising data generated under the REWARD.

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

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

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

Critical levels for Convergence

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

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

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

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

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

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

Format for convergence of REWARD program activities with other departments activities

<i>No.</i>	<i>DPR items</i>	<i>Specific activities identified for convergence</i>	<i>Mode of convergence</i>	<i>Expected outcomes</i>	<i>Remarks</i>
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				

Exercise - 10

Format for convergence of REWARD program activities with other departments activities

<i>Sl. No.</i>	<i>Activities</i>	<i>Name of the Department:</i>	
		<i>Specific activities identified for convergence</i>	<i>Mode of convergence</i>
1	Soil and water conservation		
2	Agriculture		
3	Horticulture		
4	Animal husbandry		
5	Fisheries		
6	Forestry		

8. DPR generation, community consultation and validation of DPR generated and approval protocols

**DRAFT GUIDELINES FOR
INTERNAL USE ONLY**



**Government of Karnataka
Watershed Development Department**

**DRAFT GUIDELINES FOR
DETAILED PROJECT REPORT (DPR) GENERATION USING LRI DATA AND
COMMUNITY CONSULTATION PROCESS**

**REWARD Program
(Rejuvenating Watersheds for Agricultural Resilience through Innovative
Development)**

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	B. Brief about REWARD and key principles
	C. REWARD Program description
	D. Program development objective
	E. Need for Community consultation for DPR generated using LRI data
II	Summary of Guidelines for Preparing DPR Reports using LRI data
	A. Prerequisites for preparation of DPRs/Pre Planning Phase (4 Weeks)
	B. Constitution of Watershed Development Team at SWS Level and Training
	C. DPR Generation and Community Consultation (4 weeks)
	D. Compilation and approval of SWS DPR
III	Detailed Guidelines for Preparing Detailed Project Reports using LRI data
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	Annexure - II: Self Help Groups, Area Groups & Watershed Executive Committees (WECs), under REWARD
	Annexure - III a: Training topics for CBOs
	Annexure - III b: Trainings by DATC
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	Annexure - V: DPR training – Program schedule
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	Annexure - XI: Below points were discussed with the group during transact walk

ACRONYMS

AAO	Assistant Agriculture Officer
ACF	Assistant Conservator of Forest
ADA	Assistant Director of Agriculture
AG	Area Group
AO	Agriculture Officer
CBO	Community Based Organization
CEO	Chief Executive Officer
CPR	Common Property Resource
DATC	District Agriculture Training Center
DC	District Coordinator
DLTC	District Level Technical Committee
E & S	Environment and Social Screening
EPA	Entry Point Activity
ESSA	Environment and Social System Assessment
FGD	Focus Group Discussion
FNGO	Field Non-Government Organization
FPO	Farmers Producer Organization
GP	Gram Panchayat
IEC	Information Education Communication
JDA	Joint Director of Agriculture
LRI-EM	Land Resource Inventory Extension Managers
MGNREGS	Mahatma Gandhi National. Rural Employment Guarantee Scheme
MWS	Micro Watershed
NGO	Non-Government Organization
PAT	Performance Assessment Tool
PIA	Project Implementation Agency
PPR	Pre Project Report
RFO	Range Forest Officer
RKVY	Rastriya Krushi Vikasa Yojana
RSK	Raitha Samparka Kendra
SADH	Senior Assistant Director of Horticulture
SHG	Self Help Group
SWS	Sub Watershed
TC	Training Coordinator
TL	Team Leader
ToT	Training of Trainers
WA	Watershed Assistant
WCDC	Watershed Cell Cum Data Center
WDT	Watershed Development Team
WEC	Watershed Executive Committee

I. Introduction

A. Context

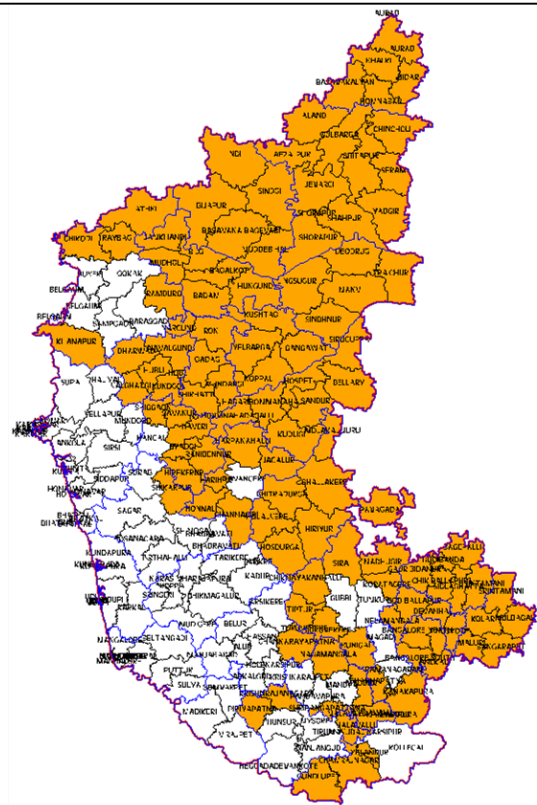
Karnataka is the eighth largest State in India, with highest percentage (79%) of drought prone area (Plate-1). More than 66% of total lands (2/3rd) in Karnataka depend only on rainfed agriculture. Recurrence of drought is a common phenomenon in Karnataka State due to spatial and temporal variations in rainfall. Frequent droughts have caused colossal loss to crops and lives of distressed farmers which has directly affected their socio-economic condition and livelihoods. In recent days due to change distribution pattern of rainfall state is also facing loss of crop and soil due to flooding. In absolute terms, Karnataka has the second largest dry land next to Rajasthan. This valuable resource which serves as the main source of livelihood for the large chunk of the rural population over a long period of time, has been subjected to poor land management practices. This has led to deteriorating soil fertility, soil loss, declining productivity, depletion of water resources, deforestation, denudation, destruction of natural pasture and diminishing biomass production, leading to low economic status in rural areas of rainfed regions in the State. To address these challenges, it is

prerequisite to adopt an integrated and holistic approach of scientific watershed development covering both land based and non-land based interventions for ensuring sustained soil fertility by addressing the issues of equity, gender participation and optimum utilization of natural resources. In this context, Watershed Development approach has been widely acknowledged as an effective solution to address the needs of rainfed agriculture. This is owing to the fact that it looks at increasing productivity of degraded lands and developing, maintaining and using natural resources on a sustainable basis.

Though initially watershed development was looked as mere conservation of soil and water through various land treatment interventions; in recent years, there has been a paradigm shift from a conventional to a multi-sectoral participatory and scientific approach. This is designed not only to develop natural resources management and improving agricultural productivity but also for the precise planning through the use of Remote Sensing (RS), Geographic Information System (GIS) & Land Resource Inventory (LRI) information.

Karnataka is the first State in India to create Watershed Development Department during the year 2000. Since then, the department has implemented many watershed projects for watershed development. Karnataka Watershed Development Project-II (Sujala-III) is one such project implemented from 2013-2019 in 12 districts of the State with scientific approach in partnership state agriculture and horticulture universities. Under this project LRI was established 2534 micro watersheds covering 14 lakh ha. Eleven pilot watershed development projects were

Frequently drought affected taluks in Karnataka



taken up based on LRI recommendations in saturation mode. The scientific LRI information generated in the project was provided to farmers as site specific scientific advisories to help to select suitable crops and application optimum quantity of nutrients thereby achieving optimum yield with reduced cost of cultivation resulting in enhanced soil health and income.

Sujala III is the first of its kind in the country. Through this project, farming community in the project area are experiencing the utility of technological application in agriculture through farm specific scientific recommendations of land resource inventory, for effective crop, farm management, and soil & water conservation practices (Plate-2). Sujala-III project has provided inputs for better understanding of hydrological dynamics and climatic variability by developing tools for measuring them and merging innovations and decision support information to address the needs of rainfed farmers and to adopt in the watershed planning and implementation system. The inputs of Sujala-III project have also contributed in formulating the Karnataka State Farmers Producers Organisation (FPO) policy for organizing farmers into commercial entities. These collectives are considered to be most effective means to reduce both production and market risk faced by agriculture sector and improving access to technology, investment and market; particularly small and marginal farmers and also aggregation of both input and output will enhance their bargaining capacity resulting in remunerative prices for their produce.

Saturation watershed treatment as per LRI under Sujala-III project



Sujala-III has created laboratories equipped with various advanced tools and equipment and other infrastructure facilities, skilled manpower in all the 5 State Agriculture and Horticulture Universities and National Bureau of Soil Survey and Land Use Planning (NBSS-LUP) for carrying out soil and water analysis and generation of data at field and laboratories and bringing out the output in digitized form using GIS to upload into the Digital Library and LRI inputs. Advanced equipment's were procured by the Karnataka State Remote Sensing and Application Centre (KSRSAC) for providing State-wide cadastral maps and high-resolution imageries. Karnataka State Natural Disaster Management Centre (KSNDMC) was provided with improved weather monitoring systems and applications to disseminate continuous climate and weather data and for feeding the same into the Digital LRI inputs. The rich data generated by these Agriculture and Horticulture Universities is not only used for Watershed Development Department but also by other developmental departments for better planning and

implementation of their land-based schemes. Karnataka State has total 19.05 million ha. geographical area of which 12.97 million ha is the treatable area and in this 6.85 million ha area is already treated and 0.89 million ha is being treated under various watershed programs. Thus about 5.23 million ha (52.31 lakh ha) rainfed watershed area is yet to be treated on watershed approach. Hence, the improved infrastructure, skilled manpower and other knowledge created in the Sujala-III project is intended to be used effectively for scaling up the Sujala-III interventions in other parts of the State and to disseminate the scientific information generated by implementing REWARD (Rejuvenating Watersheds for Agricultural Resilience through Innovative Development) program in the State.

B. Brief about REWARD and key principles

The REWARD is a World Bank assisted “P for R” (Program for Results) Program which will support the next phase of watershed development program of the Government of India’s (GoI), also referred to as the WDC-PMKSY. The proposed US\$60 million International Bank for Reconstruction and Development (IBRD) allocation to the REWARD Program is a sub- set of the new WDC-PMKSY that has an outlay of US\$4,600 million. While the GoI program is implemented across all States (except for the State of Goa), the REWARD Program will be implemented in selected States.

States are selected into the program when they meet specific qualifying and readiness criteria such as: a) extent of rainfed area in the State; b) socio-economic profile; c) financial readiness: the State leaders have agreed to take an IBRD loan and provide counterpart financing of 30 percent of the cost of the Program; d) financial performance: the States have demonstrated utilization of more than 85 percent of the funds released by the DoLR under the WDC-PMKSY in the past five years; e) institutional readiness: the States have established institutional arrangements at the State and district levels for watershed development and initiated partnerships with technical institutions; and f) demonstrated performance: the States have strong leadership in the SWD and demonstrated capacity to plan and implement watersheds at scale with evidence of results. The central agency DoLR will also borrow a modest IBRD loan for coordination and Knowledge activities

REWARD Program primarily benefits for the communities in rainfed areas which rely on land and water resources for livelihoods and ecosystem services. The sustainable development of watersheds based on better scientific inputs and technical capacities will conserve soil, improve surface and ground water availability and efficient usage and thereby enhance agricultural productivity and profitability resulting in sustainable improvement in income generation. In particular, it will have positive impacts on women, small and marginal farmers and agricultural laborers. The efforts to ensure social inclusion in watershed planning and management will also enhance the benefit the most vulnerable sections of the rural society.

