# University of Agricultural Sciences, Bangalore

## Centre of Excellence on Watershed Management under REWARD

# National level training on LRI for non-REWARD States

(Sponsored by DoLR, New Delhi)

## Training Reference material

**Special Officer**
**Centre of Excellence on Watershed Management**
**UAS, Bangalore**

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**January 09-13 and 16-23, 2023**

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## CONTENTS

# 1. LRI and it is importance in watershed planning
# What makes the difference between PMKSY 2.0 and LRI based planning

**Background:**

In the Guidelines for New Generation Watershed Development Projects – WDC-PMKSY 2.0, it has been stated that "Building Land Resource Inventory (LRI) through compilation of basic site and soil characteristics; hydrological and meteorological data; and socio-economic status. To begin with, states should cover at least 10% of projects under LRI system". Considering this, an overview of LRI approach in planning for Watershed is presented in this chapter.

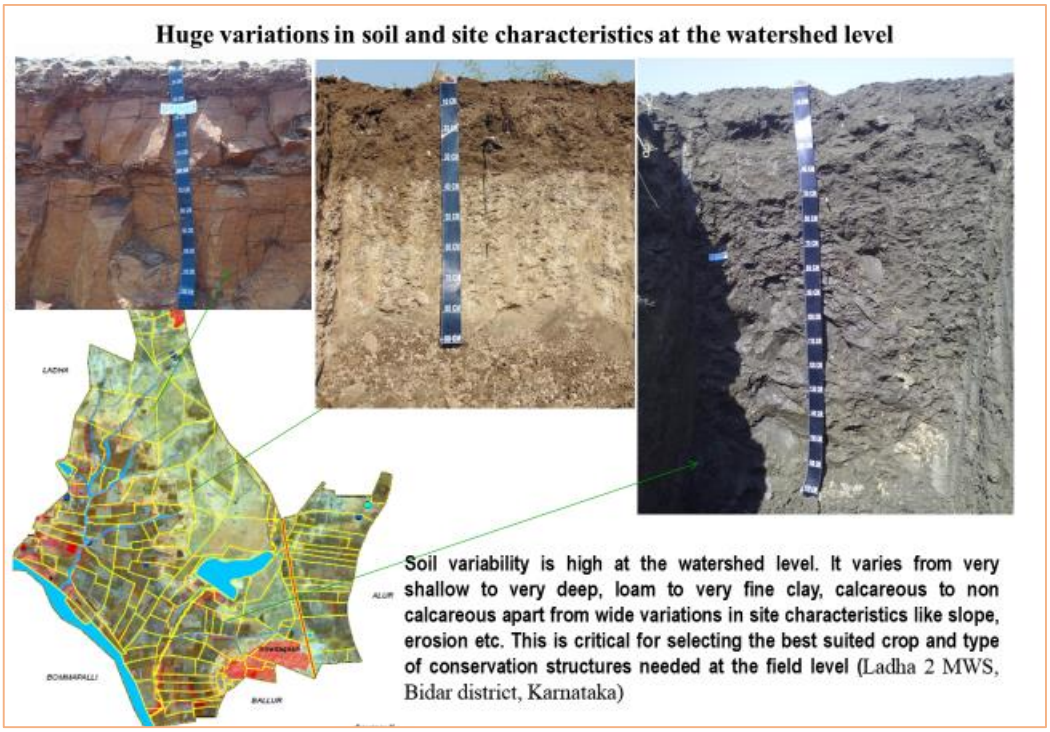
**Introduction:**

The finite land resources of our country are under severe strain due to the needs of the growing population and competing demands of land uses. Due to this about 96 million hectares of land area (MoEF 2021), representing 30 percent of the total geographical area, is degraded mostly due to erosion, salinity and alkalinity has become a serious problem in the command and arid areas, deficiency of secondary and micronutrients is widespread in the cultivated areas, ground water exploitation has become critical in most parts of the country and declining factor productivity observed in majority of the crops. Among the various forms of degradation soil erosion is the major cause for the declining factor 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 from 1977 to 2007 in the country which might be even more at present (Planning Commission, 2007). As per the High-level committee on Wastelands (GoI, 1995), the uncontrolled and continuing land degradation in the form of soil erosion is a major threat to the country's economy and observed that about two-thirds of our agricultural lands are sick in one form or other and only about 48 m ha are in good health. The situation is further compounded by climate change which has emerged as the main driver of land degradation in India, with erosion of topsoil reducing the land's carbon sink ability and water storage function in the soil. The recent study carried out in Karnataka under Sujala-3 Project has highlighted the declining status of the resource base with the very poor organic carbon, low moisture retention, unremunerated and unsustainable yield levels in the vast rainfed areas of the state (The Hindu 2018, WDD 2020).

It is obvious that urgent measures are needed not only to arrest the declining health of land resources in the country but also to regenerate the degraded lands in a reasonable timeframe. Otherwise, the cost of the neglect, estimated to be about 2.5 per cent of the GDP in 2014-15, will be too high to pay in the future (TERI, 2018). Realising this and to improve the productivity of the resources on a sustainable basis, a plethora of schemes/plans have been formulated and implemented by both state and central government in the country since independence. Even with all the budgetary provision for various schemes like Watershed Development, MGNREGA, RKVY, NFSM and others, the health of the country's resource base has not shown any perceptible change and on the other hand there is a continuing deterioration witnessed at the field level. It is obvious that there is a clear mismatch between the plans formulated and executed by various line departments and the needs or the requirements at the field/grassroots level in the country.

**Why REWARD program?**

As we know that the factors and processes affecting degradation, productivity and sustainability are very site and location specific, for any meaningful intervention needed for their restoration and management requires site-specific land resource information which is not available at present for major part of the country. As the land resources are not uniform and vary from field to field in any given landscape, generation of location specific information pertaining to the nature and extent of variability in soil, water availability, topography, land use, and advisories 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 line departments in the country. This has been highlighted by many studies/committees/working groups in the past (Planning Commission-11$^{th}$ Plan, 2007, NMSA 2009, Natarajan et al 2006, Natarajan 2022).

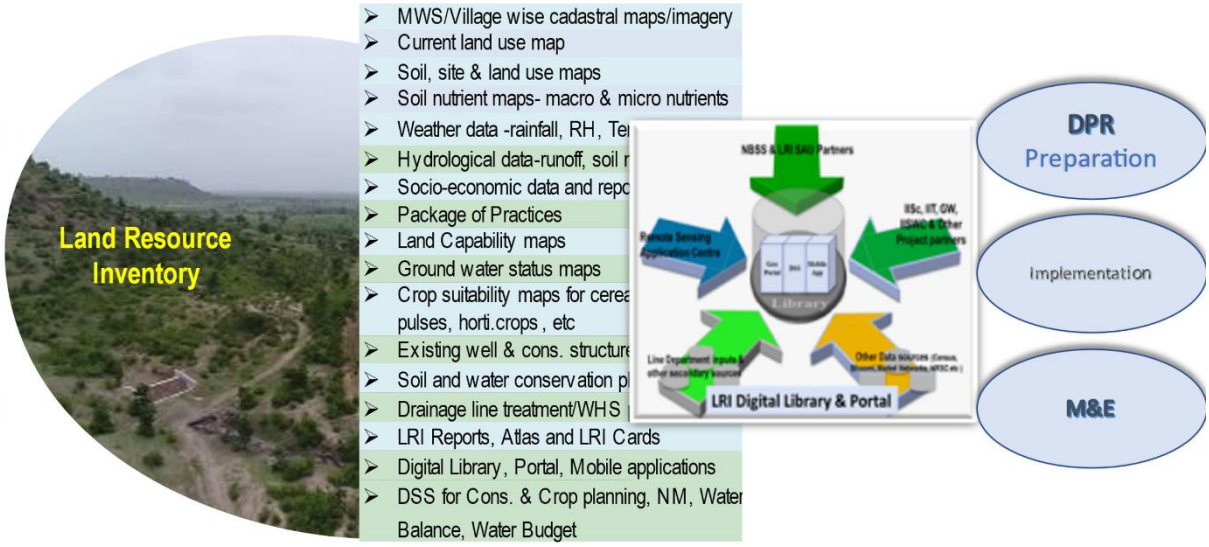



**Variability in soil-site characteristics at field/landscape level**

Realising the importance of site-specific soil and other information for taking up targeted interventions many States have taken up generation of such database and advisories and among them the most noteworthy initiatives have come from Tamil Nadu, Karnataka, Kerala and in few other States in the country (Natarajan 2022). The outcome of 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 in Karnataka, 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 cycle to four years, 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.

Appreciating the impact of the above program, the Government of Karnataka has extended it to cover the whole rainfed area of the state with Land resource inventory (LRI) technology. Similar initiatives are planned by other States after their visit to Sujala-3 project areas in Karnataka. To upscale the lessons learnt from Karnataka to other States and to support science-based planning, implementation, and monitoring of watershed interventions under PMSKY, the REWARD project (Rejuvenating Watersheds for Agricultural Resilience through Innovative Development (REWARD) is taken up in Karnataka and Odisha with the support of the World Bank from 2022 onwards. The REWARD project is designed to support the full range of watershed development activities in the country. This life cycle approach, piloted through REWARD, is expected to demonstrate the importance of LRI and hydrology, thematic maps and Decision support system (DSS) in planning interventions, role of digital library and portal in Detailed project report (DPR) preparation and program convergence. Further, the outcome of the REWARD is expected to consolidate and improve the existing guidelines and come up with appropriate protocols and new set of guidelines for science-based watershed planning, convergence of schemes and other interventions in the country later. The overview briefly presents the generation of cadastral level land resource information through LRI and hydrological investigations, thematic map generation, importance of DSS for planning interventions, role of Digital library (DL) and Portal for DPR preparation, dissemination of advisories and program convergence, role of partnerships and capacity building, and need for evidence-based Monitoring and impact evaluation of the interventions carried out under the REWARD program.




**REWARD-A life-cycle approach to Watershed Management**

**Generation of LRI and hydrological data:**

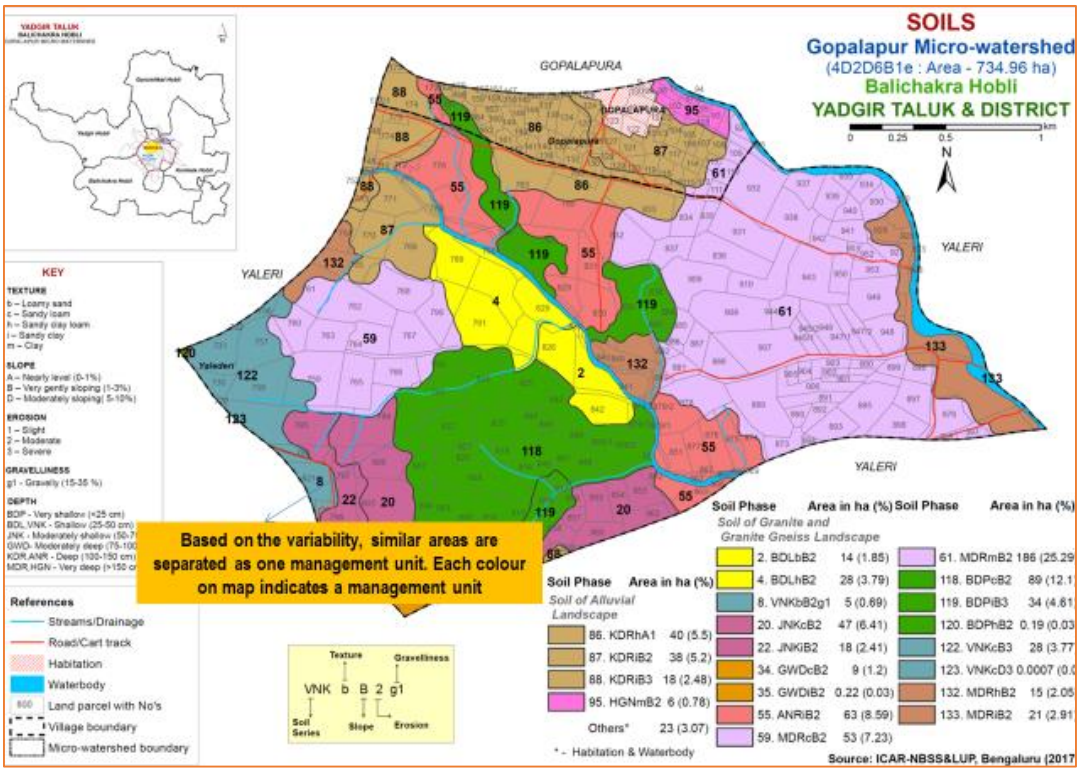
Though the importance of site-specific cadastral level information for planning watershed interventions is known for a long time, its effectiveness has been largely demonstrated by the outcome of the Sujala-3 program in Karnataka. Since the utility of LRI data depends on the base map, selection of appropriate base is critical for the generation of LRI data. In our situation, with smaller holdings and fragmentation, cadastral map is the only source which can provide all the needed information like the field boundaries, survey number and other permanent features like roads, habitations, drainage lines *etc* that can help the user to orient himself without any doubt, the mapper to show the boundaries clearly and the line departments to take up the planned interventions with confidence and certainty. Fortunately, due to the initiatives of the DoLR and State Space Application Centres the cadastral maps are digitised, georeferenced and available for the entire country in a seamless manner.