C. Program description:

Rejuvenating of Watersheds for Agriculture Resilience through Innovative Development (REWARD) is a World Bank supported watershed development program which will be implemented in 21 rainfed districts of Karnataka with a budget of Rs.600 crores. The budget will be co-shared by World Bank and Government of Karnataka (GoK) in the ratio of 70:30

and the program will be implemented by Watershed Development Department (WDD), Government of Karnataka. Program duration is from 24th March 2022 to 30th June 2026.

The Dept. of Land Resources (DoLR) is the Nodal Department at the National level and Karnataka identified as Light House State to provide technical support to other States.

Major Technical partner institutions of the program in state are National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), All State Agricultural and Horticultural Universities, Indian Institute of Science (IISC), Karnataka State Remote Sensing & Application Centre (KRSAC), Karnataka State Natural Disaster Monitoring Centre (KSNDMC) etc.

Area selected for the program implementation across 21 districts given below (Table-1)

Table 1: Details of area proposed for implementation of REWARD program

Sl. No.	District	Taluka	Area Details	No. of SWS	No. of MWS	Area for LRI (ha)
NBSS&LUP						
1	Chikkaballapura	Bagepalli	New area	23	183	90,889.67
2	Bellary	Harapanahalli	New area	16	133	84,103.81
3	Koppal	Yelburaga	New area	11	122	65,447.82
4	Gadag	Ron	New area	14	163	78,048.11
5	Koppal	Yelburaga	Sujala -III balance area	2	10	5,913.16
6	Gadag	Ron	Sujala -III balance area	2	2	900.55
TOTAL				68	613	3,25,303.12
UAS Bangalore						
7	Hassan	Arsikere	New area	20	175	1,07,240.06
8	Kolar	Kolar	New area	11	121	67,238.55
9	Tumkur	Sira	New area	21	225	1,18,871.98
10	Chamarajanagar	Gundlupete	New area	15	128	64,845.49
11	Chamarajanagar	Gundlupete	Sujala -III balance area	1	5	2,482.60
TOTAL				68	654	3,60,678.67
UAS Dharwad						
23	Belagavi	Athani	New area	14	121	66,960.88
24	Belagavi	Bailhongal	New area	12	127	72,779.68
25	Haveri	Hirekerur	New area	18	160	78,348.56
26	Haveri	Ranebennur	New area	18	169	81,459.86
27	Dharwad	Kundgol	New area	10	85	58,337.34
28	Belgaum	Athani	Sujala -III balance area	2	5	2,294.57
TOTAL				74	667	3,60,180.88
UAS Raichur						
18	Raichur	Manvi	New area	13	129	70,489.38
19	Kalburagi	Jewargi	New area	11	113	69,395.51
20	Yadgir	Shahpur	New area	24	213	1,24,267.06
21	Raichur	Lingsugur	Sujala -III balance area	5	27	15,495.02
22	Kalburagi	Kalburagi	Sujala -III balance area	3	13	7,619.77
TOTAL				56	495	2,87,266.74

Sl. No.	District	Taluka	Area Details	No. of SWS	No. of MWS	Area for LRI (ha)
UHS Bagalkot						
29	Bagalkot	Hungund	New area	15	138	83,436.77
30	Bidar	Basavakalyan	New area	13	101	69,125.17
31	Vijayapura	B Bagewadi	New area	22	204	1,19,343.97
32	Bagalkot	Hungund	Sujala -III balance area	1	5	3,253.09
33	Bidar	Basavakalyan	Sujala -III balance area	3	9	7,035.96
34	Bidar	Aurad	Sujala -III balance area	12	37	24,077.51
35	Bidar	Humnabad	Sujala -III balance area	6	13	8,557.91
36	Vijayapura	B Bagewadi	Sujala -III balance area	4	17	10,422.82
37	Vijayapura	Vijayapura	Sujala -III balance area	13	34	18,745.71
TOTAL				89	558	3,43,998.91
UAHS Shivamogga						
12	Chitradurga	Challakere	New area	26	159	1,13,841.86
13	Shivamogga	Shikaripura	New area	17	153	78,811.16
14	Chikkamgalur	Kadur	New area	20	142	1,04,377.41
15	Chikkamgalur	Kadur	Sujala -III balance area	1	5	3,645.08
16	Chikkamgalur	Tarikere	Sujala -III balance area	4	15	9,361.46
17	Davengere	Channagiri	Sujala -III balance area	6	19	11,126.48
TOTAL				74	493	3,21,163.45
GRAND TOTAL				429	3480	19,98,591.78

The REWARD program addresses key issues in National watershed management programs which are constraining better results from being achieved. The key design feature of the program is to address the challenges that the sector faces by bringing a strong science and evidence-based watershed planning, implementation and management approach that is anchored in community participation and ownership. The program seeks to achieve this balance of “top-down” versus “bottom-up” approach by demystifying science and its tools and making them accessible and comprehensible to communities who are the primary stakeholders in a watershed. In short, the program seeks to put communities at the centre of watersheds, but with strong science-based tools available to them for decision making. The action plan will be prepared scientifically for the selected 20 sub watersheds with community consultation, by using parcel wise scientific recommendations and further implemented on a saturation approach wherein, every parcel of the land will be treated as per the LRI recommendations by considering hydrological parameters. This includes soil and water conservation measures, crop management, nutrient management, agro-horticulture, agro- forestry etc.

D. Program development objective:

The Program Development Objective (PDO) 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”.

Implementation of REWARD program is aimed at collection of Land Resource information (LRI) scientifically to issue Land Resource (LRI) cards comprising site-specific recommendations for farmers to use at field level, and for preparation and

implementation of scientific Detailed project reports (DPR) for watershed development projects.

Major components of the REWARD program:

- 1) Carrying out Land resource inventory (LRI) in 19.98 lakh hectare rain-fed areas.
- 2) Watershed treatment on saturation mode in 1.0 lakh ha area (20 sub-watersheds) scientifically based on recommendations of LRI & Hydrological recommendations.
- 3) Strengthening Farmer Producers organizations (FPOs) and Value Chain Development - 25 FPOs
- 4) Providing improved site specific improved Agro-met advisories to farmers
- 5) Establishment of Centre of Excellence on science based Watershed Management at UAS Bengaluru

E. Need for Community Consultation on DPR Generated Using LRI Data

Traditionally DPRs were used to be prepared in consultation with the community by traversing the watershed area from ridge to valley with the help of RS and GIS maps. In the process interventions were identified in consultation with the farmers based on the soil type, slope, erosion status, length and width of the drainage lines etc. This process helps in engaging the community in planning different watershed interventions thereby establishing community ownership.

However, REWARD is designed to drive the frontiers of the watershed planning and management to higher levels with the advancement of science based tools. The program is implemented with the help of consortium of scientific institutions to carry out Land Resources Inventory (LRI) and hydrology and use the same for planning with the help of tailor-made algorithms and decision support systems. Besides planning, the project aims to develop LRI cards and agro advisory support for the target farmers and disseminate the same to adopt improved climate resilient agriculture practices which made available to the stakeholders through LRI digital.

This process, though helps in generating science based DPRs fails to address the basic principle of community participation, building community ownership and accountability mechanisms in line with the new generation watershed guidelines. Thus the DPRs developed through digital LRI inputs needs to be demystified about the science involved in it to the target communities for their understanding and adoption.

In this background there is a need for a detailed process guideline for undertaking the consultations with the community. This process guideline will help PIA members and grass root level functionaries like watershed assistants and NGO staff in demystifying the science based planning approach to farmers and to undertake social and environment assessment at watershed level.

II. Summary of Guidelines for Preparing Detailed Project Reports using LRI data

A. Prerequisites for preparation of DPRs/Pre Planning Phase (4 Weeks)

1. LRI data generated and available
2. PPRs for the selected sub-watersheds are finalized and approved
3. A manual/User Guide on DPR generation using LRI inputs is prepared
4. FNGOs are in place and trained at DATCs
5. Baseline data of the selected watersheds is established
6. IEC materials are prepared and sequencing activities with time lines is finalized
7. Initial awareness activities are completed
8. Orientation for the PRI members in local area is completed by DATC
9. EPA activity finalized and approved by Gram Sabha
10. CBOs - WECs, AGs and SHGs formed with as per the PMKSY guidelines.

B. Constitution of Watershed Development Team at SWS Level and Training

1. Formation of WDT Team/ DPR Preparation Team at PIA level
2. Two days Training/workshop at Block/Taluk level for demonstration of generation and validation of draft DPR and community consultation

C. DPR Generation and Community Consultation (4 weeks)

1. Downloading MWS wise DPRs from LRI inputs and consolidation for the SWS
2. AG wise treatment plan preparation for each MWS for transact 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 ESSA compliance
6. Compiling Area group wise treatment plan into MWS plan along with PRA exercise

D. 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 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

III. Detailed Guidelines for Preparing Detailed Project Reports using LRI data

A. Prerequisites for preparation of DPRs/Pre Planning Phase (4 Weeks)

1. Sub watersheds (SWS) selected for treatment by the concerned District Joint Director of Agriculture (JDA)
2. Land Resource Inventory (LRI) data generated for the selected sub-watershed and uploaded in the LRI inputs. The concerned person should ensure that LRI data available for generation of Detailed Project Reports (DPR) and to be thorough in using the LRI inputs.
3. A manual/User Guide on DPR generation from LRI inputs is provided to districts by State PIA.
4. Pre-project reports (PPRs) for sub-watersheds selected are to be finalized and submitted by the districts and get the approval of the State PIA.
5. Field-Non Government Organizations (FNGOs) are selected by State PIA and placed in the concerned districts
6. ToT for FNGOs staff along with implementing officers/field staff on CBOs training modules, DPR preparation, community consultation & validation of DPR, implementation process, Environment & Social Systems Assessment (ESSA) compliance, GP Assessment tool (PAT) reporting & documentation etc., by District Agricultural Training Centres (DATC) Mysore & Vijayapura.
7. Required baseline data of the selected sub watersheds is collected from the secondary sources including baseline of environmental and social baseline is collected and collated by the FNGO with the support of PIA. Suggested participatory methods for collecting baseline data, baseline required are furnished in **Annexure-I**.
8. IEC materials like videos, street play scripts, drone pictures on watershed status, wall painting, pamphlets, small audio & video bytes of popular persons/influencers/local elite farmers etc., on LRI technology, scientific watershed management and its importance - design and contents are prepared. Planning and sequencing of activities with time lines are finalized by the taluk PIA with the help of NGO team and RSK officials.
9. Initial awareness activities are completed-wide publicity using IEC materials Wall paintings, distribution of pamphlets, jathas, street plays, through small audio & video bytes using *Krishhi Sanjeevini* vehicles etc., are completed in majority of the villages by the NGO team with the help of field staff.
10. Panchayat Raj Institution (PRI) members in the local area are oriented on their roles and responsibilities and program interventions under REWARD- organizing one day orientation program at DATC and after the training collecting the participants feedback in a simple questionnaire formats.
11. Training modules for Community Based Organizations (CBOs) are prepared by the DATCs in consultation with State PIA and provided to the districts and teaching aids should be prepared by the NGO and taluk PIA.
12. CBOs- Watershed Executive Committees (WECs), Area Groups (AGs) and Self Help Groups (SHGs) are formed (**Formation of CBOs, Roles & Responsibilities**)

are in **Annexure II**) by NGO in the program area and started functioning; one basic training should be completed for the CBOs members by NGO on the topics provided in **Annexure-IIIa**.