Apart from this an array of high-resolution remote sensing data products (Quick bird, Worldview *etc*) are available on which the cadastral layer can be superimposed and used as a base for LRI work. The development of 2-meter contour from the Cartosat data by Karnataka remote sensing application centre (KSRSAC) will further improve the delineation of landform units. Recently, the Survey of India with the support from GoI has taken up Survey of Villages and Mapping with Improvised Technology in Village Areas (SVAMITVA, 2020) to generate ortho mosaic maps, and digital surface models at 1:500 scale by drones in the country which offers enormous scope for using it as a base for LRI in the future.

After the base map selection, the assessment of the status and changing condition of soil, water, land use and related resources at the field level is carried out by following the critical steps as indicated below (USDA, 2019, Natarajan *et al*., 2016).

- Interpretation of the imagery and preparation of base map
- Field traversing, checking and correction of units delineated based on variations observed in rock types, landforms, land use, slope, drainage *etc*.
- Selecting transects, profiling and study of soil-site characteristics
- Grouping similar areas based on soil-site characteristics into management units
- Mapping the extend and distribution of the units on the cadastral map
- Collection of profile and grid points for analysis
- Preparation of land use and land cover map
- Well inventory
- Mapping existing conservation and water harvesting structures
- Establishing model watersheds and benchmark soils and their instrumentation
- Collection of weather and climatic data, soil moisture, ground water level, demographic, socio-economic and farmer details
- Analysis of soil samples, processing of field data and maps and finalisation of soil and other maps through the GIS


**Site and Soil (profile) characterisation during LRI**



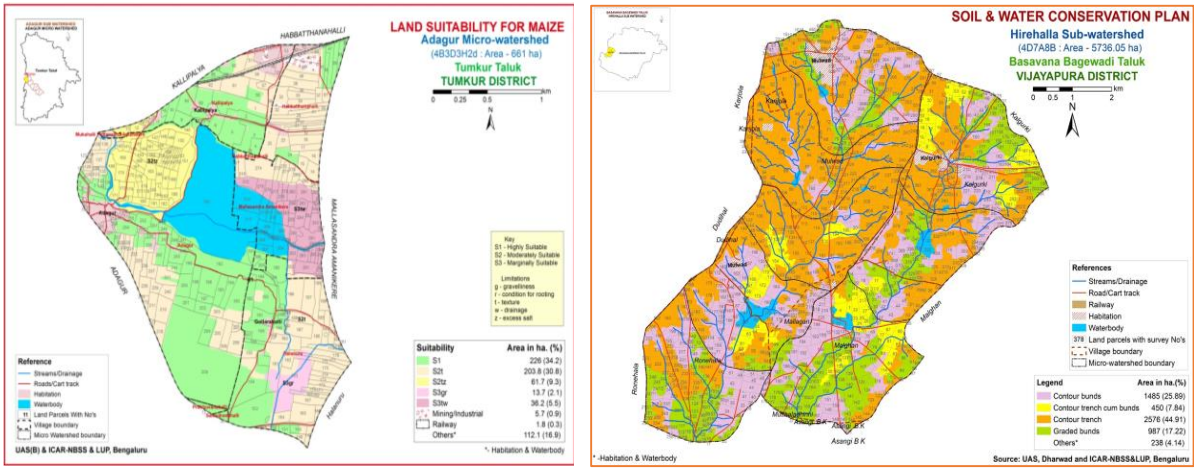

**LRI for grouping similar areas into management units, Gopalapur MWS, Yadgir**

**Development of criteria needed for interpretation and thematic map generation:**

The LRI data per se is of not much use or value to the planners unless it is converted into a form or format which they can understand and use it for planning and implementation of their programs. This is a real challenge and calls for the involvement of subject matter specialists from different disciplines. For example, to assess the suitability of an area for a crop needs a team of specialists trained to use the LRI data who can effectively identify the constraints of the soil, weather and climate and optimum conditions required for its growth. The assessment

becomes difficult when many factors and processes are considered together which is further complicated by the interaction of one factor/parameter with the other or with all of them. This calls for the development of criteria, models, algorithms, and guidelines by a team of specialists which can facilitate the assessment for crop selection, soil and water conservation interventions, nutrient management, runoff, water budgeting *etc*. It is important to remember that the criteria, models, or algorithms *etc* developed needs to be tested in the field and validated with multi location trials before they are rolled out for use. This exercise needs to be an ongoing one and as and when additional information is received necessary improvement/refinement needs to be incorporated and the models/criteria modified accordingly.

Based on the criteria, models, and guidelines developed and integrating the same with the LRI data, the required thematic maps on the constraints, potentials, suitability, soil and water conservation, nutrient status and their management, runoff estimation, soil moisture assessment, crop water requirement, water balance and budget *etc* can be generated for any mapped area. For example, for finding out the suitability of the land resources for a particular crop, first the soil-site-hydrology criteria for suitability assessment is developed with the involvement of domain specialists, and based on the criteria, algorithm and flow chart assessment for the selected crop is carried out and suitability map generated. Similarly, based on the criteria developed, suitability for other crops/land uses can be carried out and maps generated for use. Likewise, thematic maps for soil and water conservation, land capability, moisture availability, water balance *etc* can be developed at the farm/water shed level as per the requirement of the users.




**Suitability of Adagur MWS for Maize and Conservation plan for Hirehalla SWS**

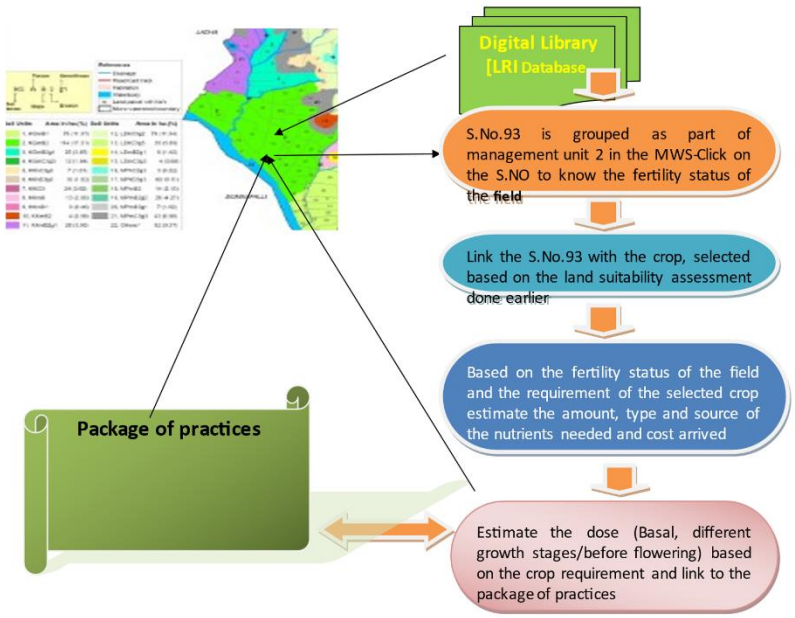
**Development of Decision Support System (DSS) for resource optimisation:**

The development of DSS, a computerized expert interactive information system, is critical to decide on the most appropriate interventions that can be taken up for implementation based on the available information. Since LRI provides all the required spatial and non-spatial information and thematic outputs needed for planning it will be of great help if appropriate DSS are developed to facilitate the decision-making process by user departments apart from bringing uniformity in their assessment. Under Sujala-3 project, an attempt has been made to

develop few DSS models to facilitate watershed planning in Karnataka, as indicated below which can be further improved and new ones developed as per the user needs in new project areas in the country based on LRI coverage.

- 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 on Land Capability Classification
- DSS on crop based Nutrient Management and Soil Health
- DSS for estimating Surface runoff at farm/MWS/SWS levels
- DSS for designing the Size and location of Farm ponds and Check dams based on runoff model
- DSS for estimating the Crop water requirement at MWS/SWS levels based on the existing land use or crops that are planned to be taken up for cultivation
- DSS for estimating Soil Water balance at MWS or higher levels
- DSS for Water budgeting taking into consideration the needs of various uses/users at MWS/ Village level- crop needs, human needs, livestock needs *etc*.

It has been observed that the development of DSS has significantly reduced the time required for watershed planning, targeting of soil and water conservation investments where it is critically needed, estimation of water balance and water budgets, farmer decision-making around crop selection, precision farming, nutrient management, program convergence among the line departments and other activities at the farm and watershed levels (WDD 2020).




**DSS for site-specific nutrient management**

**Preparation of DPR/Land use plan:**

The relevance of the LRI information and their outputs depends on the extent they are used in the preparation of land use plans by the line departments and their acceptance by the farmer

and other stakeholders at the grassroots level. The land use plan or the DPR should be able to capture not only the constraints, potentials, and suitability of the resource base for different crops and other uses but also include the alternatives for making choices, cost estimates for taking up the identified intervention, action plan for implementation and expected impacts of the interventions carried out in the area. This is not a standalone exercise to be carried out by any one department or agency, but a joint exercise carried out with the involvement of both data generators and data users in an iterative manner. For example, the conservation plan is prepared by the integration of the LRI data with the criteria table developed for the selection of different structures along with costs norms involved by the LRI partner and Watershed Development Department (WDD). Similarly, the plan for taking up other interventions are also developed jointly and included in the DPR, which is not a closed document but a dynamic one which gets revised as and when necessary, based on the feedback received during implementation. It is important to note that the success of the land use plan/DPR depends on the active involvement of all stakeholders in planning, validation, implementation, and monitoring stages of the program. This life-cycle approach for planning will ensure the successful implementation of the programs designed at the farm or grassroots level in the country.

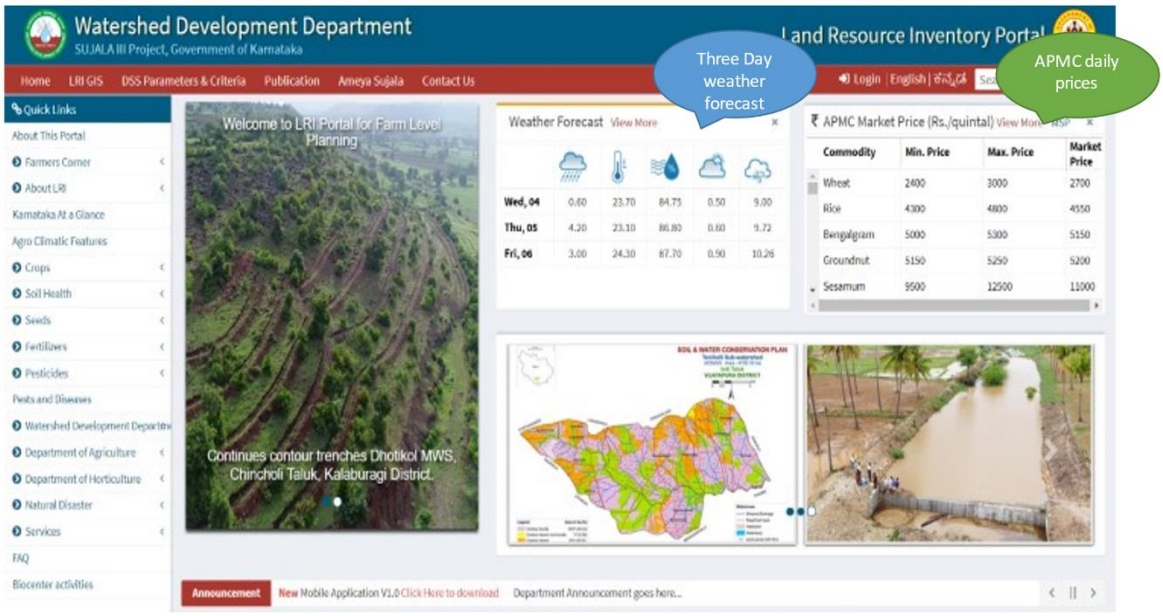
**Development of digital library, LRI portal and mobile applications:**

For effective dissemination of information, all the spatial and non-spatial database and thematic maps generated from LRI and hydrology and information compiled from different sources along with the Decision Support Systems developed can be migrated and integrated in a single platform (Digital Library and LRI Portal) and the same can be made available to the line departments, farmers and other users on real time basis through web and mobile applications. The availability of site-specific land resource information, thematic maps along with the Decision Support System and advisories on a single platform will be of great help to the Watershed, Agriculture, Horticulture, and other line departments to prepare science based Detailed Project Reports in a shorter span of time. The user can also generate the required maps and reports as per the area of his interest with the help of the Portal. The development of LRI portal in Karnataka has helped to automate the preparation of the DPR which used to take years earlier, watershed cycle gets reduced to 3 to 4 years which used to take 6 to 7 years and real time convergence of the programs by various line departments made possible in the state.