13. About 50 members per Micro watershed (MWS) comprising all WEC members with active Area Group members have taken to one exposure visit (one day) to a nearest successful watershed to understand the impact of natural resource management through soil and water conservation activities under watershed development programs.
14. Entry Point Activities (EPA) are finalized and approved by Gram Sabha, implementation started by the NGO.

Entry point activities are taken up by the field staff and NGO to build rapport with the village community and gain their confidence towards people-centric project development. EPA may be planned based on the public demand and considering local situation in the villages. EPA action plan should be finalized by proper consultation with the village community/WEC and get vetted from the Gram Sabha and forward it to the district JDA for approval. While taking up EPA field staff and NGO to ensure proper estimate, following guidelines and execution based on budget provision and to take preferably in convergence with other ongoing schemes like MGNREGS, RKVY etc., for sourcing the funds.

B. Constitution of Watershed Development Team (WDT) at SWS Level and Training

1. **WDT / DPR Preparation Team:** District JDA will form WDT team at PIA level. WDT is a core group of 15 to 20 members involving taluk ADA-head, SADH/ACF/ADH & RFO, RSK-AO & AAO, District coordinators (out sourced), LRI Extension Managers (out sourced), FNGO Team Leader & Watershed Assistants, WEC President & other two local Gram Panchayat (GP) members, 4 to 5 representatives from AGs, SHGs and local FPO.
2. Details of Composition, Roles and responsibilities WDT team is given in **Annexure-IV**
3. A two days Training workshop should be organized at taluk/block level including district and taluk level officials, PIA/WDT/NGO officers/representatives of WEC, AG & SHGs and active farmers. District, JDA to conduct the program with the help of concerned LRI partner and DATCs and also involve identified speaker's/resource persons to educate about significance of REWARD program.

Details of the program schedule and topics is given in **Annexure-V**

- a) Day-1: regarding use of LRI and Hydrology outputs in science based watershed planning and demonstration of generating draft DPR using DSS modules in LRI inputs.
- b) Day-2: Field visit at MWS level to understand the process of Validation of DPR and how to read/ use the DPR and conducting community consultation and PRI exercises. In this regard, standard checklist should be prepared for points to be observed during field validation of DPR and community consultation.

C. DPR Generation and Community Consultation (4 weeks)

1. Generation of MWS wise DPRs using LRI data and consolidate the generated plan at the SWS level, as per the format given in Annexure VI for private land and Annexure VII for Drainage line and Common land treatments.
2. Prepare AG wise treatment plan on as per the format given in Annexure VIII and carry the same during transact walk along with different thematic maps generated through LRI.
3. Draw date and AG wise plan for each AG and give wide publicity through public announcements and pamphlets.
4. Identify a suitable place for community gathering and give a brief about tasks to be accomplished during the transact walk.
5. Identify 2 to 3 CRPs for each MWS and orient them about DPR and community consultation.
6. Arrange for coffee/ tea, snacks, lunch packets and water during transact walk
7. Arrange for logistic support like vehicle, shamiyana, display boards etc.
8. Fix AG wise responsibility of mobilizing the farmers to Community Resource Persons (CRP) and FNGO staff.
9. WDT will be divided into 3 sub-groups and 3 to 4 MWS will be allotted to each group based on no. of MWS located in that SWS. Thus, sub-groups can be formed as follows;
 - a) AO+WA+FNGO-TL+LRI-EM+2 AG Reps+2 SHG Reps +1 to 2 WEC members+ local FPO President /CEO / Board Member.
 - b) AAO-1+WA+FNGO-TC+LRI-EM+2 AG reps+2 SHG reps+1 to 2 WEC members + local FPO President / CEO / Board Member.
 - c) AAO-2+WA+District Cordinator+LRI-EM+2 AG reps+2 SHG reps+1 to 2 WEC members + local FPO President / CEO / Board Member.

SADH/ACF, ADH & RFO of the respective district should actively involve with the teams and monitor the consultation and ground truthing activity closely and ensure the ESSA compliance in preparation and implementation of the DPR.

10. Teams member's involvement in community consultation;

Participants	Individual / Private lands	Common lands and Drainage lines	Vulnerable Groups
Field NGO	<ul style="list-style-type: none"> • Field Guide and Community organizer • Technical Staff if any 	<ul style="list-style-type: none"> • Field Guide and Community organizer • Technical Staff if any 	<ul style="list-style-type: none"> • Field Guide and Community organizer
Assistant Agriculture Officer (AAO)	AAO assigned to that micro-watersheds	AAO assigned to that micro-watersheds	AAO assigned to that micro-watersheds

Participants	Individual / Privatelands	Common lands and Drainage lines	Vulnerable Groups
Watershed Development Team (WDT)	Specialist in <ul style="list-style-type: none"> • Horticulture • Livestock • Agriculture • Forestry 	Specialist in <ul style="list-style-type: none"> • Horticulture • Livestock • Agriculture • Forestry 	Optional
SWS Executive Committee (WEC)	Preferably the entire committee and <ul style="list-style-type: none"> • President • Secretary • Treasurer • Gram Panchayat Representatives Compulsorily: Representatives from AGs and SHGs	Preferably the entire committee and <ul style="list-style-type: none"> • President • Secretary • Treasurer • Gram Panchayat Representatives Compulsorily: Representatives from AGs and SHGs	<ul style="list-style-type: none"> • President • Secretary • Treasurer • all SHG representatives
Area Groups	All members belonging to the area	All members belonging to the area	
SHGs	Representatives of the WEC	Compulsorily: All members of the SHGs dependent on CPRs in the mini-micro-catchment and the micro-watershed Representatives to WEC	All members of the concerned SHG, especially representatives of all the SHGs
Individual families	A male and female adult from each family whose land is included for planning	Those families using common property resources or with lands adjoining the Nala etc.,	Those in SHGs

D. Steps for community consultation and validation of DPR;

1. Each group will take print of draft DPR and treatment plan to each Area Group for community consultation and validation; follow the Ridge to Valley approach.
2. First team will visit each and every land (individual as well as common property) and discuss area specific problems and opportunities and ways in which people plan to upgrade their land to make it more productive.
3. 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, its structure and soil type, slope, vegetation, cropping pattern, land use, water availability (including irrigation), etc. with LRI inputs and mark if any corrections/inclusions required.

4. Compare map of the land showing existing structures, land use, drainage lines etc., with actual observations and do necessary corrections. Explain treatment plan generated using LRI inputs to AG and note down the anyconcern/modification/ feedback of the farmers.
5. Carry the AG wise DPR prepared as per the Format furnished in **Annexure VIII** and record the suggested modifications or deletions in **Annexure IX**.
6. 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 as per format in **Annexure X**. For common land treatment opinion of the WEC and neighbour farmers should be recorded.
7. Prioritize the interventions over time line and prepare tentative year wise action plan with budget, 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. It may be suggested to issue a Beneficiary card to each farmer.
8. Make tentative land treatment plans for the lands of absentee owners by consulting their neighbours/friends or relatives with technical inputs from the WDT. As and when these farmers decide to become a part of the programme these tentative plans can be revised and reconfirmed. Request the local Area Group to keep these absentee persons informed.
9. Along with individual farmer wise plan, share the common land and drainage line treatments proposed as per the LRI based DPR, wherever proposed common land and drainage line treatments falls within the area of each AG.
10. It is expected that on each day one to two AGs could be completed, by assuming 3 to 4 Area groups (1000 to 1500 ha. /group) and thus four days required for one MWS.

E. Consolidating Area group wise treatment plan into MWS plan;

1. End of the day after completion of transact, group will assemble at a pre-identified place and present summary of treatment plan on private land and CPRs and get the approval by taking signatures of representative of PIA, FNGO and WEC/GP and at least 5 to 6 farmers on back side of the DPR map as per the enclosed format in **Annexure XI**
2. Photo documentation during transact and at the end of the day meeting should be done, this responsibility should be entrusted to any one member of the task team having good quality camera in the mobile. Minimum of 10 - 12 photos, minimum of 3 photos while planning for CPRs from different angles/sides should be captured and documented.
3. If possible display the treatment plan on a tripod stand and take the photo while explaining.
4. On 5th day PRA exercise will be done as per the guidelines given in section-IV below.
5. Hence, 15 days required to complete DPR and get Gram Sabha (GS) approval for 3 MWS by each team. Thus, by assuming 9 MWS per SWS, planning for the entire SWS can be completed in 15 days by three teams, maximum it can be extended upto 20 days.
6. Take the opinion of the community on impact of activities on social and environment conditions and record if any modifications/suggestions required.

7. The AAO/DC/FNGO-TL/TC along with concerned WA should assess the environmental and social risks from activities (especially if any adverse effects on the vulnerable groups).
8. Ensure any banned chemicals and materials which are hazardous to environment are not suggested under the project and also inform about the same to farmers /Gram Sabha.
9. Plan any risk management measures together with community and eliminate any activities which seem to be high risk.
10. Append the ESSA details to the DPR- (Appendix-V & VI).
11. AG wise intervention plans for both private and common land are to be consolidated at MWS level and consolidated DPR for the MWS has to be prepared.
12. Conduct a PRA exercise at village level and get the approval for the consolidated MWS plan, if there are more than one village in a MWS, PRA can be conducted at major village by inviting all AG, SHG, WEC members concerned to that MWS.

Things to consider while planning for the common lands and drainage lines

1. Visit these lands with the respective Area Groups and SHG members. Interact with the people to understand the specific issues related to these lands.
2. Assess the existing conditions compare it with the maps generated in LRI inputs
3. Share the details of rainfall, runoff, existing water bodies and potential for water harvesting, extent, type of erosion etc., and interventions proposed with estimated budget etc.
4. Observe details of existing structures, treatments already done and compare with map already generated.
5. Study the land and land uses in the Common Property Resources (CPRs)
6. Estimate the human and animal population dependent on the CPRs.
7. Take the community's opinion on planning to improve common lands and resources and interventions proposed in the plan and get their consent and note down if any changes or modifications suggested.
8. Identify the prominent users/beneficiaries of the CPRs developed and record their names and other details which should be annexed to the final DPR which will help in preparing Operation and Maintenance (O& M) strategy for CPRs.
9. Along with estimated budget for the interventions discuss the cost sharing arrangements with the community.

F. Consolidation and approval of MWS DPRs at SWS/GP/WEC Level:

The multiple levels of planning at farmer's level, AG level and for common lands are consolidated at the micro-watershed level to develop appropriate MWS plans under REWARD.

Resource and intervention mapping:

1. After completing the transect in all the Area groups area, on 4th day the Task Team with the lead taken by the FNGO, carries the Resource and Intervention mapping at the village level, if there are more than one village in a MWS, PRA can be conducted at major village. All the AG members and the SHG members and all families having stake in the MWS catchment are invited.

PRA exercise will be done for the following reasons:

- For triangulation (Cross-verification) of information gathered during transect done for planning.

- For seeking clarifications on any issue that might have arisen duringtransact.
- For finalising the activities to be taken in the watershed on individual andcommon lands.
- For discussing implementation strategies, cost sharing aspects, labouravailability for the works, etc.
- For carrying out ESSA (Environment and Social Systems Assessment) to ensure that there is no adverse effect on environment and social systemby implementing the proposed activities (details in section VIII).
- To include the suggestions/modifications required in the MWS plan andplace before GS.

2. **The modalities of carrying out PRA exercise are explained below:**

Steps	Details
a) Call members from all AGs & SHGs and all those families who have stakes in the watershed.	The meeting should be conducted in a large open ground with some space to display charts, maps, etc.
b) Display micro-watershed wise large digital Resource Map of the watershed (size 8X10 feet)	Prepare large Micro-watershed wise digital resource map of the watershed marked with proposed structures and display in the PRA. The map should contain the following features: <ul style="list-style-type: none"> • Drainage lines • Existing soil and water conservation structures • Various types of land with survey boundaries (common lands and individual lands) • Major land features • Vegetation etc.
c) Explain proposed watershed activities indicated on the map	Explain the people about proposed watershed structures indicated on the map. Include all interventions on private lands and common property resources.
d) Overview of the intervention proposed	Referring to the consolidation sheets, discuss the various interventions proposed, the total budget - whether it is within the permissible limit of the project, cost sharing for various components, budget provision from theREWARD and budget coming from the convergence with other schemes etc. Technical appropriateness of the intervention need to be discussed.

<p>e) Discuss broad implementation issues</p>	<p>Discuss the following issues in great detail:</p> <ul style="list-style-type: none"> • What is the total quantum of work, what is the labour requirement and what is the labour availability? How can additional labour be mobilized and what are the options if there is a shortage of labour. If machinery is to be used for earth moving - what is the impact on the budget and to what extent should machines be used? • Will the labour required for all the works come from the vulnerable families in the micro watershed? • Do the land treatment activities accommodate the livelihoods needs of the vulnerable groups? • Are there special activities with usufruct sharing mechanisms to support the vulnerable groups? • Do the interventions planned, complement the analysis of the PRA information-like in the fodder planned in the watershed sufficient for the cattle and livestock dependent on it. • Discuss the mechanisms to collect people's contributions for work and document the same
<p>f) Environmental and Social Safeguard Strategies</p>	<p>Any physical treatment activity is having any adverse impact on environment and social systems? If yes, how to manage those?</p>

3. 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 through LRI inputs.
4. Convene a General Body/ Gram Sabha meeting of the WEC (Quorum at least 50%) 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.
5. 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.
6. After General Body approval, the plans are to be finalised by FNGO and submit to PIA along with a summary of SWS plan for technical scrutiny.

G. Verification and approval of the Consolidated Sub-watershed DPR:

1. Taluk PIA office will verify component wise project allocations, unit costs, contribution rates and total budgets allocation for all the MWS plans received from the different WECs and prepare a component wise consolidated plan for the SWS and submit to DLTC headed by district JDA for technical scrutiny.
2. 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.
3. 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/WDD to place before PEC.
4. State PIA/WDD will submit the SWS DPRs before the PEC and upon approval forward to district JDA.
5. JDA will forward the approved DPRs to Taluk PIA and in turn to field staff, FNGO & WECs to take up implementation.
6. Funds can now be transferred to the WECs for work implementation based on their requisitions.

H. Capacity building for different stakeholders

Trainings for the CBOs formed namely Watershed Executive Committees (WECs), Area Groups (AGs) and Self Help Groups (SHGs) will be provided by NGO in the program area at village level in 3 phases of project i.e. Preparatory, Implementation and withdrawal phases. Training topics provided in **Annexure-IIIa**.

Further trainings for Project implementing Agency, FNGO staff, selected WEC members etc. will be conducted by DATC Mysuru and Vijayapura. Details of the trainings provided in **Annexure-IIIb**

I. Ensuring Gender and Social Equity

Women are more vulnerable than men in their respective social groups and therefore are considered for special interventions under REWARD adopts the following policy to combat their vulnerability.

1. Priority should be given for women's SHGs. The General body of the SWS must enroll both men and women as members from each family. The Area Groups can also women as members even if the land ownership is with the men in the family. The FNGO must ensure that women actively take part in preparing the DPR.
2. When meetings are called to discuss the progress on land treatment both male and female members of the family should be called. These meetings should be frequent (at least thrice a year) and should discuss the status of contributions for private land treatment, the work planning and implementation.
3. 33% of the WEC members should be women - from either SHGs or Area Groups.

4. Either the president or the vice president should be women
5. For any exposure visits minimum of 30% should be women
6. Not less than 80% of the income generating activities should be allocated to women members of SHGs

Opportunities for SCs/STs and small & marginal farmers

1. All the SC/ST families and Small & marginal families must be covered in SHGs
2. The WEC must ensure that SC/STs are representation
3. At least 25% of participants in all training programmes and exposure trips must be from SC/ST families
4. 100% of SC/ST and small & marginal families must be covered through SHGs under skill training programmes (excluding those families who have already been covered under any other programme or scheme)
5. The SHGs must provide credit to all the SC/ST and small and marginal families to start micro enterprise on priority basis.

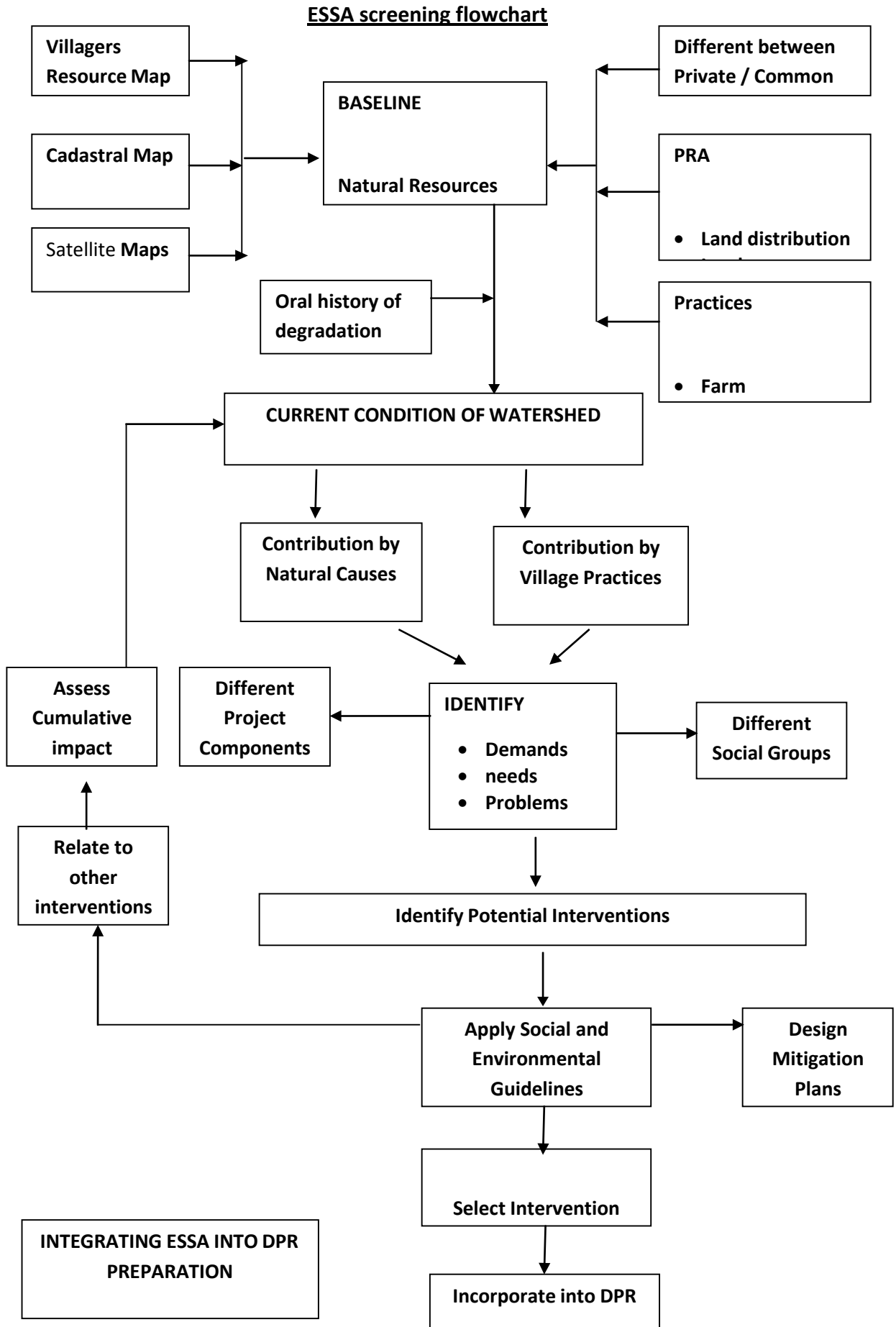
J. Integrating Environment and Social Issues into DPR Preparation

The methodology for mainstreaming social and environmental issues into integrated watershed planning at micro watershed level has been shown in the flowchart below. The significant steps are as follows:

1. The process of mainstreaming begins with establishing baseline data for the watershed. With respect to status of the natural resources, as well as the people's dependencies on the resources.
2. The inputs such as fragile and environmentally sensitive areas etc. would come from the different sources like secondary sources available with different departments, identified by the community and other locally available sources. which will be overlaid on the cadastral map, and supplemented by the satellite images prepared by KSRSAC.
3. The social baseline including different traditional practices followed by different sections of the village (farming, livestock, and non-farm activities), the geographical distribution of land and its ownership will be taken into consideration.
4. The baseline would be supplemented by documentation of oral history by the villagers to provide an overview of what were the causes of the degradation/ enhancement of natural resources over time and how this has affected the people's dependence.
5. The Current Condition of the watershed would thus be assessed in the context of the contribution over time and space, both by natural causes like floods, droughts and manmade causes like industrialization, road widening etc. as well as the village practices (cultivation, clearance, grazing).
6. This would lead to an identification of what are the demands of the different social groups (landowners, marginal farmers, landless), what are the needs of the watershed area (soil, water, vegetation), and what are the ensuing problems.
7. This would provide set of potential interventions that could fulfil the demands of the

people's dependency on the natural resources of the watershed, on both arable as well as non-arable lands, and focusing on harnessing the benefits of resources along the natural drainage lines.