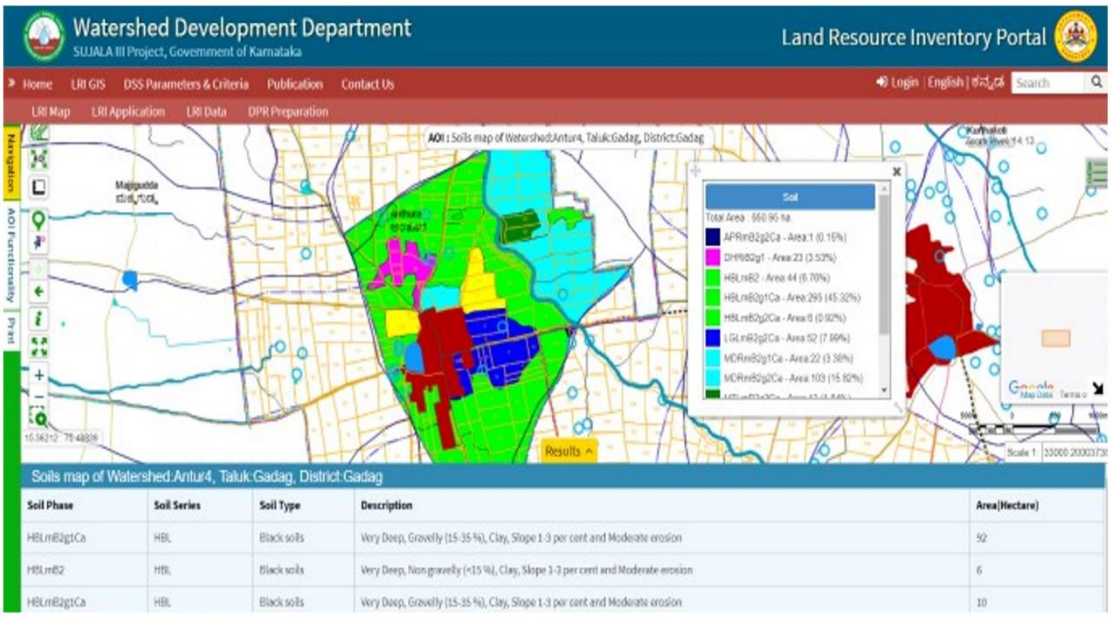
**Partnerships, capacity building and training for upscaling REWARD program:**

The generation of cadastral level LRI, hydrology and other datasets, thematic outputs and advisories is not possible by any lead institute alone or by any other organisation and hence establishing partnerships with appropriate institutions at the state and country levels is critical for executing and upscaling REWARD activities in the operating states. For effective implementation of the program, it is important that not only the partners should be on board to generate the required data but also the institutions/agencies who can add value to the data and most importantly the user departments to support the program due to the advantage they derive in using the LRI outputs and tools should be brought together for this purpose. Accordingly, a consortium of partners and user agencies/line departments is needed to take up the program on a mission mode. The successful implementation of KWDP II program in Karnataka with the establishment of a consortium of 14 partners/user agencies with defined roles and

responsibilities will form the template for taking forward the REWARD program in Odisha, Karnataka, and other states in the country in the coming years. The establishment of dedicated RS, GIS, analytical and field facilities at the partner institutions with the required manpower, working capital and training will help in the generation of thematic outputs as and when needed, facilitate the preparation of DPRs for any area of interest and disseminate the information and advisories to the users on real time basis.




**Landing page of the LRI Portal displaying weather and commodity prices**




**Viewer can select AoI, view, download, print, save or generate maps as required**

Towards this, the role of the Centre of Excellence (CoE) on Watershed Management in established in Karnataka as part of the REWARD program will play a critical role in imparting training to the REWARD program states and subsequently in the operationalisation of PMKSY programs in the country in the coming years. Apart from this, the success of the program will

help in the development of new generation guidelines for watershed management under PMSKY in which about 26 m ha are planned to be covered in different states by 2030.

**The difference between PMKSY and LRI Approach**

In terms of institutional arrangements, convergence of programs and implementation strategy are same in both the programs. However, there is a difference in preparation of DPR. The LRI and hydrology outputs are integrated with decision criteria tables for selection of soil and water conservation measures, crop suitability and nutrient management plan. The data collected from the inventories is stored as digital library in the portal. The decision support system developed for major activities will help the project staff to prepare the draft activity plan in the office by accessing the data from portal. Validation and cross verification of the developed plan to be done in the field before its approval at different levels. By this, it is possible to complete DPR preparation within two months, the specified conservation measures and treatments will be more precise, restrict to site specific size of the structures leading to cost saving, site specific or land parcel wise appropriate crops can be advocated with proper nutrient management. There will be saving in man hours for preparation of DPR. Helpful for impact assessments also.

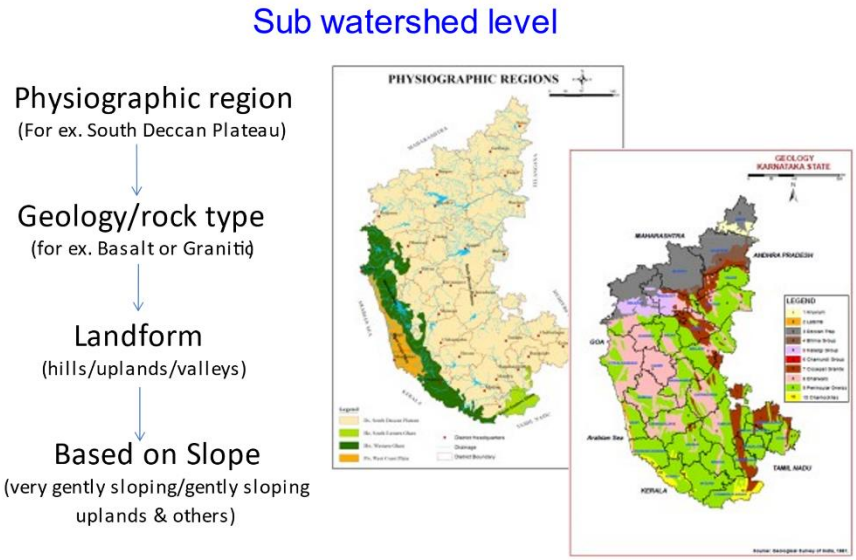
Article Contributing Author: Dr. Athiannan Natarajan

## 2. LRI approach - data generation process and institutions

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

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

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




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

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

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

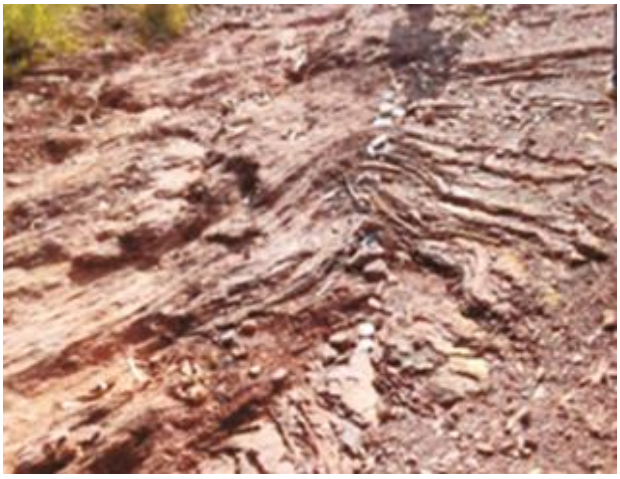
the uplands can be subdivided into rolling, undulating, gently sloping, very gently sloping and nearly level lands based on their extent and slope at the MWS level.

**Red sand stone**

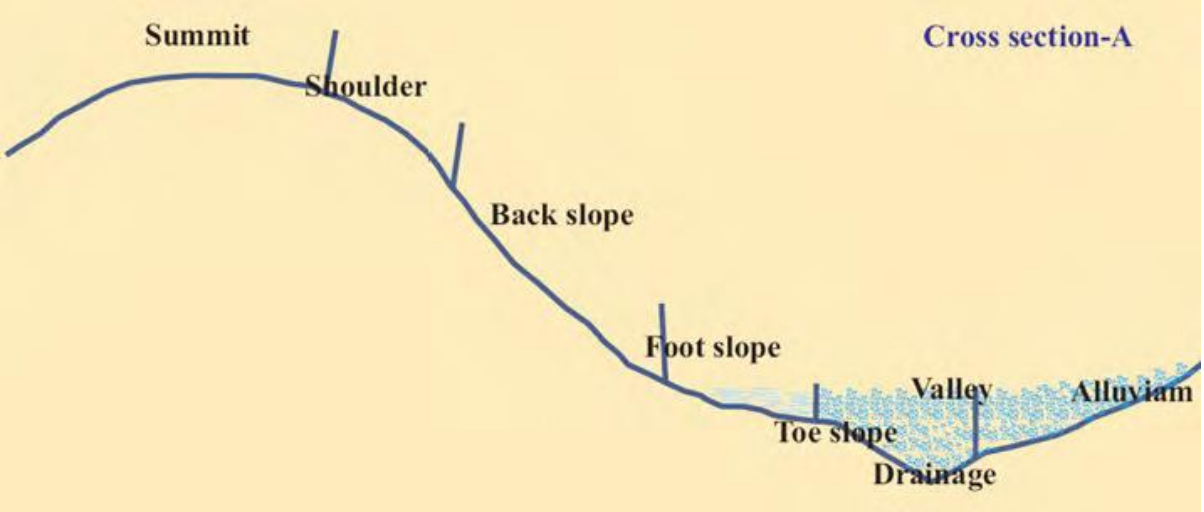
**Basalt Rock**

**Granite**

**Laterite**

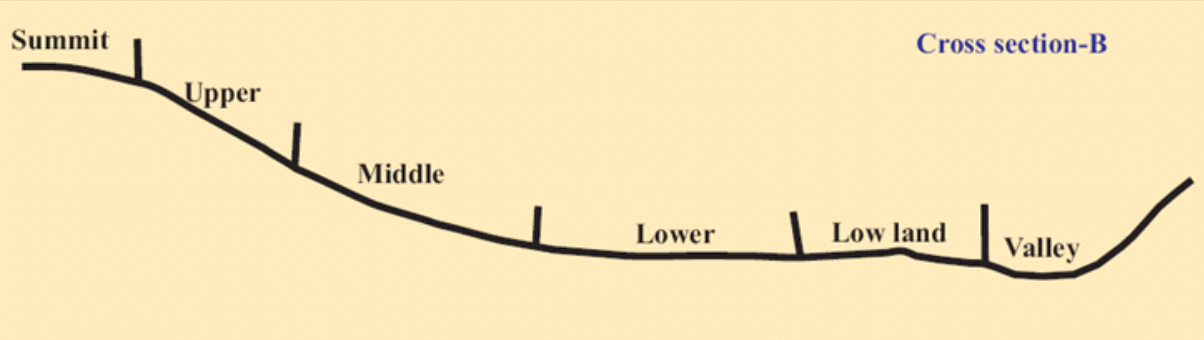


**Schist**




**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

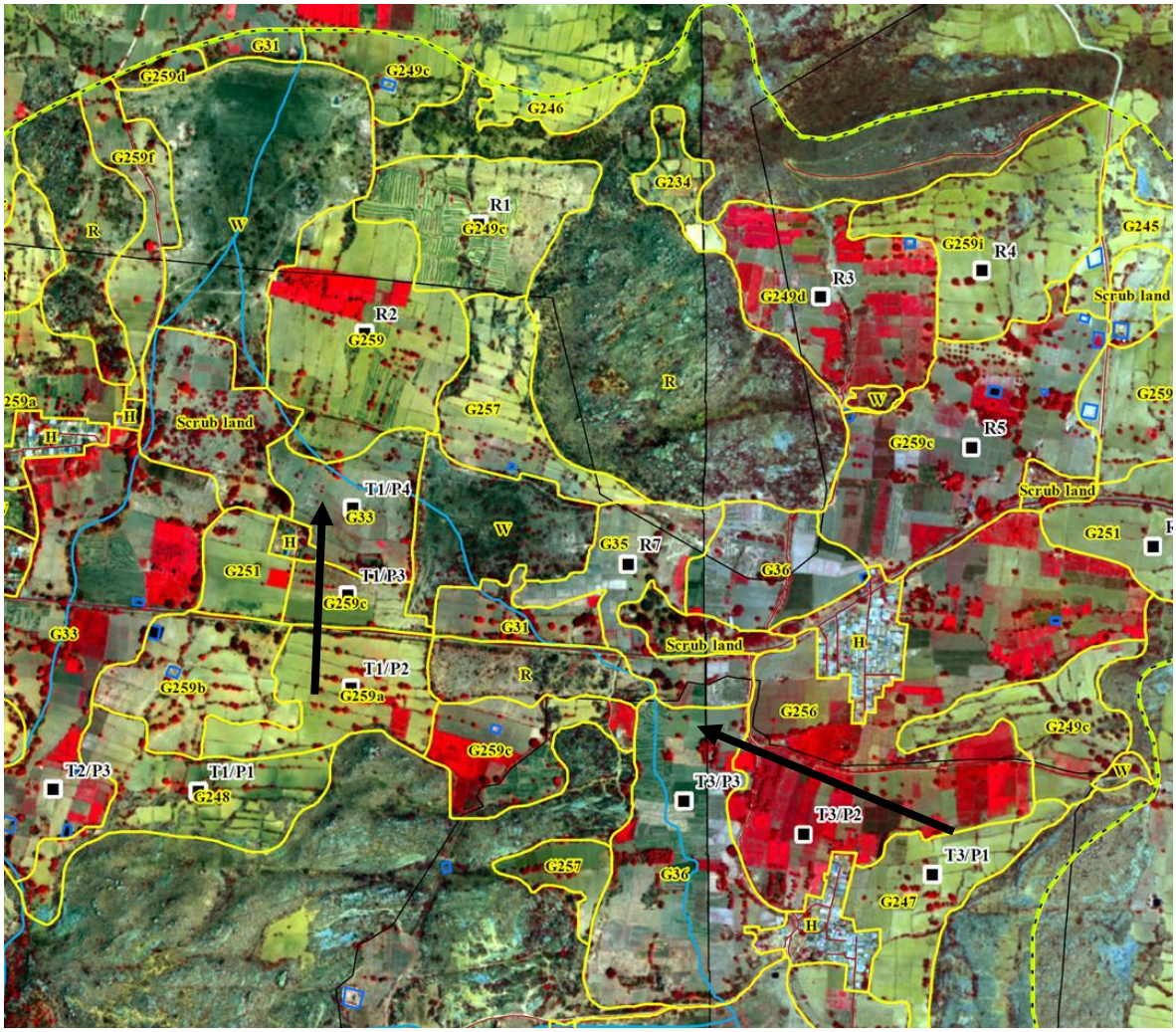
- **D Deccan Plateau**
- **DS South Deccan Plateau**
- **G Granite and Granite Gneiss Landscape**
  - **G1 Hills/Ridges/ Mounds**
    - G11 Summits
    - G12 Hill/Side Slopes
      - G121 Side slopes with dark grey tones
    - G13 Isolated hillocks
  - **G2 Uplands**
    - G21 Summits/ Nearly Level Lands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

**Identification of transect for profile studies:**

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

Criterias for transect identification:

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




**Transects and randoms marked for profile study**

**Field activities: Traversing and validation of interpreted map**

**a) At Sub watershed level:**

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

**Differentiating Characteristics for identifying Soils at SWS level**

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

**b) At Micro watershed level:**

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

**Study of site characteristics (phases):**

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

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

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

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

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

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

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

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

Gg - indicates the name of the district, Gadag

Sht - indicates the name of the taluk, Shirahatti

Rtr - indicates the name of the village, Ranatur

T1 - Transect No.1 in Ranatur village

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

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

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

or

R1 Random profile No.1 from Ranatur village

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

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

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

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

Kp - indicates the name of the district, Koppal District

Gn - indicates the name of the taluk, Gangavati Taluk

Kav - indicates the name of the village, Kavalur village

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

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

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

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

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

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

## Profile study

**Description of Site characteristics:**

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

The 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.