8. When the social and environmental guidelines are applied to these potential interventions, they become an analytical tool for selecting the most optimum set of interventions that would enhance the productivity as well as equity of the watershed, and these are incorporated into the Action Plan.
9. In case the impact of the interventions is likely to be severe, then management measures have to be redesigned without altering science behind such intervention to suite the local needs and this feedback is critical for selecting/modifying/rejecting a particular intervention or activity.
10. Another critical issue to be addressed is to assess the cumulative impact of all these activities, which would then change the current condition of the watershed, the nature of the villagers' dependency on the resource base, and the consequent interventions.
11. Get community opinion by conducting one or two focus group discussions at each MWS level for each group once all the interventions are finalized after community consultation.
12. ESSA screening flowchart and formats are given below.



ANNEXURE-I

1. Suggested PRA methods for establishing baseline on natural resources and vulnerable families in the watersheds

Method	Use
Wealth Ranking	Serves to rank families in the village according to their economic status and thus identify all families that are vulnerable. Further analysis in this exercise can yield data on who among the vulnerable group are members of existing SHGs and other CBOs.
Resource Mapping	Helps to identify natural resources in the village/micro watershed and assess their status in terms of condition, ownership, usage, conflicts, dependency of vulnerable groups, etc.
Social Mapping	Identifies the existing village infrastructure and habitation patterns in the village, key infrastructure and other needs that can be used for identifying EPAs.
Time line Trend and Seasonality analyses	Helps to understand the history of the village Reveals the important trends in the condition of natural resources in the village (water availability, rainfall, forest cover, etc.) and the seasonal variation relevance to the watershed project (rainfall, pest and disease attacks, water availability, etc.)

2. SWS wise baseline data to be established by FNGO

#	Particulars	Source
1.	Population (OBC/SC/ST/Minorities/others and gender distribution)	Census /Taluk Office
2.	Size class distribution of farmers	Agril. Dept.
3.	No. of landless households	Agril. Dept.
4.	Land use classification	census
4.	Livestock population	Livestock census
5.	occupational paten	census
6.	Work Force(Main workers & Marginal workers)	census
7.	Area, production and productivity of major crops	Agril. & Horti. Dept.
8.	Reserve forests & Eco-sensitive area nearby	Forest Dept.
9.	Any endangered species nearby	Forest Dept.
10.	Soil quality issues	LRI data
11.	Any factories or industries depending on the natural resources like water, timber etc.	District Industries Dept.
12.	Any heritage sites nearby	District Directory, District at a glance
13.	Identification of vulnerable groups	Wealth Ranking
14.	Resource Inventory of Natural Resources and CPRs	Resource Mapping
15.	Listing of Existing CBOs in the watershed area	Grama Panchayat/Women & Social Welfare Dept./house hold visits

16.	<ul style="list-style-type: none"> GIS map on eco-sensitive and cultural sites like reserve forest, areas reserved for endangered species, protected animal corridor, physical and cultural heritage monuments, religious or socially sacred areas etc. area impacted with salinity (Ece=>4.0) & sodicity (ESP=>25), waterlogged area, designated wet lands as per Ramsar classification etc. 	LRI inputs
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3. Format for collecting environmental baseline data

1. General information			
Sl. No.	Criteria / Information to check for	Details	
1.1	Date of Site Visit	:	
1.2	Site information	Village	:
		Micro Watershed	:
		Watershed	:
		Gram Panchayat	:
		Taluk	:
	District	:	
1.3	Name of site visit person	:	
1.4	Name and designation of information provider	:	
1.5	Visiting in presence of (Full name & Designation)	:	
1.6	Type of utilization (mention agriculture/wasteland/fallow)	:	
1.8	Land pattern of the area (Plain / Valley / Hilly / Plateau etc.)	:	
1.9	Land Ownership	:	
1.10	Land pattern/type and utilization to adjacent upper ridge area	:	

Sl. No.	Criteria / Information to check for	Details	Issues or Management Measure in brief
2. Resources			
2.1	Forest Land		
2.1.1	Nearest forest area (Reserve forests, Protected forest or Revenue Forest)		
2.1.2	Distance from project Watershed		
2.1.3	Is the Project located in ecologically sensitive zones? Mention distance of nearest ecologically sensitive area with details		
2.1.4	Is there any Wildlife sanctuary, Bio- reserve, National Park or notified Eco Sensitive Zone in the area of influence?		
2.1.5	Important/ Sensitive animal (fauna)		

2.1.6	Important/Sensitive plant (flora)		
2.1.7	Current use of forest for any livelihood activity		
2.2	Grazing Land		
2.2.1	Area (indicate any encroached area separately)		
2.2.2	Fallow Land		
2.2.3	Pasture Land		
2.2.4	Culturable Waste Land		
2.2.5	Season of green fodder scarcity		
2.2.6	Season of green and dry fodder scarcity		
2.2.7	Major animals grazed in land		
2.2.8	Nearest grazing area from the watershed (km)		
2.3	Biodiversity		
2.3.1	Major type of animals in area		
2.3.2	Major type of plants in area		
2.3.3	Are there any migratory birds?		
2.3.4	Season of the migratory birds found		
2.3.5	Primary habitat of migratory birds		
2.3.6	Important/Sensitive animal (fauna) in locality		
2.3.7	Important/Sensitive plant (flora) locality		
2.3.8	Any medicinal plants found in area		
2.3.9	Are there any diseases found in domestic animals		
2.3.10	Is there available any veterinary doctor/hospital?		
2.4	Agriculture Need to check if ground data is align to LRI and DSS data, if not then have to mention it clearly in Remark column		
2.4.1	Cropping pattern (mono-cropping/ mixed cropping/crop rotation)		
2.4.2	Main crops grown (Rabi, Kharif, and horticultural crops)		
2.4.4	Pesticides/ fertilizer usage		
2.4.5	Source of irrigation		
2.4.6	Extent of irrigation (% of sown area which is irrigated)		
2.5	Soil Quality		
2.5.1	Any Soil Quality issue including salinity range of soil		
2.5.2	Any heavy metal or pesticide reported in soil.		
2.6	Ground Water		
2.6.1	No of tube wells		
2.6.2	Total number of dried-up tube wells		
2.6.3	Depth of Ground water of active and in use tube well (indicate feet or meters) approximate		
2.6.4	Mention Ground water quality issue (like salinity, nitrate, Fluoride, Heavy metals etc.)		
2.7	Surface Water		
2.7.1	No of ponds		

Reference material, CoE-WM

2.7.2	Details of Wetland (Ramsor classification)with its location with its watershed number		
2.7.3	Details of any canals, streams with location in respect to watershed		
2.7.4	Mention any surface water quality issue.		
2.7.5	Period of water availability in ponds		
2.7.6	Distance of Major river from the watershed		
2.8	Common Property Resources		
2.8.1	Is there any common property resource area located within the watershed		

Community Based Organizations under REWARD

1. Self Help Groups under REWARD

How to involve Self-Help Groups?

Identifying the vulnerable families

- ◆ Identify and prepare the list of existing SHGs
- ◆ Identify vulnerable families in the villages in the micro watershed through PRA using Wealth Ranking Exercise.
- ◆ Find out if any of the vulnerable families are not covered under existing SHGs
- ◆ If there are such families, try to accommodate them with the existing SHGs or else form new SHGs for left out families.
- ◆ Corroborate the outcome with BPL list for the village
- ◆ Crosscheck the findings with the villagers and by visiting concerned families in case of mismatched data.

Formation of SHGs

If there are any vulnerable families were not covered under the existing SHGs additional SHGs can be formed by following below points.

- ◆ Hold formal or informal meetings with those families that are eligible to form SHGs and provide them with sufficient information to clarify why they need to be in SHGs and how they can form a group
- ◆ If required expose them to nearby well-functioning SHGs
- ◆ Once a group of people agree to form a self-help group facilitate them to conduct their meetings regularly at a fixed time and place and maintain basic documents like the Minutes Book and passbooks, cashbook, etc. Ask the members to get registered in the respective groups by paying a minimum membership fee fixed by the group itself.
- ◆ Help the group to start regular savings, to fix the amount to be saved and the frequency of savings
- ◆ Facilitate the group to purchase essential books, registers, seal, identify its representatives, etc.
- ◆ Support the group to open a savings Bank Account in the name of the group
- ◆ Introduce detailed book-keeping systems, train the bookkeeper of the SHG
- ◆ Support the SHG to form its own rules, regulations and norms regarding sanctions if rules are violated
- ◆ During the process provide the SHG members with the essential modules of training

Functions of Self-help Groups:

Self-help Group members have a responsibility to improve their economic position by regular savings and credit in the SHG. Self-help Groups must play a pivotal role in the REWARD by being active partners of the WECs by addressing the issues, concerns and rights of the vulnerable groups in the program. Their role and functions in REWARD are as follows:

- All members of the SHG are members of the general body of the WEC. Additionally, they should meet weekly, ensure at least 80% attendance in their weekly meetings, save regularly and maintain required books.
- Each SHG must select a member to represent the group in every WEC; some of them will be members of WEC and others are invitees, the SHG must also change this representative every year
- The SHG should attend all the general body meetings of the WEC
- The SHG, by virtue of being a part of General Body, can review the progress and accounts of the WEC and suggest areas for improvement; the SHG may also request the WEC to call a special meeting for the same
- Assist the WEC to collect contributions for the watershed activities.

Vulnerable Group Sub-Plan related

- Prepare and submit a Vulnerable Group Sub-Plan to support its members for non-farm or on-farm income generating programmes (IGPs)
- Select suitable candidates for Entrepreneurship Development and Skill Training programmes with a preference to landless and marginal farmer members.
- Assist the Entrepreneurship Development FNGO (EDP) to frame proposals for individuals and groups in the SHG.
- The SHG representative to the EC should participate in preparing the DPR and share the information with SHG members.
- Prepare and submit a list of people who need employment opportunities and willing to provide labour for watershed activities
- Actively involved in planning activities for common land treatment so that SHG members and other vulnerable families can be benefited from these activities in the long-term through usufruct rights and income generation
- Actively involved in implementing activities on common land by taking up contract for such activities.
- Influence the WEC to ensure equal wages for men and women

Learning and Linkages related

- Attend all training and exposure programmes conducted.
- Establish linkages with banks and other institutions for the social, economic and political betterment of the members.
- The SHG representative in the W E C must come back and share all the W E C meeting proceedings with their respective groups.

2. AREA GROUPS (AGs)

Area Groups of farmers owning land in a particular mini-micro catchment within a micro watershed. By forming Area Groups, the project aims to decentralize some of the micro management decisions and increase people's participation beyond the Watershed Executive Committee.

- **Membership:** All farmers owning land in a particular mini-micro-catchment are members of Area Groups. The catchment is delineated in such a way that 40-50 farmers have land in the area. This way membership of the AG is limited to a small number. In case a farmer owns land in more than one mini-micro-catchment, s/he may choose to be a member of any one Area Group as per the convenience.
- Since plans are prepared first at the farmer level and then consolidated at the Area Group and the MWS level, the role of Area Groups becomes very important during planning, monitoring and post project management.

How to form Area Groups?

- Download the sub-watershed and micro watershed maps showing drainage lines and cadastral boundaries from the digital library.
- Identify smaller drainage lines on the micro watershed map and superimpose the drainage map on a cadastral map. Demarcate smaller contiguous area around these drainage lines covering about 100 to 150 ha.
- Form such 4 to 5 area groups per MWS.
- Generate survey no. wise Khatedar list showing the names of farmers owning lands in each group.