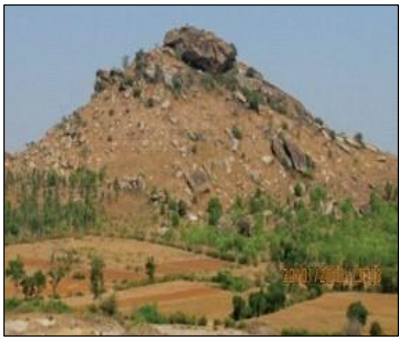
Any physical, recognizable feature of a landscape, having a characteristic shape and mappable area at the scale of survey is to be recorded

| *Major landscape areas* | *Landforms identified* |
|---|---|
| Basalt landscape | Plateau, Mesas, butte, summits, escarpments, side slopes, sloping uplands, plains, valleys |

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

**Gently sloping severely eroded uplands**

**Elongated plateau in basalt landscape**



**Conical residual hillock**

**Gently sloping uplands**

**Steeply sloping low hills**

**Level (< 1 %) lowlands**

**Typical landform units of granite gneiss and basalt landscape**

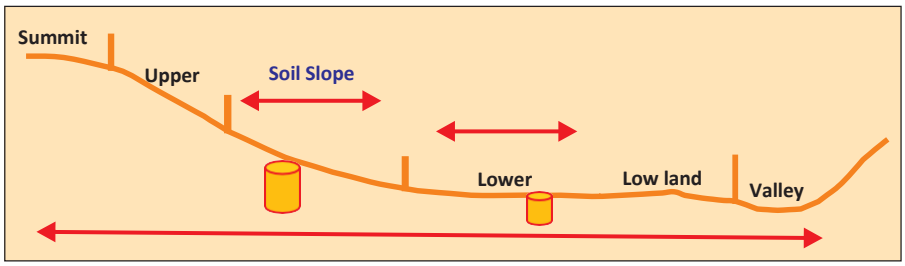
**Micro-features** - Any discrete, natural or artificial surface feature, occupying very small area on the land surface, which cannot be delineated at the scale of mapping are known as micro features. These small features individually cover less than 100 $m^2$ area and the height difference will be within few metres from the ground level. For example, small gullies or sand dunes if

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

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

**Profile position -** In a hilly area the profile position can be indicated as summit, shoulder, backslope, 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.

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

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

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

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

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

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

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

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

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

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

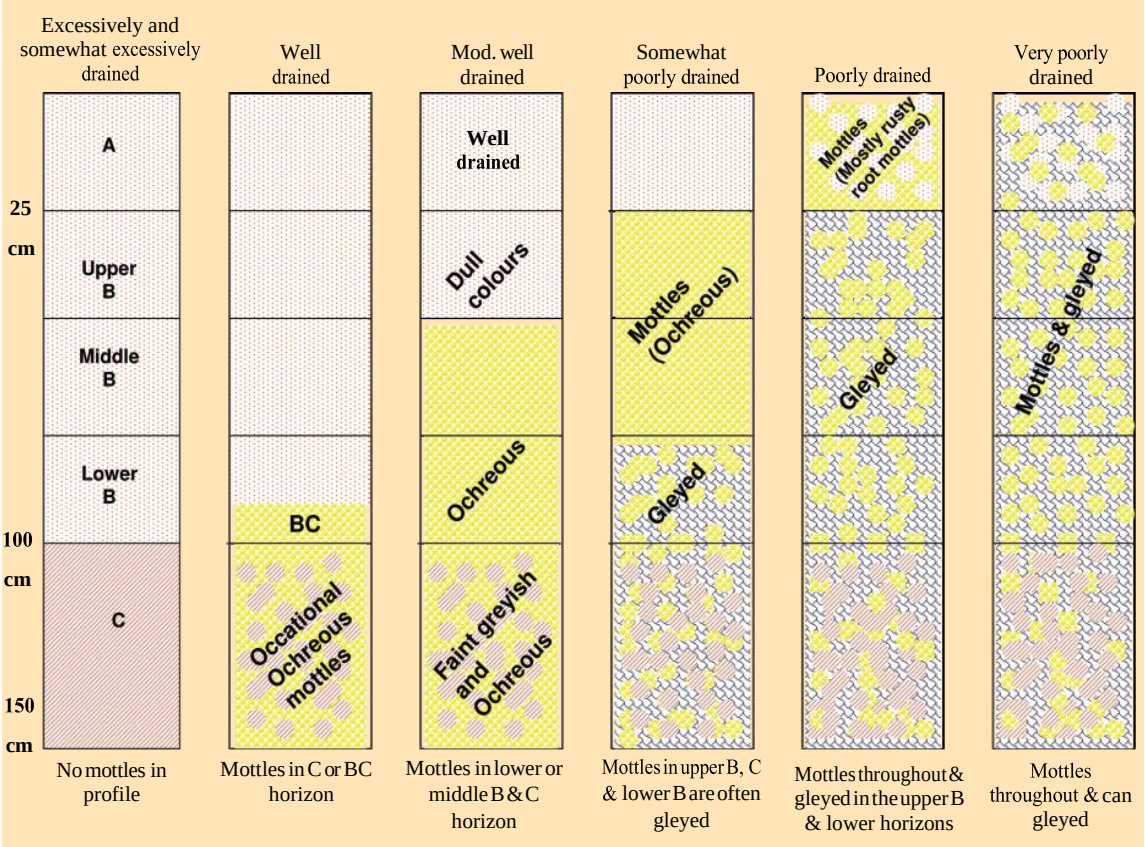
**c) Slow -** Surface water flows away **slowly** that free water lies on the surface for significant periods or enters rapidly into the soil. This condition is observed normally in nearly level or very gently sloping areas or in sandy soils.

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

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

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

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




**Morphological changes due to prolonged wetness and poor drainage**

**Description of various drainage classes of soil**

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

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

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

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

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

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

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

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

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

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

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

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

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

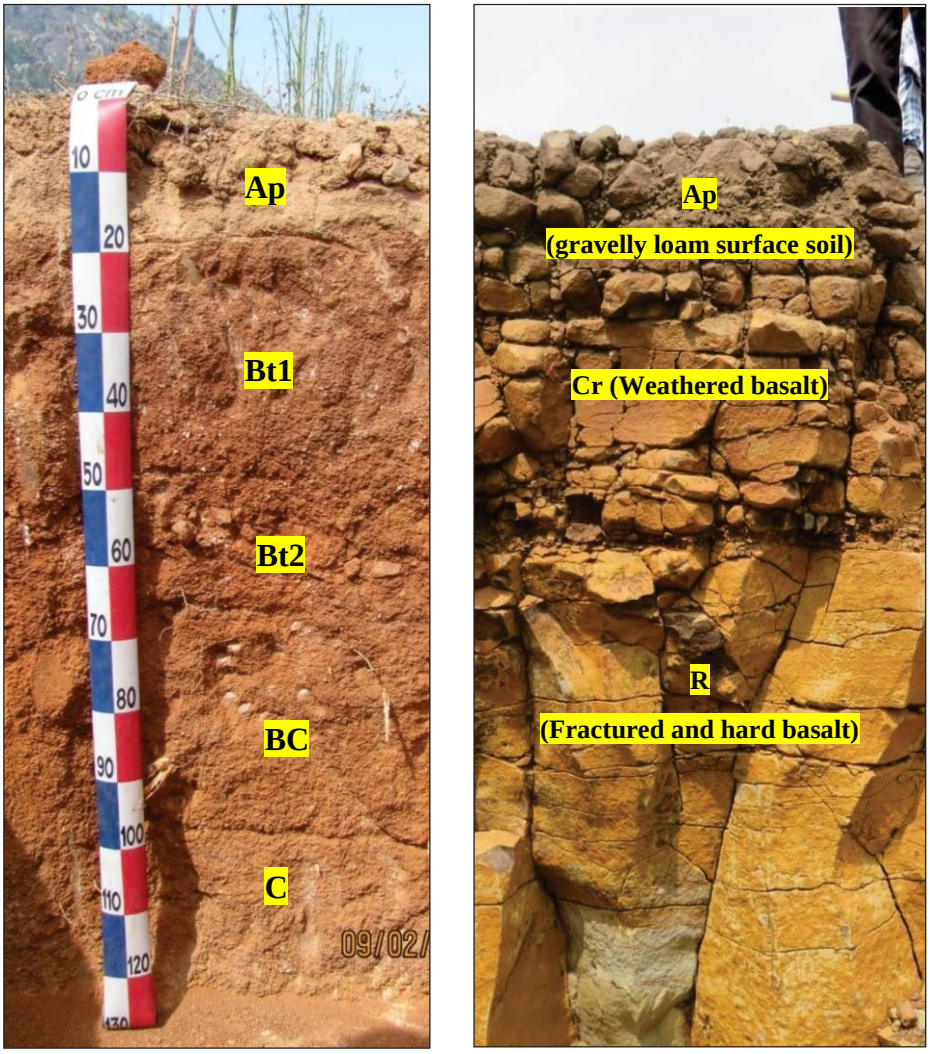
**Elevation -** Elevation refers to the height of a point on the earth's surface, relative to mean sea level. It can be determined from the contour maps or by using Global Positioning System (GPS). The elevation of the area is to be noted in the box based on the GPS measurement.

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

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

## Soil characters

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




**Typical horizon designations used to describe profile development**

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

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

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

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

**b. Master Horizons and Layers**

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

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

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

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

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

**C horizons -** Horizons, excluding hard bedrock, that are little affected by pedogenic processes and lack properties of O, A, E, or B horizons. The material of C layers may be either like or

unlike that from which the solum presumably formed. The C horizon may have been modified even if there is no evidence of pedogenesis.

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

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

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

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

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

**Conventions for using letter suffices**

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

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

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

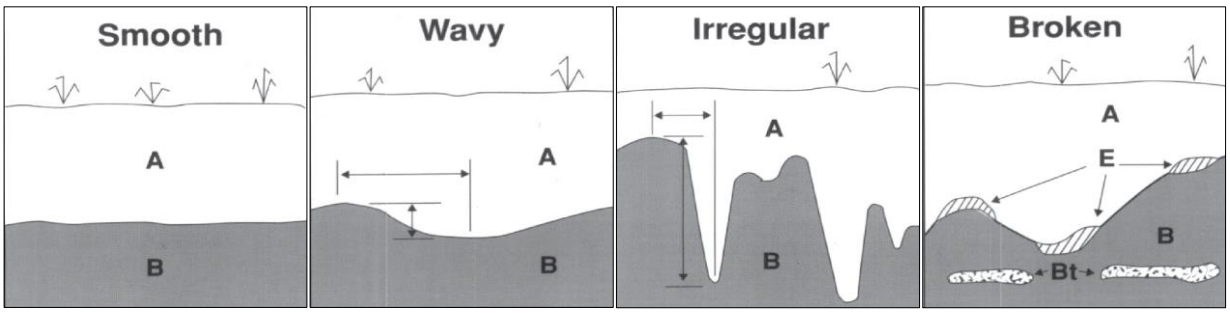
**Boundaries of horizons and layers -** A transitional area or layer present between two adjoining horizons or layers is known as the boundary. Boundaries vary in **distinctness** (contrast) and in **topography**.