Functions and Role of Area Groups:

- All members of the AGs are constituents of the General Body of the WEC and are expected to function similar to Self-help Groups in planning and implementation.
- Their main responsibility is to plan the programs in their area and get the work executed.
- The AG should attend all the general body meetings of the WEC and suggest areas for improvement; the AG may also request the WEC to call a special meeting for the same if required.
- Assist the WEC to collect contributions for the watershed activities

Watershed Planning and Implementation

- All AG members should participate in preparing the sub-plan with technical guidance of watershed development team, the AAO and the FNGO staff.
- AG representatives to the WEC should involve in the consolidation of DPR and share the information with the AG members.
- AG members should be aware of the environment and social aspects and comply with any issues identified.
- Collect the contribution for watershed activities and remit the same to the WEC.

- Maintain the structures created in their micro watershed
- Mobilize funds for maintenance and development works on their lands
- Attend all training and exposure programmes conducted.
- The AG representative in the EC must come back and share all EC meeting proceedings with their respective groups.

3. Watershed Executive Committee (WEC)

i) Composition of watershed executive committee

Watershed EC is the conglomeration of community-based organizations, elected representatives of GP, WDD officials and NGO representative. Watershed -Executive Committee is constituted to implement the watershed projects with the technical support of multi-disciplinary team of Watershed Development Department (WDD). The Watershed Executive Committee (WEC) is constituted as a subcommittee of Grama Panchayat under Karnataka Gram Swaraj and Panchayat Raj Act 1993, Section 61 (A). It operates at Gram Panchayat (GP) level consisting of following representatives;

Sl. No.	Members	Designation
1	President of Gram Panchayat	Chairperson
2	Gram Panchayat Member from project area	
3	Area Group members (5-6)	Member
4	SHG Members (4-5)	Member
5	Farmer Producer Organization Members (2-3)	Member
6	Agriculture Officer/Assistant Agriculture Officer	Treasurer cum secretary

*Note: In order to ensure gender participation, gender equity and social inclusion, preference will be provided for women and SC and ST members.

ii) WEC office

The Watershed Executive Committee (WEC) would be provided with an office space in the premises of GP office or housed in the nearby RSKs. The office will be supervised by the treasurer/secretary of the respective WEC/RSK wherein the records and documents related to the respective watershed area along with land resource information data sets will be maintained. This office shall be equipped with minimum office infrastructure. The office expenses including rental expenses if any shall be charged from the administrative expenses of the project.

iii) Roles and responsibilities of the WEC

The most important people's body responsible for the project success is the WEC, as it shall shoulder the major responsibility for preparing and executing the project plan. It shall be guided all along by the WDT.

- To ensure active partnership of the project community in planning and implementation.
- To approve works and activities to be taken up as per action plan and DPR. It shall adhere to cost norms approved by the State Government, i.e., Schedule of Rates

- (SRs) for different infrastructure works. In case of individual beneficiary activities, the rates as prescribed under the scheme shall be the norm.
- c) To prepare plans for implementation at GP level and submit it in the planning module of e Gram Swaraj LRI inputs with the help of WDT.
 - d) To open two separate bank accounts in one a zero balance joint bank account in one of the scheduled banks and operate it under the joint signature of the account holders (President-WEC, Project leader of PIA & Treasurer cum Secretary-WEC) and second for operating WDF fund.
 - e) To receive funds entitled under these Guidelines into the bank account and after expenditure submit utilization certificates to PIA for further submission.
 - f) To focus on nurturing community participation by supporting various Area Groups, Self- Help Groups as well as FPO. It shall enforce regulatory norms relating to various assets and resources created and developed through action plan with the help of Gram Panchayat.
 - g) To conduct annual audit of natural resources leading to asset maintenance plan, water budgeting exercise, twice a year for establishing regulatory norms on water use, and laying down protection norms for regeneration of the common land.
 - h) To own resources during the implementation of project activities and enforce its implementation by taking necessary support of Gram Panchayat and PIA. The new generation watershed development program is expected to generate wider experiences in community managed participatory governance of natural resource management for universalization.
 - i) To finally transfer the assets created to the Gram Panchayat at the end of the project. Further, it shall take an active part in inspecting the assets and works from time to time and ensure their repair, maintenance and up gradation as required. For this, financial resources available from ongoing schemes under GP and Watershed Development Fund (WDF) may be accessed.

iv) Role of secretary cum treasurer, WEC

Concerned RSK AO will be the Secretary cum treasurer of the WEC (WC), would work under the direct supervision of the Project Implementing Agency (PIA) and President of Watershed Executive Committee (WEC). The Secretary will be responsible for the following tasks:

- a) Convening meetings of the Gram Sabha, Gram Panchayat,
- b) Facilitating the decision-making processes in the context of Watershed Development.
- c) Taking follow up action on all decisions.
- d) Maintaining statement of accounts and all other records of project activities and proceedings of the meetings
- e) Ensuring payments and other financial transactions.
- f) Record of all works and activities carried out and assets transferred to the GP.

v) Role of gram Panchayat

- a) GP shall assist in the process of social mapping that helps to understand the socio-economic condition of the GPs and of households that mutually helps in deciding and allocating resources in the watershed area besides helping in formation of FIGs and market linkage activities.
- b) Assisting WEC in identification of beneficiaries for watershed Developmental activities.
- c) Facilitate the convergence of various projects/ schemes to institutions of watershed development project.
- d) Convening Gram Sabha for getting approval of the DPRs
- e) Provide office accommodation and other requirements to WEC.
- f) Allocate usufruct rights to deserving area groups/ SHGs over the assets created. Maintain asset registers and WDF fund during and post watershed development period.

Trainings for CBOs**I. SHG Trainings:**

Project Phase	Module	Topic
Preparatory Phase	S1	Orientation on REWARD Program, functions, roles and responsibilities, ESSA compliance and participatory planning.
Implementation Phase	S2	Gender and social Inclusion, implementation and Maintenance, accounts and book keeping
Project Withdrawal Phase	S3	Project Withdrawal Strategy, Linkages and Post-Project Maintenance.

II. Area Group Trainings (AGs):

Project Phase	Module	Topic
Preparatory Phase	AG1	Overview of REWARD, formation, functions, roles and responsibilities, ESSA compliance, gender & social inclusion, participatory planning and DPR preparation.
Implementation Phase	AG2	Environmental and social Screening under REWARD and gender & social inclusion
Project Withdrawal Phase	AG3	Project Withdrawal Strategy and Post-Project Maintenance

III. Watershed Executive Committee (WEC):

Project Phase	Module	Topic
Preparatory Phase	E1	Orientation about REWARD, roles & responsibilities, DPR preparation and community validation
Implementation Phase	E2	Book Keeping, Accounting, Transparency, reporting, Beneficiary Contribution, Implementation and monitoring and Gender & social Inclusion
Project Withdrawal Phase	E3	Project Withdrawal Strategy and Post-Project Maintenance.
	E4	Exposure Visit

Trainings to be conducted by DATCs for field level stakeholders

Sl.No.	Training title	Participants	No. of Participants	SWS	Total Participants	No. of Trg	Duration (Days)
1	Induction training for FNGO staff	TL-1, WM-1, WA-5, and Ac-1	8	20	160	4	4 days
2	Orientation program for the Department Staff	JDA, DDA, ADA	3	20	60	2	2days
3	Orientation , DPR preparation, ESSA, Implementation Staff	RSK AO, TO, AAO	5	20	100	3	3 days
4	Training on Social mobilisation, CBO formation and functioning, roles and responsibilities, book keeping and accountancy, LRI based DPR preparation	FNGO (TL & TS), AAO, Dist. Coordinator	4	20	80	2	3 days
5	Environmental and Social Assessment Training	FNGO (TL & TC), AAO, Dist Coordinators	4	20	80	2	2 days
6	DPR preparation, validation and Implementation	WA, TC	6	20	120	4	2 days
7	DPR preparation, validation and Implementation	3 from each EC, FGNO-TL and WM, Avg 4 LRI extn Managers/SWS	9	20	180	6	2 days

Reference material, CoE-WM

8	Technical trainings on insitu soil and water conservation structures	AO / AAOs	3	20	60	2	5 days
9	Implementation of DPRs in model watersheds and Quality control	WA	5	20	100	2	3 days
10	Technical training on water harvesting structures and Quality control	AO / AAOs	3	20	60	2	5 days
11	Technical training on Agro-Horti-silvi pasture	ACF, RFO, SADH, AHO	2	20	40	2	2 days
12	Training on Income Generating and Livelihood Activities	Training Co. and TL, Dist Co	3	20	60	2	3 days
13	Refresher course on soil and water conservation structures and Quality control	AO / AAOs	3	20	60	2	3 days
14	Documentation of Success stories, Project Exit Strategy and post project maintenance	3/EC, FGNO-TL, TS, District Co., AAO	9	20	180	4	2 days
15	Maintenance of community WHS using WDF	PDO, EC president, AO	9	20	180	4	One day
16	Induction Course in case of staff turnover (30%)	AO, AAO, NGO staff	3	20	60	2	3 days
17	Training to EC members in one model Subwatershed in each DATC	EC members	45	2	1080	12	2 days

I. Composition of Watershed Development Team (WDT)

1. Assistant Director of Agriculture of the Taluk-Team leader
2. Senior Assistant Director of Horticulture
3. Assistant Director of Horticulture
4. Assistant Conservator of Forest
5. Range Forest Officer
6. Agriculture Officer of respective RSK
7. Assistant Agriculture Officer of the respective RSK
8. District REWARD Coordinator
9. FNGO team leader
10. FNGO training coordinator
11. FNGO Watershed Assistant
12. WEC President
13. Two GP representatives
14. Two to three representatives from the Area Groups
15. Two to three representatives from the SHGs
16. Two to three representatives from the local FPO

II. ROLE OF MAJOR PARTNERS DURING PLANNING:

Role of Agriculture assistant (AAO) / Watershed Assistant (WA)

- Be a part of the task team and actively participate in planning
- Make available all the maps related to the area, the khatedar list, etc.
- Give the required technical assistance during planning.
- Check the appropriateness of the interventions suggested by the farmers with regards to their location, their size, the utility, technical feasibility, etc.
- Participate actively in the resource and intervention mapping and give technical inputs during the process.
- Assist the FNGO in consolidation of plans prepared at farmer and Area Group level. Bring to the notice of the FNGO in case of technical inappropriateness of any intervention.
- Facilitate the process of approval of the DPR by the General Body and answer queries related to technical aspects if any.
- Environment and Social Impact assessment to be carried out by using the prescribed formats.

- Assist the documentation officer of the FNGO to compile the field information.
- Verifying the compiled information – once again with the AG's, before finalizing.
- Prepare annual action plan for implementation.