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

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

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

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



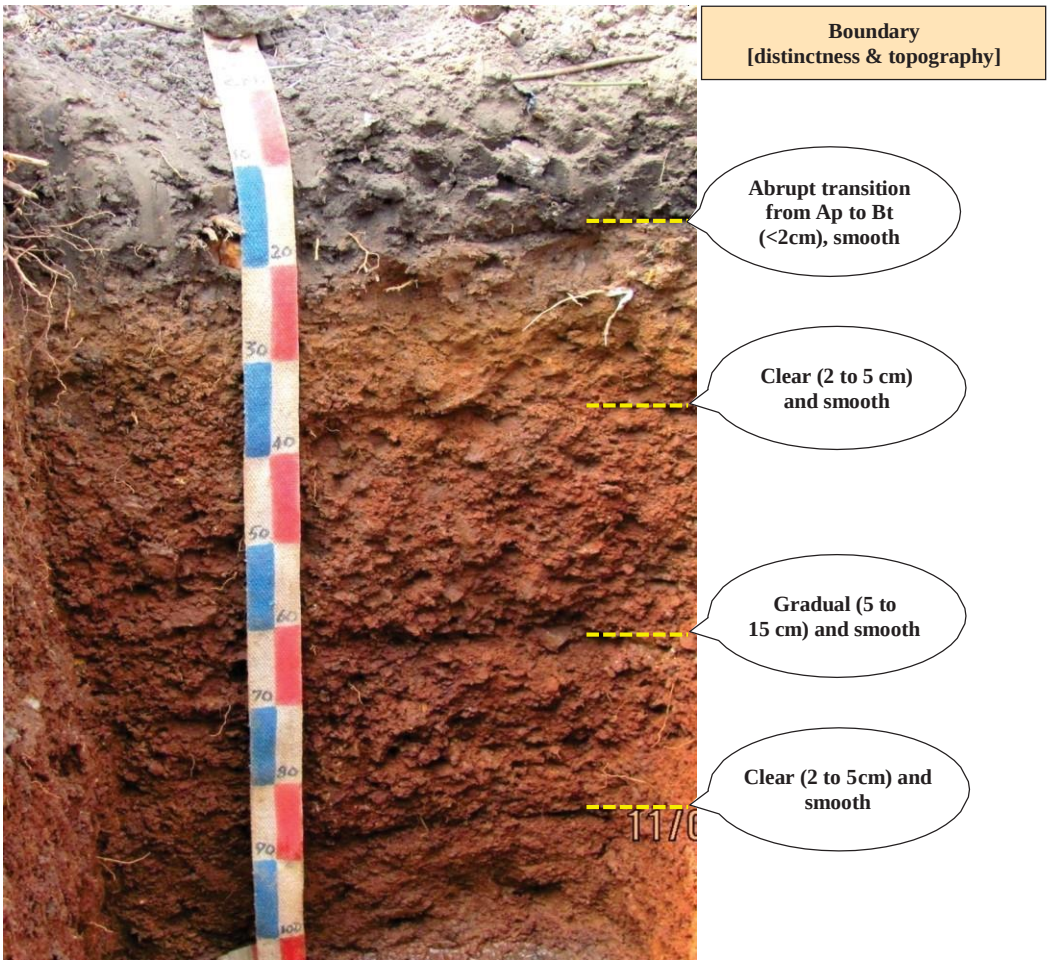

**Topography of the soil boundaries as seen in the field**

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

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

colour used for soils.

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




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

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

than in bright sunlight. Hence, determination of soil colour is undertaken in shade by utilising the shadow of the person holding the colour chart.

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

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

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

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

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

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

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

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

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

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

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

**Guide for assessment of soil texture in the field**

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

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

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

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

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

**Based on shape (type)**

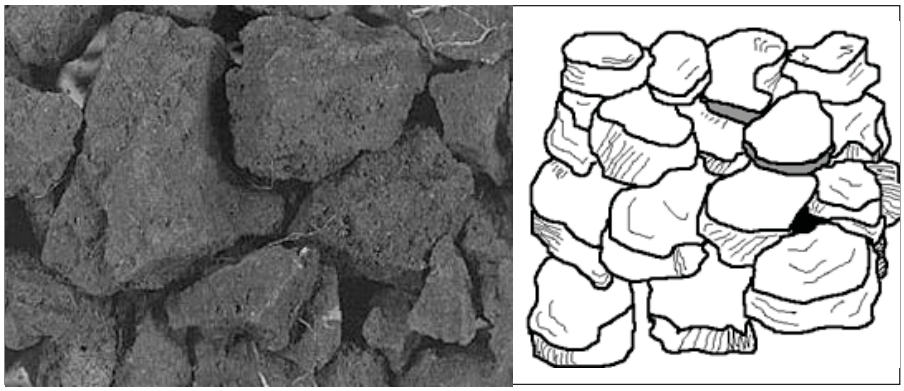
| | |
|---|---|
| Platy | The units are flat and plate like and horizontally oriented |
| Prismatic | Vertically elongated units with flat tops, the individual units are bounded by flat to rounded vertical faces |
| Columnar | The units are like prisms and are bounded by flat or slightly rounded vertical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

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

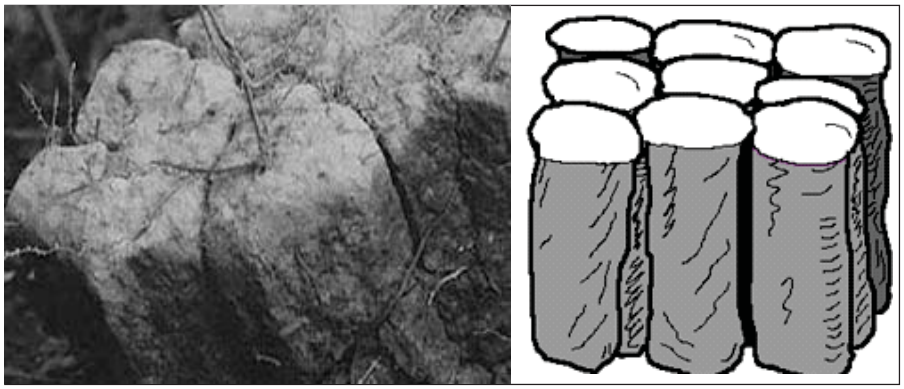
| *Size classes* | *Grannular, Platy (mm)* | *Prismatic & Columnar (mm)* | *Blocky (mm)* |
|---|---|---|---|
| Very fine | < 1 | < 10 | < 5 |
| Fine | 1-2 | 10-20 | 5-10 |
| Medium | 2-5 | 20-50 | 10-20 |
| Coarse | 5-10 | 50-100 | 20-50 |
| Very Coarse | > 10 | > 100 | > 50 |

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

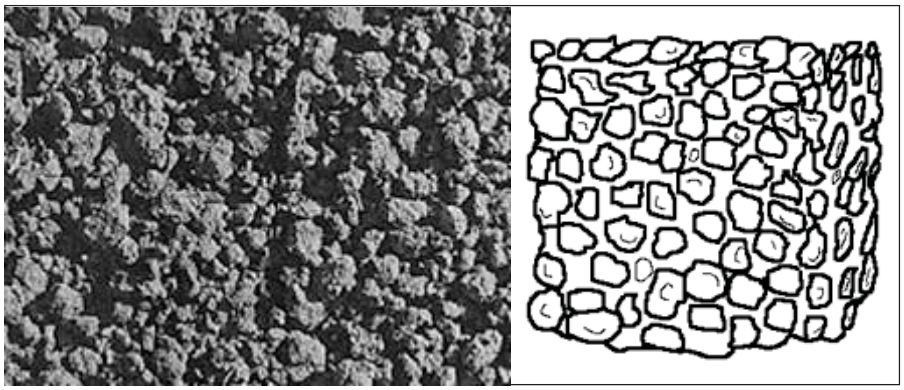
| | |
|---|---|
| Structureless (0) | No discrete units observable in place or in hand sample |
| Weak (1) | Units are barely observable in place or in a hand sample |
| Moderate (2) | Units well-formed and evident in place or in a hand sample |
| Strong (3) | Units are distinct in place (undisturbed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



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



**Columnar - Vertical columns found in arid climate**



**Granular - Resembles crumbs and seen in surface horizons**

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

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

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

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

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

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

**Redoximorphic Features (RMF) -** Mottles are already described under the section soil colour. RMF mottling is normally associated with wetness. The colour pattern of RMF, is due to depletion or concentration of pigments compared to the matrix colour and formed by oxidation/reduction of Fe and/or Mn coupled with their removal, translocation, or accrual; or a

soil matrix colour controlled by the presence of $Fe^{2+}$. RMF are described separately from other mottles, salt concentrations or clay films.

**RMFs include the following:**

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

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

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

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

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

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

**Quantity** (% of area covered)

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

**Size** (Refer size class under mottles or concentrations)

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

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

**Colour -** use the Color chart to describe them

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

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

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

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

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

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

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

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

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

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

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

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

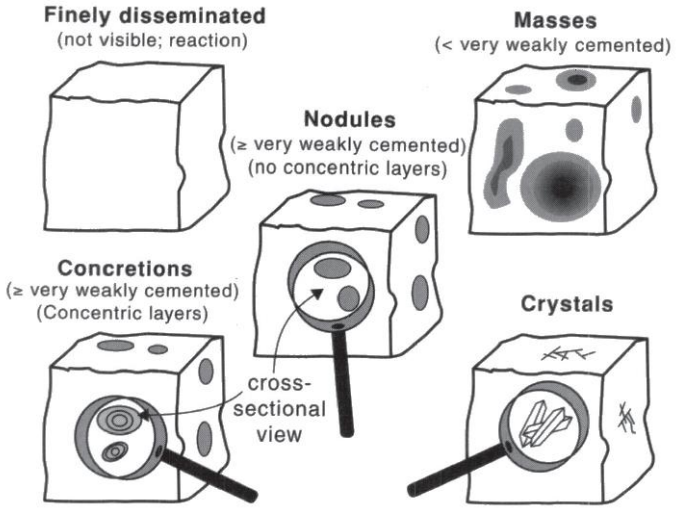
**c. Size** is like the classes used for describing mottles.

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

**e. Colour** chart to describe the colour.

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

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




**Types of concentrations present in soil**

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

**a. Kind -** Includes carbonate coats, clay films, organic stains *etc.*

**b. Amount of ped and void surface features** - Estimate the relative per cent of the visible surface area that a ped surface feature occupies in a horizon

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

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

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

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

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

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

**Size of Roots (and Pores)**

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

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

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

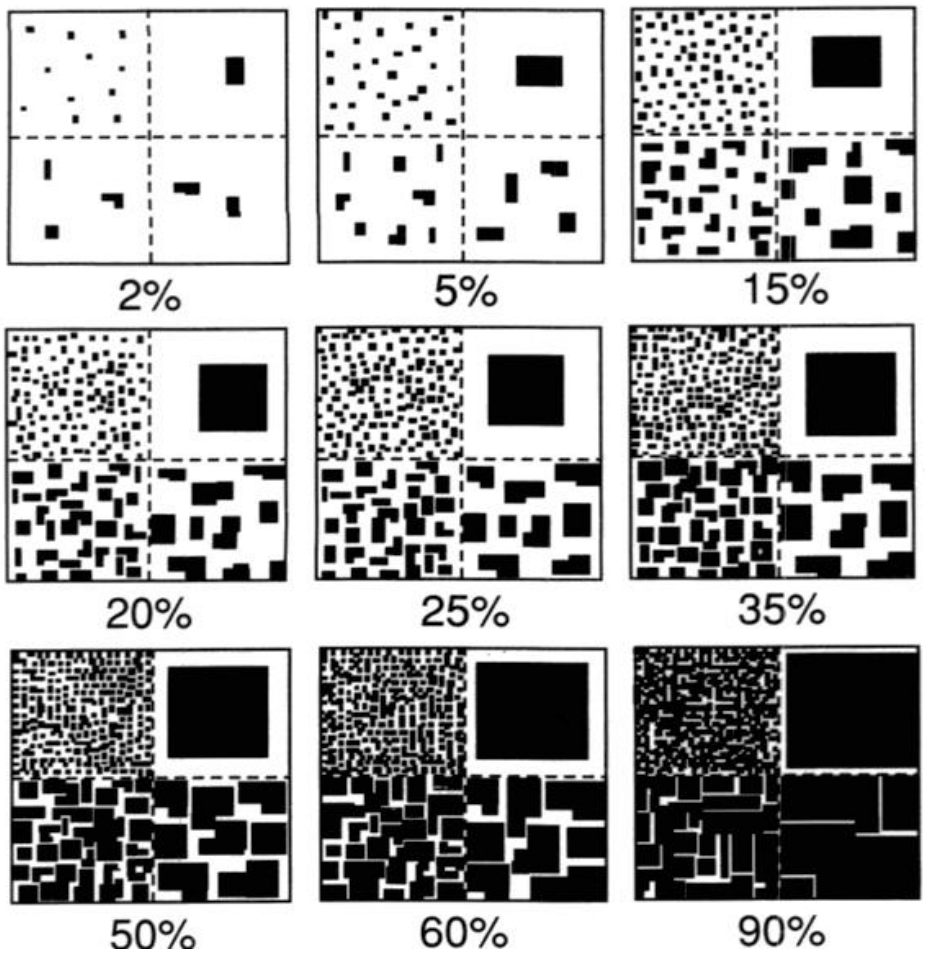
**Soil crusts -** A soil crust is a thin (e.g. <1 cm up to 10 cm thick) surface layer of soil particles bound together by living organisms and / or by minerals into a horizontal mat or small polygonal plates. Soil crusts form at the soil surface and have different physical and /or chemical characteristics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