III. Role of FNGO

- Lead role along with AAO/WA and WEC in the entire planning process starting from planning on farmers land to the preparation and finalization of SWAP.
- Conduct resource and intervention mapping exercise at each mini-micro catchment and micro watershed level.
- Consolidate the DPR at the Area Group and micro-watershed level and present the finalized document to the scrutinisation committee.
- Ensure integration of Environmental and Social issues in DPR by helping to generate ESA in prescribed formats.
- Ensuring participation of SHGs, Area Groups in DPR preparation.
- Ensure participation of all the vulnerable families dependent on the resources of the common property while planning on common lands.
- Ensure that the vulnerable families are benefited from planning on the common land - in terms of labour availability, sharing of usufructs, etc.
- Ensure that the landless and other category of people dependent on agriculture labour for their livelihood are not deprived of it in this project.
- Assist the SHGs and Area Groups in preparing plans for maintenance of the assets and help them to develop norms for equitable sharing of benefits and resources.
- Facilitate the approval of DPR at the General Body.
- Facilitate the WEC to prepare Annual Action Plan along with AAO / WA.
- Help in resolving any conflicts that arise during planning.

IV. Role of the Watershed Executive Committee (WEC)

- Be a part of the task team and actively participate in the planning process starting from the farmer level planning to the preparation of the DPR.
- Based on their experience from the exposure visit, try to educate the farmers about the various activities that can be taken up under a watershed programme.
- Orient the farmers about the contribution aspects of the works proposed and stress on the need for timely payment of contributions.
- Ensure participation of all the vulnerable families dependent on the resources of the common property while planning on common lands.

Reference material, CoE-WM

- Ensure that the vulnerable families are benefited from planning on the common land - in terms of labour availability, sharing of usufructs, etc.
- Actively participate in preparation of annual action plans
- Ensure that the landless and other categories of people dependent on agriculture labour for their livelihood are not deprived of it in this project.
- Plan for management and maintenance of the common property resources with active participation of all the people dependent on those resources.
- Call for the General Body meeting and get the SWAP approved.
- Follow up the process of DPR approval.

ANNEXURE-V

DPR Training

Program schedule for 2 days district level training workshop on DPR preparation using LRI inputs

#	Subject	By	Timings
<i>Day-1</i>			
1	Introduction about REWARD program, Program objective, Uniqueness, Activities & Implementation methodologies, Institutional arrangements, M&E etc.,	District Joint Director of Agriculture	10.00 am to 10.30 am
2	Land Resource Inventory (LRI) and Hydrological studies under REWARD: Data collection, analysis & integration into Digital library & LRI inputs, Adoption of LRI and Hydrological recommendations for Watershed development projects.	Nodal scientists from concerned partner institution.	10.30 am to 11.30 am
Tea Break: 11.30 am to 11.45 am			
3	Orientation about Preparation of draft Detailed project reports (DPR) for watershed treatment using LRI & Hydrological data/atlasses & running DSS in the LRI inputs: Process involved in preparation of draft DPR, community consultations & approval, EPA, implementation in convergence with other schemes like MGNREGA.	Deputy Director of Agriculture, DATC, Mysore/Vijayapura	11.45 am to 12.30 pm
4	Orientation to Watershed development team (WDT) about their role in preparation and approval of draft DPR by involving community and adoption of ESSA principles in implementation.	Deputy Director of Agriculture, DATC, Mysore/Vijayapura	12.30 pm to 1.00 pm
5	Orientation of WEC, AG & SHGs about their role in preparation and approval of draft DPR by involving community.	Concerned NGOs representative	1.00 pm to 1.30 pm
Lunch Break: 1.30 pm to 2.00 pm			
6	Live demonstration of DPR preparation through LRI inputs for a selected micro-watershed.	M/s Ceinsys Tech Pvt. Ltd.	2.00 to 3.00 pm
Tea Break: 3.00 pm to 3.15 pm			
7	Practice sessions regarding draft DPR preparation through LRI inputs for the participant members.	M/s Ceinsys Tech Pvt. Ltd.	3.15 pm to 5.30 pm
<i>Day-2</i>			
1	Field visit to nearby project micro-watershed for demonstration of field validation and community consultation of draft DPR prepared	Entire Team led by ADA	Forenoon
2	Demonstration of PRA Exercises	FNGO staff led by team leader	Afternoon

Private Land Treatment Plan Format:

SI No	MWS_CODE	Hobli	G.P Name	Village	Survey_hiss	Acr	Gunta	Area_ha	Owner Name	Gender (M/F)	Caste (SC/ST/OBC /Minority/General)	Category (MF/SF /MEF/LF)	Farmer code	AG Code	Fruit ID	Soil Phase	Activity (SWC /HORT. / FORT. /DLT)	Sub Activity (TCB, GB, SCB, FP, WW, HORT, AGRO FORT)	Size / Section	Quantity	Actual RMT / HA / NO	Unit Cost	Total Activity Cost	Total Beneficiary Cost	S1	S2	S3
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1																											
2																											
3																											

Drainage Line and Common land treatment details

		District :														
		Taluk :														
		Sub Watershed Name :					Sub Watershed Code :									
		Micro Watershed Name :					Micro Watershed Code:									
Sl. No.	Village	Survey No.	Identification /Ownership	Location	SWC/HORT/FORT/DLT)	Sub Activity	Dimension / Section	Quantity	Unit Cost	Total Cost	Expected No. of Beneficiary					User Group
											SC	ST	Minority	Others	Total	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1						Boulder Check										
2						Rubble Check										
3						Check Dam										
4						Gokatte										
5						Institution plantation										
6						Nala Rivetment										
7						Nala Plantation										
8						Tank Development										
9						Water Way										
10						Block Plantation										
11						RRS										
12						RTW										
13						Nala Bund										
14						Diversion channel										

Annexure VIII

Area Group Treatment Plan:

Area Group Name & Number:_____

Name & Code of the MWS_____

Total Area of Area Group:_____

Name of the Village_____

Taluk_____

District:_____

(The above information should be on cover page of AG wise treatment plan. The print out of AG wise DPR excel sheet needs to be carried for transect walk and if any changes/ corrections suggested by farmers at the time of transect walk, they need to be noted down in the below format. The changes/modifications should be based on field situation and in line with LRI inputs.)

Annexure IX

Any suggested modifications or deletions should be recorded in the following format

Sl. No.	Soil Phase	Survey No./Nos.	Farmer name	Private Land(PL)/CPR	Recommended Intervention	Suggested Modification/Deletion

Precaution to be taken while recording the modifications or deletions;

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

Screening Guidelines on Social Issues

Sl. No.	List of Questions	Yes	No
1.	Will the implementation of the activity adversely impact the Labour force available within the area?		
2.	Will the implementation of the activity adversely impact the Livelihoods of the people dependent the resource?		
3.	Will the intervention on Common Property Resources/pasture lands deprive rights of vulnerable community?		
3.	Do the Vulnerable families have a share in the benefits accrued out of the common property resources?		
4.	Will the implementation of the activities displace any of the families concerned?		
5.	Does the activity promote Child Labour?		
6.	Does the activity have any adverse impact on the Health?		
7.	Does the activity promote any conflict among the Community?		
8.	Does the activity have any adverse impacts on the indigenous people/vulnerable families in terms of displacement or their livelihoods being affected?		
9.	Does the activity have any adverse impact on the health of the people?		

Note: If any of the answer to the questions is “YES”, then the intervention may be avoided or taken up with mitigation measures? If mitigation measures are applicable, list out the measures.

After completing the environment and social screening summarize the issues, mitigations planned, and management plan against the core **Principles of ESSA** in the following table;

#	Core Principles	Remarks/mitigation and management plan
1.	Environmental and Social Management	Is ESSA issues are brought to the notice of the community, No. of FGDs done, append proceedings of the FGDs with date, place and photo documentation
2.	Natural Habitats and Physical Cultural Resources	Are there any Natural Habitats and Physical Cultural Resources within watershed area or with in the radius of 1 km. If yes, is it discussed with the community, is there any impact on them? If yes measures taken?
3.	Public and Worker Safety	Whether safety measures are taken while executing the works? What measures are taken avoid accidental drowning in water bodies? Are the farmers being aware of safety measures to be taken while using chemicals and fertilizers and safe disposal of empty cans/bottles? Is measures are taken to safely dispose the solid waste generated during construction works?
4.	Land Acquisition	Is there any land acquisition proposed? If yes, is it acquired with acceptance of the legal owner and compensation paid?
5.	Indigenous Peoples and Vulnerable Groups	Are there indigenous people in the watershed area? Are their cultural values are taken into consideration before taking any activity? Is land of all the vulnerable families

#	Core Principles	Remarks/mitigation and management plan
		are taken up for treatment? Weather all landless people are included in vulnerable sub plan (IGA)?
6.	Social Conflict	Are there any social conflicts while planning for intervention, particularly for drainage line interventions and CPRs? If yes, mention in detail and how it was resolved?

Annexure XI

Below points were discussed with the group during transact walk;

1. The existing condition of the land and water resources were widely discussed and importance & scientific approach about watershed activities were explained to the members present.
2. Survey no. wise interventions proposed based on LRI studies were brought to the notice of the farmers
3. Inputs regarding suggestions and modifications with respect interventions proposed by the farmers were also recorded for further needful action.
4. Importance of considering the environment and social issues were also brought to the notice of the farmers and ESSA screening was also carried out for the activities and observations were also recorded in the suggested formats.
5. Other issues discussed _____

Name & Signature of the PIA representative

Name & Signature of the FNGO representative

Name & Signature of the WEC/GP representative

Sl. No.	Name of the farmer	Gender (M/F)	Category	Signature

9. Assessment of REWARD program- process monitoring, achievement of DLIs, evidence-based impact assessment

Under REWARD program, Process monitoring is extremely important for producing high quality works and at the same time through progress monitoring it is ensured the timelines of project deliverables are achieved. In Sujala-III project, it has been proved that selection of an appropriate subset of variables can improve the performance of the project. This aspect of M&E is very important for WDD as REWARD will be implemented in P for R mode. WDD proposes to hire a third-party agency to monitor the qualitative and quantitative aspects of the program. The agency will monitor REWARD program activities based on results framework. It will carry out qualitative studies and indicate improvements which would help us to refine the theory of change, key performance indicators and make mid-course corrections.

Establishment and monitoring of benchmark sites:

In order to establish scientific monitoring mechanism for precision impact evaluation both during and after the program implementation, REWARD will establish Bench mark sites in 1 lakh ha area where the saturation mode of watershed treatment is planned across 20 sub watersheds. Within this one lakh ha area, about 25 percent of the MWS (50 MWS) will be selected and in each MWS about 3 bench mark sites will be selected. This is equal to 50 MWS X 3 BM sites=150 BM sites in total. Apart from this about 20 BM sites are planned to be selected as controls outside the treatment areas. Total BM sites in the program districts=170, which is equal to 34/university partners. These bench mark sites will be established and monitored by the university LRI partners in their respective jurisdictional area. The LRI partners will also provide required data to M&E agency at regular intervals for effective monitoring and scientific evaluation.

Program management information systems (MIS):

Input-output and results monitoring would be supported by a web-enabled computerized MIS which would be an integral part of the M&E system. To start with REWARD will have a dedicated MIS system which will then be integrated into the overall WDD MIS systems. WDD will design MIS with the help of Centre for e-governances Government of Karnataka or through an outsourced agency. MIS Support in this area would cover;

- i) Initial assessment of management information requirements and potential for ICT automation;
- ii) Software development;
- iii) Customization;

- iv) Field testing and system rolling out; and
- v) Sustained technical support for maintenance, including further adaptation and refinement.