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

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

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

**For estimation of per cent of area covered in soil**




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

PEDON DESCRIPTION FORM – SITE CHARACTERISTICS

| NBSS & LUP | Agricultural University | Dept. of Agriculture | Author:<br>Date : |
|---|---|---|---|

| Series Name: | Map unit Symbol: | Soil Classification: |
|---|---|---|

| Observation No.: | Topo sheet No.: | Imagery No.: | Base map:<br>Scale: | Cadastral Sheet No.: |
|---|---|---|---|---|

| Location: | Latitude: ° ′ ″<br>Longitude: ° ′ ″ | Plot (Survey) No.: | Village: Block:<br>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 | | | | | | | | | | Erosion | Very slight | Slight | Mod. | Sev. | V. Sev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gradient (%) | 0-1<br>A | 1-3<br>B | 3-5<br>C | 5-10<br>D | 10-15<br>E | 15-25<br>F | 25-33<br>G | >33<br>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 | | Occassional | Frequent | | Very Frequent | | Salt/Alkali (% sur. coverage) | No | | <20 | 20-50 | >50 | | |
| pH | <4.5 | 4.5-5.5 | 5.5-6.5 | 6.5-7.5 | 7.5-8.5 | 8.5-9.5 | >9.5 | E.C. | <2 | 2-4 | 4-8 | 8-15 | 15-25 | 25-50 | >50 |

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

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

| FIELD NOTES | SKETCH |
|---|---|
| | cm |
| | |
| | |
| | |
| | 50 |
| | |
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| | 100 |
| | |
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| | |
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| | 150 |
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| | 200 |

**Notes :**

1

| Observation Method: | | Auger | Minipit | Roadcut |
|---|---|---|---|---|

| | Depth (cm) | Horizon | Bnd [1] D T | Diag. Hori. | Matrix Colour Dry | Matrix Colour Moist | Texture [2] | % clay | Rock Frags [3] Sz Knd Vol | Structure [4] Grade Sz Type | Consistence [5] Dry | Mst | Stk | Pls |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | |
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| | Mottles/ Redox features [6] Qty Sz Cn Col Sp Loc | Coats/Films/Stress Features [7] Amt Dst Cont Kd Loc Col | Concentrations [8] (Conca, Conir, etc.,) Qty Sz Cn Kd Col | Roots [9] Qty Sz Lc | Pores [10] Qty Sz Shp | pH | Effer [11] (dil Hcl)- 1,2,3 | Sample bag No. |
|---|---|---|---|---|---|---|---|---|
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1. **D-Distinctness:** a-abrupt, c-clear, g-gradual, d-diffuse, **T-topography:** s-smooth, w-wavy, i -irregular, b-broken
2. **Texture:** s-sand, ls-loamy sand, sl -sandy loam, l -loam, sil -silt loam, si-silt, scl -sandy clay loam, cl -clay loam, sicl -silty clay loam, sc-sandy clay, sic-silty clay, c-clay.
3. **Size:** fg- fine gravel(<2cm), cg-coarse gravel(2-7.5cm), cb-cobbles(7.5-25cm), st-stones(25-60cm), b-boulders(>60cm).
4. **Grade:** 0-structureless, 1-weak, 2-moderate, 3-strong; **Size:** vf-very fine, f-fine, m-medium, c-coarse, vc-very coarse **Type:** gr-granular, cr-crumb, clr-columnar, pr-prismatic, pl-platy, abk-angular blocky, sbk-subangular blocky, sg-single grain, m-massive, c-cloddy.
5. **Dry:** l-loose, s-soft, sh-slightly hard, h-hard, vh-very hard, eh-extremely hard, **Moist:** l-loose, vfr-very friable, fr-friable, fi-firm, vfi-very firm, efi-extremely firm, **Stickyness:** so-non-sticky, ss-slightly sticky, ms-moderately sticky, vs-very sticky, **Plasticity:** po-non-plastic, sp-slightly plastic, mp-moderately plastic, vp-very plastic.
6. **Quantity(qty):** f-few(<2%), c-common(2-20%), m-many(>20%); **Size(sz):** 1-fine(<2mm), 2-medium(2-<5mm), 3-coarse (5-<20mm), 4-very coarse(>20mm); **Contrast(cn):** f-faint, d-distinct, p-prominent ; **Colour(col); Shape(sp):** c-cylindrical, d-dendritic, i-irregular, p-platy, s-spherical, t-threads, r-reticulate; **Location(Loc)**-matrix/ped/pores/others.
7. **Amount(Amt):** vf-very few(<5%), f-few(5-<25%), c-common(25-<50%), m-many(50-<90%), vm-very many(>90%);**Distinctness(Dst):** f-faint, d-distinct, p-prominent; **Continuity(Cont):** c-continuous, d-discontinuous, p-patchy; **Kind(Kd):** Type of coating/stress features; **Location(Loc)**: on bottom/top or all faces of peds; **Colour(Col)**: Munsell
8. **Concentrations:** Quantity(qty), Size(sz), Contrast(cn) and Colour are to be described similar to that of the mottles; **Kind(Kd)**: Disseminated materials, Masses, Nodules, Concretions, Crystals and Biological concentrations.

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

**Soil series 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 |

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

# 3. LRI atlas- understanding and interpretation of maps for watershed planning

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.

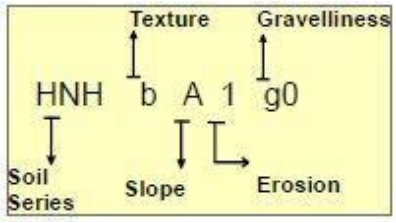
**9. Location of wells map:** The total number of wells (open wells and bore wells) existing in the particular watershed area will be indicated in the maps along with their location.

**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 about LRI atlas, refer the soft copy of the LRI atlas loaded in the pen drive supplied as part of training kit.**

## 4. An overview of hydrological assessment for watershed planning

**Hydrological monitoring & assessment:**

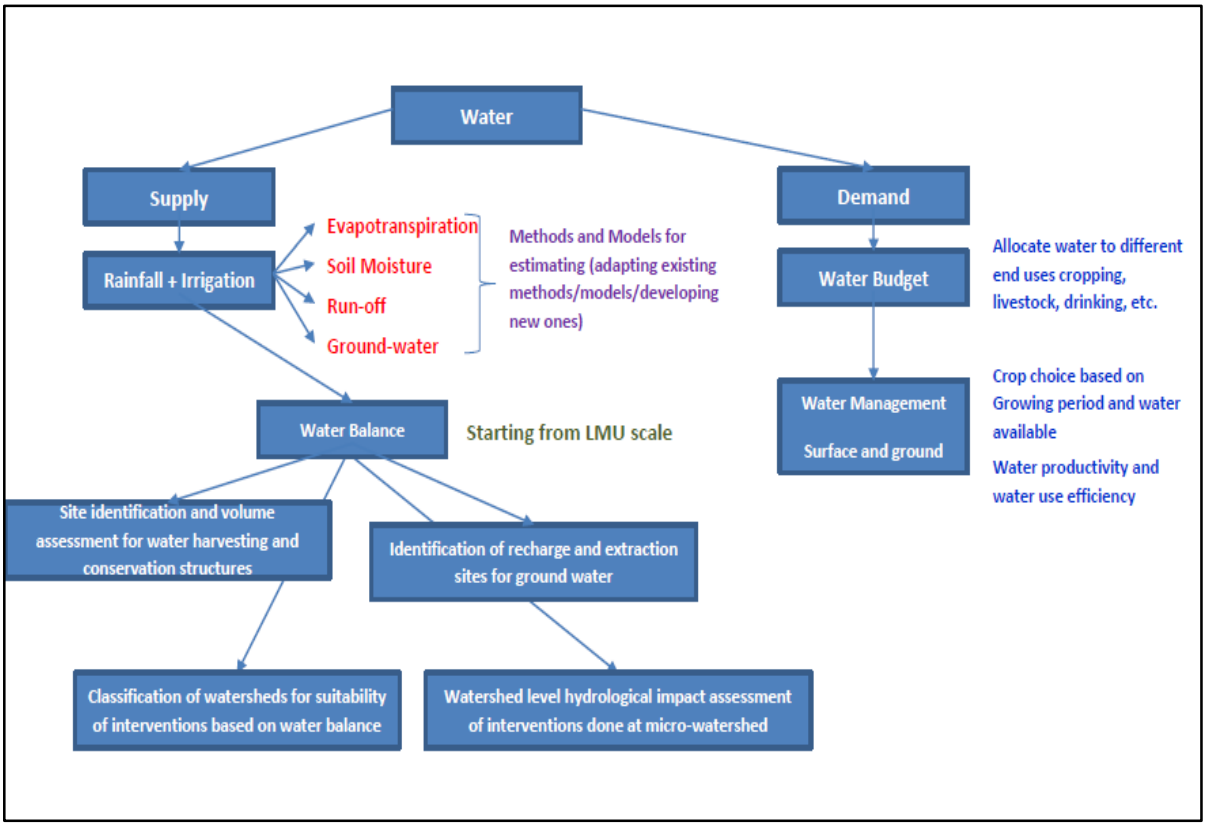
The objective is that hydrological monitoring aided by advanced data & innovative models that will be used under this project will aid in producing hydrological budget at relatively higher temporal frequency (e.g. weekly/monthly) and also at the desired spatial granularity in the micro watersheds, for improved sustainable water management.

The focus is to

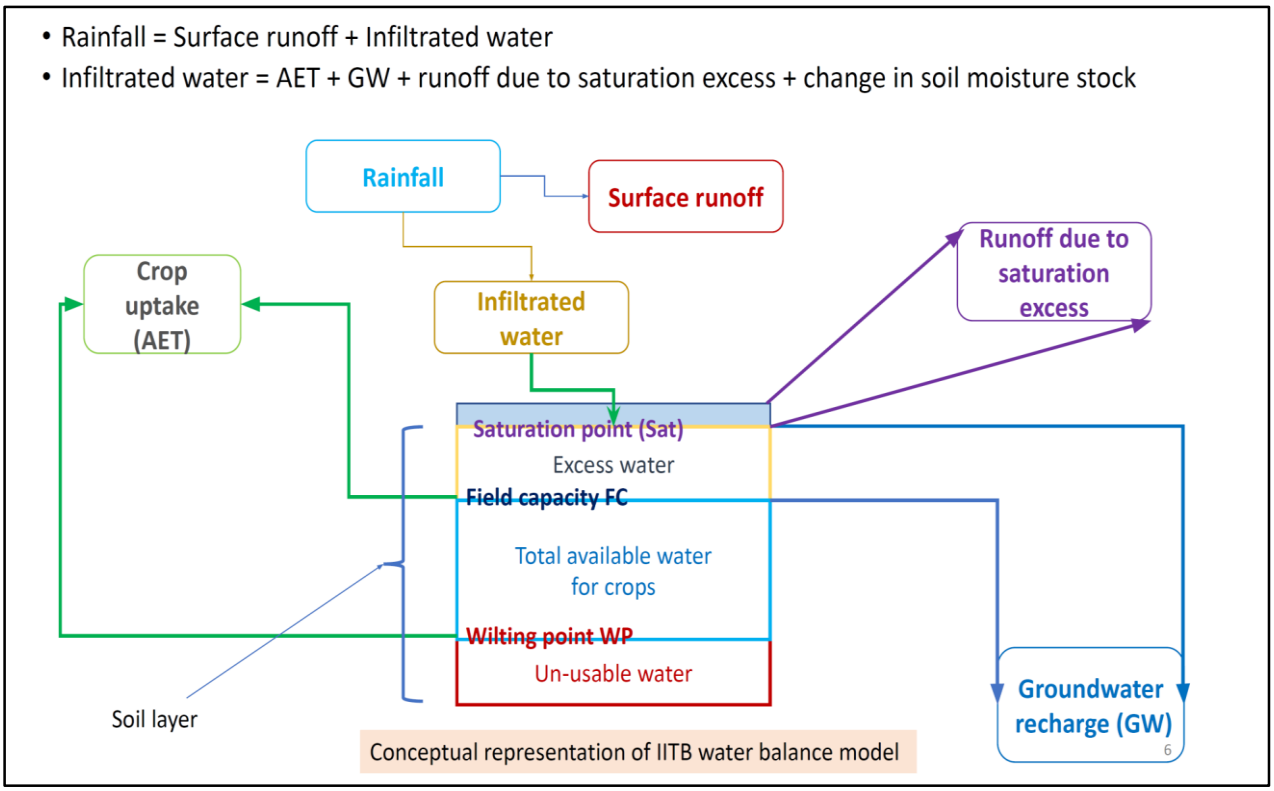
(i) assess the sustainability of the project watersheds for future climate; and

(ii) estimate water budget in the watersheds to facilitate improved design of soil & water conservation measures.

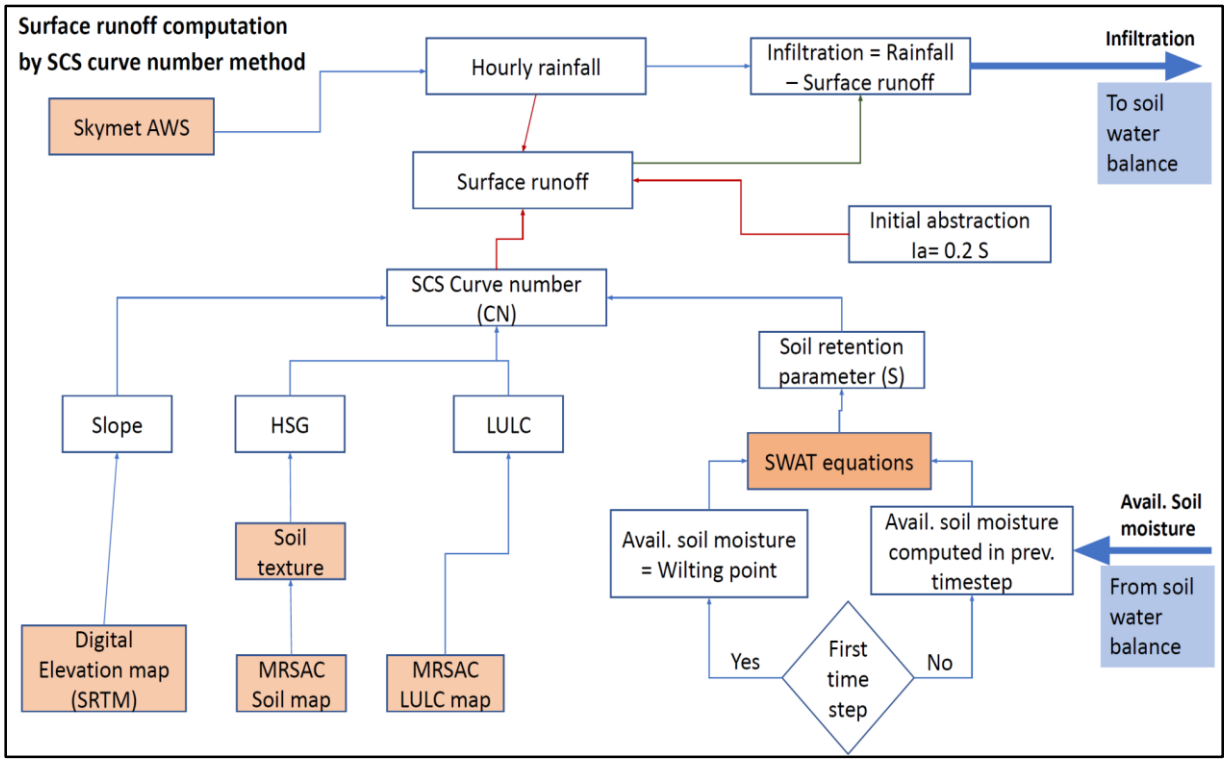
The additional objective is to integrate the hydrological variables with the land resource inventory mapping for developing robust integrated watershed management plans.




**Hydrology in REWARD**




**Conceptual representation of water balance model**




**Surface runoff computation: SCS curve number method**

# 5. Approaches in hydrological assessments

**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 processesand 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 condition s, 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 andyield, water quality surface and groundwater, and canopy variables (LAI, biomass, crop yield, cropmanagement 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 atmosphereinterface. The evaporation is controlled directly by the surface soil moisture; the transpiration is controlled by the soil moisture present in the root zone. The precipitation passes through surface soil moisture to reach the root zone. Hence, surface soil moisture could be able to provide some insight into the root zone soil moisture. This means that surface soil moisture may be a useful variable to predict the hydrological cycle over land. Apart from hydrology, it is also useful in various other applications e.g., agronomy, drought management and in the improvement of disaggregation/downscaling of precipitation *etc*.

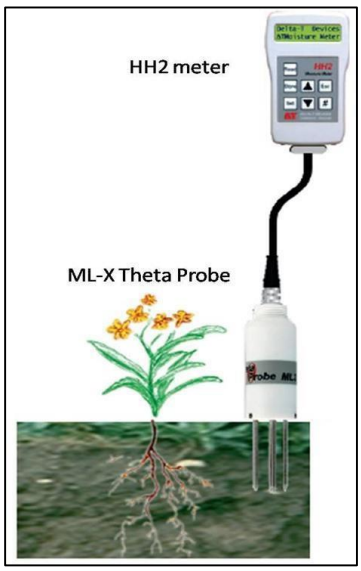
**Surface soil moisture:**
Currently, surface soil moisture is assessed for the following three main reasons:

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

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

**Volumetric soil moisture measurement (Theta Probe):**
Surface soil moisture is measured using ML2x theta probe (Delta-T devices, Delta-T Devices Ltd,Cambridge, UK), which measures soil moisture averaged over 0 to 5 cm depth and equipped with a HH2 meter for spot measurements and display. Accuracy of measurements is ± 1 %. 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 reducesthe 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 therods is used by Theta Probe to measure the apparent dielectric constant of the soil. A linear correlation exists between the square root of the dielectric constant, (Ve), and volumetric moisturecontent, (0), which is used to convert the measured dielectric constant to soil moisture.




**Theta probe and HH2 meter (Delta T Devices)**

**Steps to be employed for the measurement:**

- ✓ The theta probe needles should be inserted (penetrated) fully into the soil vertically. Takecare while inserting the probe in stony soils as it may damage the needle. In such cases ifit 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 atthe 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 wherethe 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 affectthe 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 croptype.

**Soil moisture profile**

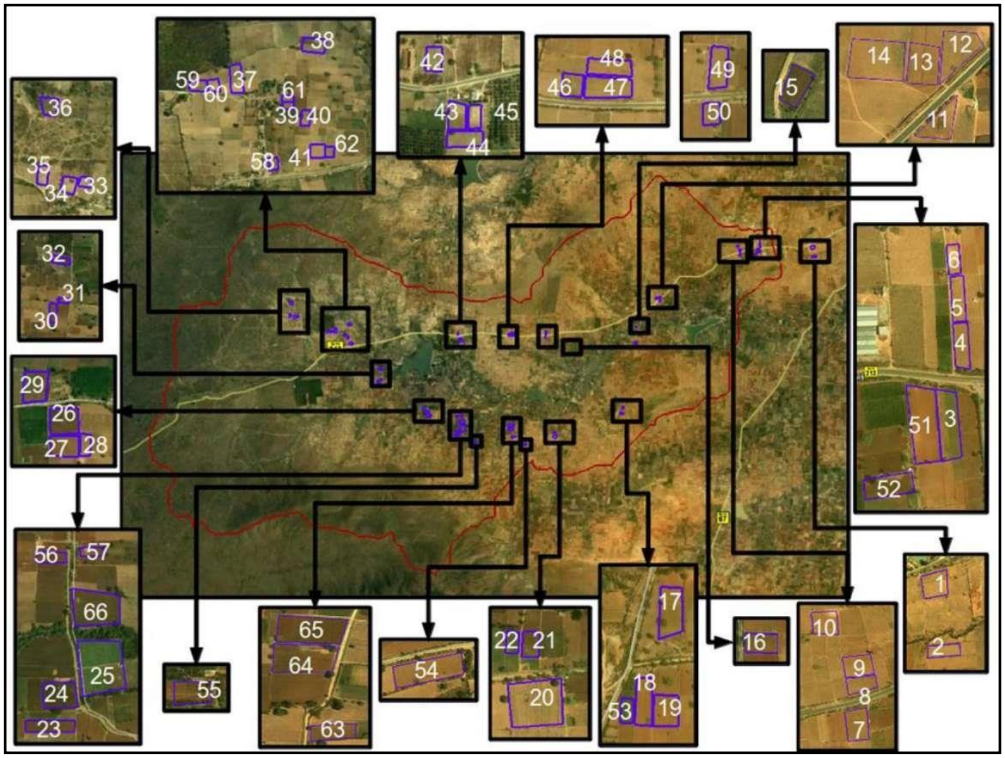
The procedure for profile soil moisture measurements, the instruments used and their operating principle, calibration techniques are discussed below. Profile soil moisture are being monitored/measured either continuously or intermittently at regular frequency in a watershed for cropped and uncropped 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. Thevolumetric 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 moisturemeasuring range from 0 to 60 % (volumetric water content) and an accuracy of ±2%. Measuring volume: The effective penetration depth of the probe T3 is about 15 cm with the highest sensitivity in the immediate vicinity of the access tube, and decreases exponentially as distance increases.




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

**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 canbe 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 fewtimes 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 itto 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 ofthe 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:**

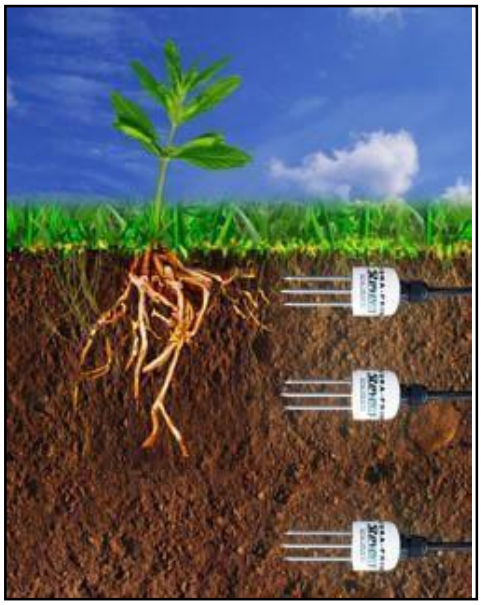
- ✓ Open the cap of the access tube and insert the sensor slowly into the tube till the sensor is fully below the ground level. Note down the reading from the data logger.
- ✓ Now slowly push the sensor further down to the required depth (depth is marked in the cablewith a white tape) and continue taking 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 suchcases 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 loggerwith 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 back to the unit by thesoil, 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 whichin turn is used to accurately estimate soil water content.



**Schematic of HYDRA Probe Soil Moisture Sensor**

**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 inthe 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 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 inthe trench

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

**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.

**For more details, refer the soft copy of the hydrology manual loaded in the pen drive supplied as part of training kit.**

# 6. Water budgeting, water balance and preparation of hydrology atlas for a sub watershed

**Preparation of hydrologic atlas:**

Integrated Hydrological Assessment & Monitoring involves hydrological data gathering, behavior mapping & processes understanding at micro-watersheds scale. The objective is that the hydrological monitoring aided by advanced hydrological data & customized models developed in the process will aid in producing hydrological budgets at relatively higher temporal frequency (e.g., weekly/monthly) and also 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 a number of 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 micro-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 the annual series.

**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.

**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.

**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,

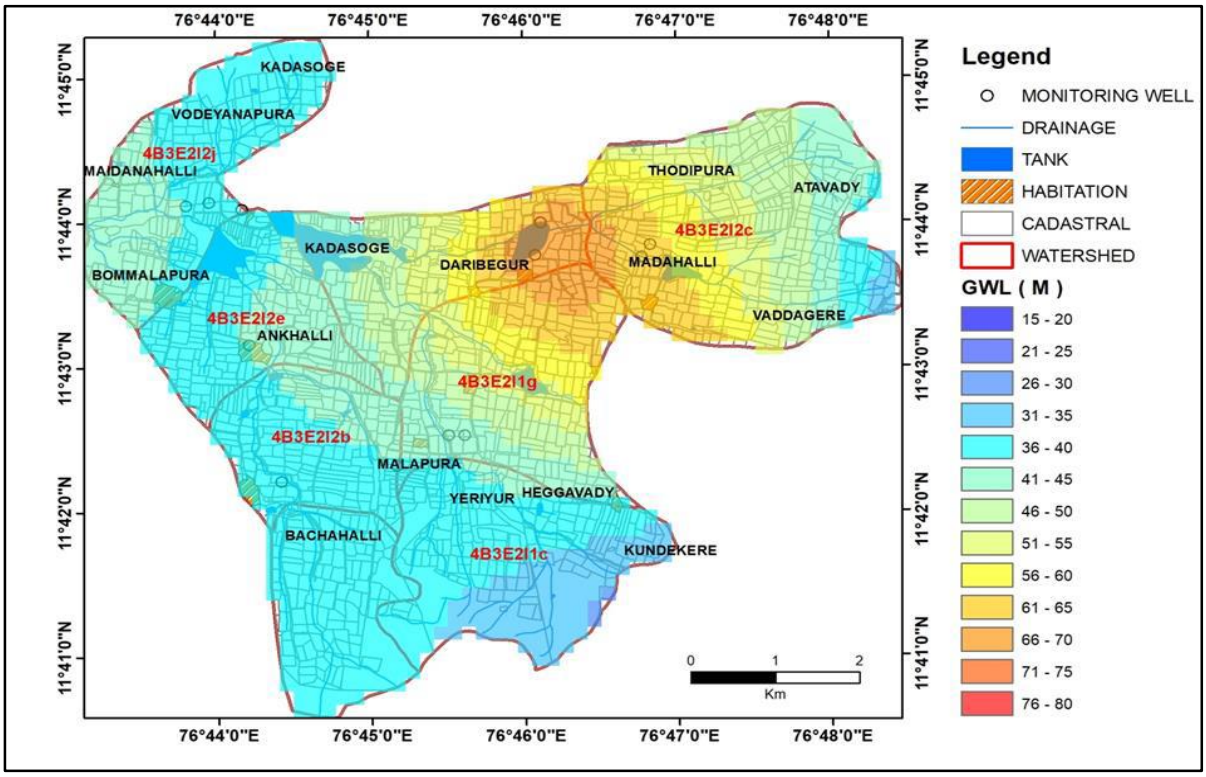
$$P=Q+AET+R+S$$

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.