Independent verification agency (IVA):

As the REWARD program is an P for R program, an Independent Verification Agency (IVA) will be hired through a competitive bidding process to verify the progress of Disbursement Linked Indicators (DLIs) and provide feedback on a periodical interval. The Independent Verification Agency (IVA) selected to carry out this assignment will be engaged for a period of 5years 'subject to satisfactory performance.

The specific scope of Services would include:

- i) To carry out an independent verification of achievement of the DLIs reported by WDD for each of the disbursement claim under the program based on the verification protocol agreed between GoK and the World Bank.
- ii) Preparing and submitting independent and comprehensive verification reports to WDD for DLI achievement reports for each disbursement claim prepared by WDD in the form and substance acceptable to WDD and the World Bank.
- iii) The IVA will verify the DLIs as per the agreed terms, through desk review and physical inspection to confirm the accuracy and quality of results and eligible disbursement amounts claimed by the WDD in its supporting documentation with each disbursement claim.
- iv) In accordance with good audit practice, verification will take place against a sampling framework and frequency, described in detail in the Verification Protocol.
- v) The IVA will develop a detailed verification protocol that builds on the verification protocol contained in the Program Appraisal Document [PAD] for collecting and processing of data required for assessment and validation of DLIs.

Financing Mode by the World Bank

Three Types of financing

- Investment Project Financing: provides financing to governments for activities that create the physical/social infrastructure necessary to reduce poverty and create sustainable development.
- Development Policy Financing: Provides budget support to governments or a political subdivision for a program of policy and institutional actions to help achieve sustainable, shared growth and poverty reduction.

- Program-for-Results (P f R): links disbursement of World Bank funds directly to the delivery of defined results, helping countries improve the design and implementation of their own development programs and achieve lasting results by strengthening institutions, enhancing systems, and building capacity.

Triggering of DLIs in different years						
Sl. No.	Disbursement Linked Indicators	2022	2023	2024	2025	2026
1	DLI1- WCs and GPs demonstrate satisfactory WM as measured through a performance assessment tool. (Percentage)		√	√		√
2	DLI2- Land area treated with science-based watershed management technologies. (Hectare (Ha))	√	√		√	√
3	DLI3- Adoption of resilient agriculture technologies and practices by (number of farmers). (Number)			√	√	√
4	DLI4- Farmer Producer Organizations with 25% increase in business turnover relative to baseline. (Number)			√	√	√
5	DLI5- Number of professionals who complete certified training on improved watershed management provided by National Center for Excellence on Watershed Management. (Number)		√	√	√	√

Disbursement Linked Indicators & year wise amount linked to each DLI										(Rs. In Crores)	
DLI No.	DLI	Allocation		Reimburse ment/unit	Total Target	2022	2023	2024	2025	2026	Total
		USD in ML.	INR in Cr.								
1	30 %WCs and GPs demonstrate satisfactory WM as measured through a Performance Assessment Tool (PAT).	9.28	68.65	0.99	23		22.88	22.88		22.88	68.65
2	Land area treated with science-based watershed management technologies.(ha) & during 2022 on signing MoU with partners	20.05	148.37	0.26	200	43.29	52.54		26.27	26.27	148.37
3	Number of farmers who adopt resilient agriculture technologies and practices (in 000,)	10.10	74.73	2.77	27			22.42	26.15	26.15	74.73
4	Farmer Producer Organizations with 25% increase in business turnover relative to baseline.(nos)	10.425	77.15	5.14	15			30.86	30.86	15.43	77.15
5	Number of professionals who complete certified training on improved watershed management provided by national center for excellence on watershed management.	10.00	74.00	2023-0.123 & 2024 to 2026-0.057	1125		18.5	18.5	18.5	18.5	74.00
Total		59.85	442.89			43.29	93.92	94.66	101.78	109.24	442.89

REWARD-GP Performance Assessment Tool-Preparatory Phase-Total Score: 100-DLI 1

Sl. No	Performance Indicator		Score	Means of Verification	Responsibility & Reporting	Max Score
1	Watershed Executive Committee (WEC) formation process	Average of 60% and above representation from GP members, representatives of SHG & AG members with representation from SC & ST, Women farmers and landless households from the respective project villages should be present in the WEC formation meeting.	10	Meeting Records: Attendance, photos, proceedings of the meeting etc.	RSK and PIA	10
		<60%	5			
2	WEC members composition as per the PMKSY: WDC guidelines	Representation of members of GP /AGs / SHGs / Women / Landless / SC & ST farmers as per PMKSY: WDC Guidelines	5	GP Resolution issued regarding formation of WEC	RSK and PIA	5
3	Capacity Building Trainings for WEC/SHG/AG members I. S1 trainings for SHG members 2. AG1 trainings for AG members 3.E1 trainings for WEC members 4.DPR preparation, validation and Implementation training to WDT team 5. Orientation for the PRI members in local area by DATC/SATCOM	If the average participation is $\geq 80\%$ of WEC members/other target group members in the total trainings held during preparatory phase (20 marks)	20	Training Records: - Attendance records, photos and minutes of the meeting	FNGO/DATC/PIA	20
	If the average participation is 60% to 80 % of WEC members/other target group members in the total trainings held during preparatory phase (10 marks)	10				
	If the average participation is 40% to 60 % of WEC members/other target group members in the total trainings held during preparatory phase (5 marks)	5				
	< 40 % of the WEC members/ other target members have attended training (0 marks)	0				

REWARD - GP Performance Assessment Tool –Preparatory Phase

Contd....

4	Community Consultation process As part of Community consultation, conduct Focused Group Discussions (FGDs) during the DPR preparation process as an indicator of community consultation). The focused group discussions will primarily focus on the issues and their possible solutions as perceived by respective groups. Minimum 3 FGDs should be conducted	1. FGDs with AG members on LRI recommendations with farmers on upper ridge, middle ridge and lower ridge	10	Meeting records: Attendance, photos, Proceedings of the Meeting etc.,	PIA/FNGO/RSK	20
		2. FGD with land less households	5			
		3. FGD with women SHGs	5			
5	Community consultation for demystifying science based DPR through transact walk and PRA exercise for treatment plan	Conducting PRA exercise by involving GP members, representatives of SHG & AG members	10	Transact and PRA Photos & Proceedings	RSK and FNGO	10
6	Ownership of the DPR DPR approved in the Gram Sabha - (The quorum for the meeting of a Grama Sabha shall be not less than one tenth of the total number of members of the Grama Sabha, or hundred members, whichever is less. As per THE KARNATAKA PANCHAYAT RAJ ACT, 1993)	More than the minimum quorum	10	Gram Sabha - Meeting Resolution, attendance, Photos	PIA, RSK and FNGO	10
		Minimum quorum of Gram Sabha members presents	5			

REWARD - GP Performance Assessment Tool –Preparatory Phase**Contd....**

7	Effective IEC: At least one wall painting and jatha on key interventions / community responsibilities / community awareness in a prominent place in each revenue village of the watershed	YES (marks will be allotted in proportion to jatha & wall paintings carried out in the villages of Gram Panchayat)- 80-100% coverage	10	Geo-tagged Photographs	PIA and RSK	10
		50-80 % coverage	5			
		<50%	0			
8	One exposure visits for the team comprising WEC, AG and SHG members (30 members) within the state (before the DPR)	Yes	5	Geo-tagged Photographs, Attendance	RSK and FNGO	5
		No	0			
9	EPA completed (All the activities to be completed within timeline approved)	Yes	10	Approved EPA action plan, Geo-tagged Photographs, Financial Progress Report - approved by PIA	PIA and FNGO	10
		No	0			
TOTAL of Preparatory Phase						100

DLI-2: Land area treated with science-based watershed management technologies. (Hectare (Ha))

Measures the area (in hectares) of watersheds where science-based watershed development has been prepared & implemented in a saturation mode.

Criteria

- DPRs have been prepared utilizing LRI outputs and approved by Gram Sabha-Year 2023
- Science-based watershed development will include measures related to restoration of degraded land and rainwater harvesting to address drought vulnerability

- Implementation of watershed development works has been undertaken in saturation mode. ‘Saturation’ refers to treatment of at least 70% of all parcel of land that has been recommended for treatment in DPR with different interventions
- 50% of the area/MWS are treated by 2025 and project completion are ready
- Another 50% of the area/MWS are treated by 2026 and project completion are ready

DLI-3: Adoption of resilient agriculture technologies and practices by (number of farmers). (Number)

- Measures the number of farmers who adopt at least one technology/practice from a core set of resilient agriculture technologies and practices recommended through agro-advisory.
- **Multiple channels:** LRI cards, weather based agro-advisories over mobile, bulletins, communication from extension workers, farmer training programs, etc.
- The core set of resilient agriculture technologies and practices has to will be as defined by the Government of India / respective state governments to strengthen resilience to climate change impact for the given agro-climatic zone.
- Year Wise Target

2024	2025	2026	Total
8100	9450	9450	27000

- The indicator will track the farmers by gender & social group

DLI-4: Farmer Producer Organizations with 25% increase in business turnover relative to baseline. (Number)

- Measures the number of Farmer Producer Organizations (FPOs) supported under the REWARD Program, that achieve an **annual sales turnover that is at least 25% higher than their baseline levels** (i.e., preceding year)
- The average sales turnover will be calculated based on annual sales reported by the FPOs in their annual audited financial statements during the assessment year against base year.
- Year Wise Target

	2024	2025	2026	Total
As per WB	6	6	3	15
As per WDD	10	15	5	30

- A separate agency “**Technical Support Agency (TSA)** will be hired to support selected FPOs- PIA need to monitor the agency

DLI-5: Number of professionals who complete certified training

- Measures the number of professionals who complete certified training on improved watershed management provided by Center for Excellence on Watershed Management (CoE-WM).
- Considered as met if minimum targets for number of trainees who successfully complete the training and are certified.
- The certification will be based on successful completion of a learning assessment, designed, and used by CoE.
- A robust definition and process for certification shall be finalized.

Year Wise Targets

2023	2024	2025	2026	Total
150	325	325	325	1125

Soil-Site Characteristics Criteria**Soil Depth Classes**

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

Soil Texture a- Sandy b- Loamy sand c- Sandy loam d- Loam e- Silt loam f- Clay loam g- Silty clay loam h- Sandy clay loam i- Sandy clay k- Silty clay m- Clay	Soil Slope A- Nearly level (0-1%) B- Very gently sloping (1-3%) C- Gently sloping (3-5%) D- Moderately sloping (5-10%) E- Strongly sloping (10-15%) F- Very Strongly sloping (15-25%) G- Moderately Steeply Sloping (25-33%) H- Steeply Sloping (33 - 50%) I- Very Steeply Sloping (>50%)
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Erosion e0 - Nil e1 - Slight e2 - Moderate e3 - Severe e4 - Very severe	Soil Gravelliness g0 - Non gravelly (<15 %) g1 - Gravelly (15-35 %) g2 - Very gravelly (35-60 %) g3 - Extremely gravelly (60-80 %) g4 - Considered as part of the topsoil (>80 %)
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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	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
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