**Spatial distribution of depth to groundwater:**

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

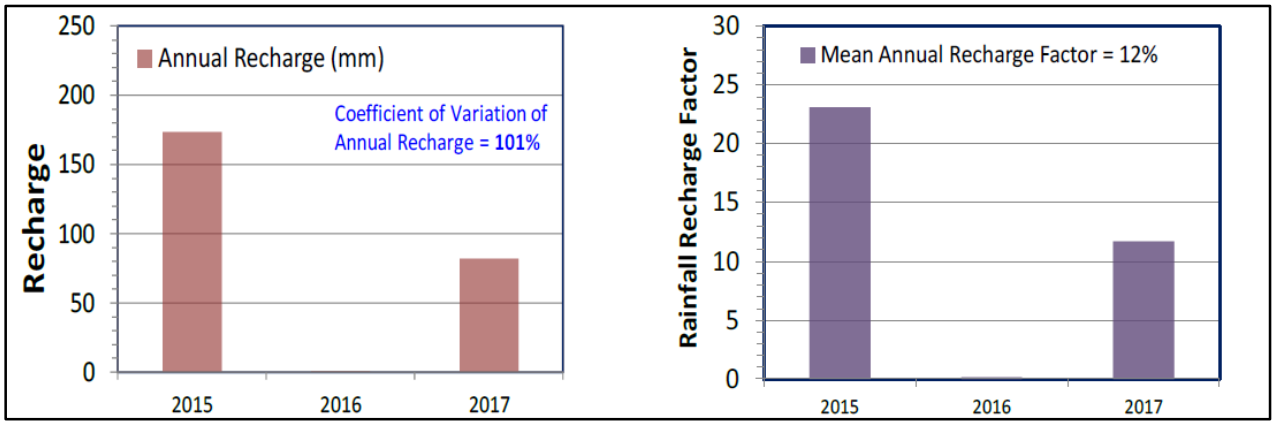
- Inverse Distance Weighted (IDW) Approach: In IDW, the value at an unknown point is estimated by giving weights proportional to the inverse of the distance (between the known locations and the unknown location) raised to the power value $p$. Typically, a value of $p$=2 is used; however, care should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




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

**Ground water recharge:**

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




**Sample plot showing annual recharge and mean annual recharge factor 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.

**Water quality maps:**

Prepare the map of groundwater quality parameters following the IDW or Kriging method of interpolation.

**Depiction of 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:**

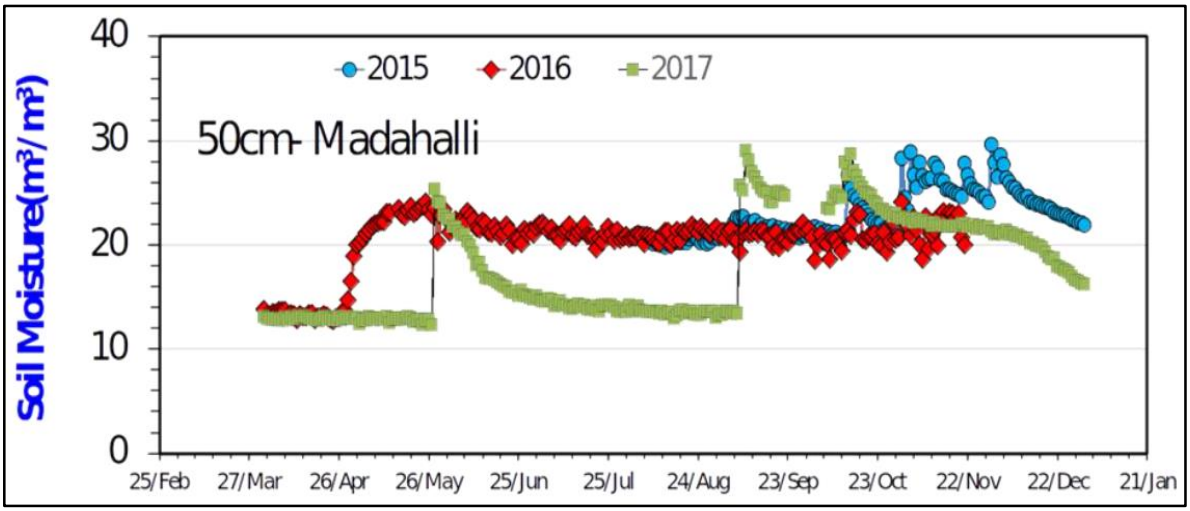
These maps are prepared using satellite remote sensing products. The following facts are to be noted:

- 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.

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.



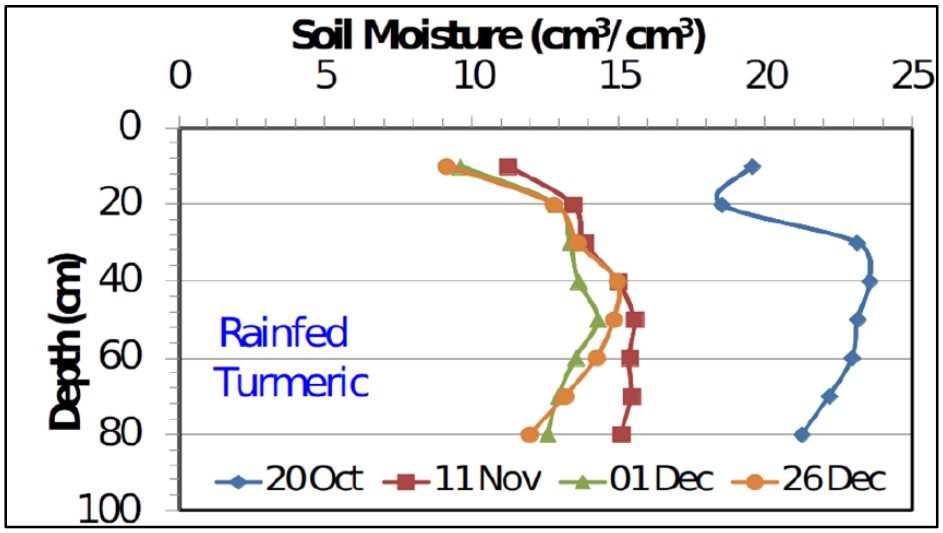

**Root zone soil moisture time series plot at the particular location in the study watershed**

**Depiction of 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 10 cm, up to the depth of 80 cm.

A sample soil profile plot is shown below.




**Sample profile soil moisture plot**

**For more details, refer the soft copy of the hydrology atlas loaded in the pen drive supplied as part of training kit.**

# 7. An over view of decision support systems developed under Sujala-3 project and their application for selection of site specific appropriate measures

A Key component of Sujala-3 Project is the development of Decision Support System (DSS) along with LRI Digital Library, LRI Portal and Mobile Application for real time dissemination of LRI information and advisories to the farmers, line departments, research institutions and other stakeholders in the state. A DSS is a computerized expert interactive information system developed and integrated in a Geographic Information System environment (GIS) to support decision-making in a particular field or domain. The development of DSS for watershed development/natural resource management depends on the availability of spatial and non-spatial information, like data on soil, water, land use, hydrology, demography, climate, base maps, remote sensing data, and other resource information and models, algorithms and rules that can help to infer the outcome.

The objectives of developing DSS

- To facilitate the project management in planning, execution and monitoring of various watershed development and other programs in the state
- To integrate Land Resource Inventory, Hydrology, and other database with GIS, MIS and other systems for easy retrieval of information and visualization.
- To support dynamic use of MIS and GIS, monitoring and evaluation, seamless integration of online and offline activities, and dynamic updating of the information.
- To facilitate the convergence of various programs implemented by Watershed, Agriculture, Horticulture, Forestry, Animal Husbandry, Rural Development and other line departments at the watershed/village level in the state.
- To develop criteria, algorithms and models, knowledge base and expert systems needed to help the decision makers to access relevant information from a combination of raw data, documents, and personal knowledge, or models to identify and solve problems and make appropriate decisions as and when needed.

The Decision Support System is developed primarily to serve the needs of planning, implementation and monitoring of watershed development programs in the state by Watershed Development Department, Departments of Horticulture, Agriculture, Animal Husbandry, and other line departments, LRI project partners, and other stakeholders. The DSS development is based on the integration of data generated by LRI partners and compiled from other sources (Annexure 1) with criteria, models and algorithms already available or developed under this project. It is critical for the successful implementation of various watershed programs, other line department schemes and for empowering farmers and other stakeholders in the state. As a part of Sujala-3 Project, nine Decision Support Systems are developed in the first phase to facilitate the departments to take up key interventions and to provide advisories to the farmers and other stakeholders at the grassroots level as indicated below.

**DSS modules developed as part of Sujala-3 project**

| *Sl. No.* | *Decision Support System* |
|---|---|
| **Group 1** (Soil & Water conservation plan, Crop selection, Land Capability Classification and Nutrient management) | |
| 1 | DSS for **Soil & water conservation plan**-to identify the type of structures, their design and estimate, for both arable and non-arable lands/areas |
| 2 | DSS for **Crop selection** (Based on physical suitability and cost benefit ratio) |
| 3 | DSS for delineating prime farmlands/arable and non-arable lands based on **Land Capability Classification** |
| 4 | DSS on crop based **Nutrient management** and **soil health** |
| **Group 2** (Surface Runoff, Size and location of Farm Ponds and Check Dams, Crop water requirement, Soil Water balance and Water budgeting) | |
| 5 | DSS for estimating **Surface runoff** at farm/MWS/SWS levels |
| 6 | DSS for designing the **Size and location of Farm ponds and Check dams** based on runoff model |
| 7 | DSS for estimating the **Crop water requirement** at MWS/SWS levels based on the existing land use or crops that are planned to be taken up for cultivation |
| 8 | DSS for estimating **Soil water balance** at MWS or higher levels, considering the RF, crop requirement, Runoff, evaporation and other losses, soil moisture and ground water. |
| 9 | DSS for **Water budgeting** taking into consideration the needs of various uses/users at MWS/ Village level- crop needs, human needs, livestock needs etc. |

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 generated through Land Resource Inventorisation and available to the users in the form of LRI and Hydrology Reports and Atlases. 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. 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.

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 crop suitability assessment helps the planner to prepare a matrix of suitable and not suitable crops for a given area and the farmer to choose the best suited crop for the farm.

The DSS on **Nutrient management** enables the farmer to choose the type, quantity and time of application of fertilisers to the selected crop under cultivation based on the nutrient status of the soil and the planner to identify the extent of deficient/sufficient areas for taking up

appropriate interventions. 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.

The DSS on Land Capability, Runoff, Farm Ponds and Check Dams, Crop water requirement, Soil moisture and water balance and Water budgeting facilitate the departments to take up key interventions and to provide advisories to the farmers and other stakeholders at different levels.

The development of the nine Decision Support Systems was based on the criteria, type of models, algorithms and state of knowledge available at present in the respective domains. The output from the model/DSS may or may not reflect the existing field situations due to various reasons. Hence the outputs generated by using the DSS needs to be verified/validated in the field and recalibrated/modified wherever necessary with inputs/feedbacks received from the stakeholders before they are finally deployed in the Portal.

**For more details, refer the soft copy of the DSS book loaded in the pen drive supplied as part of training kit.**

# 8. Preparation of smart/ table top DPR by integrating LRI and hydrology outputs with decision support systems

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

**Pre-requisites for DPR preparation:**

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

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

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

**Phases involved in preparation of DPR:**

The phases involved in the process of DPR preparation under REWARD are (a) pre- planning activities in the field, (b) DPR generation in the office, (c) community consultation and

validation in the field and (d) compilation and approval of DPR. In each phase, several steps are involved and are detailed in the following paragraphs.

*Phase-1: Pre- planning activities in the field (4 weeks)*

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

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

*Phase-2: DPR generation in the office (4 weeks)*

1. Prepare survey number wise conservation plan: Refer draft conservation plan map generated by LRI partners, link the same with the farmer's details obtained from Bhoomi, software developed and available in the GoK website along with cost details

   (In case of non-availability of conservation plan in the portal, select conservation measures manually based on decision criteria LMU wise and then Survey No wise)
2. Prepare drainage line treatment, water harvesting structures, and other interventions needed like common land treatment, waste land treatment reclamation *etc*. based on the inputs provided in the LRI atlas, reports and digital library

(Select water harvesting structures based on decision criteria, water budgeting and water balance manually if the plan is not available in the portal)

3. Preparation of survey number wise crop plan by using the crop suitability maps generated for the area and linking the same with farmer's details
4. Include the package of practices to be followed during the entire duration of the crop selected (Decision criteria for selection of crops and nutrient management based on LRI output)
5. Similarly, prepare tentative plan for suitable horticultural crops, forestry, sericulture, animal husbandry and other interventions for the watershed area
6. Draft DPR generation - consolidation of all activities for a MWS and consolidated for SW

*Phase-3: Community consultation & validation (4 Weeks)*

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

*Phase-4: Compilation and approval of SWS DPR (4 Weeks)*

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

**LRI output required for DPR preparation:**

The final output of land resource inventory will be recorded in the form of atlas and report which can be used for DPR preparation. 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, climate, water, vegetation, crops and cropping patterns, socio-economic conditions, marketing facilities *etc.,*

helps in identifying soil and water conservation measures required, suitability of crops and other usesand finally for preparing viable and sustainable land use options for each and every land parcel. For detailed information about atlas, unit 3 can be referred.

**Hydrology output required for DPR preparation:**

Integrated hydrological assessment & monitoring component as a part of erstwhile Sujala-3 and present REWARD projects aims at detailed investigation involving hydro-geomorphological data inventory, documentation of responses in terms of mapping & carrying out of analytical processes for understanding of interrelations among the components of hydrological balance pertaining to representative pilot micro-watersheds (20 No. out of which 09 No. under the process of establishment) and that of operational sub watersheds in 18 Semi-Arid and water stressed Districts of Karnataka State. The objective of hydrological monitoring aided by advanced hydrological data & customized models developed under this project will aid in interpreting hydrological balance and budgets using relatively higher temporal frequency (15 min/ daily/ monthly/ seasonal/ annual) and also at the desired spatial granularity (soil phase unit) in micro watersheds towards improved and sustainable water management. The focus is also to assess the sustainable groundwater draft under prevailing geological and land use conditions and groundwater level changes & water yields in hard rock aquifers of the selected watersheds. 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 at sub watershed scale for developing decision support the rainfall-runoff relations, soil moisture status, relations among PET, AET and rainfall. The details of hydrological inventory, analysis and documentation are given as data products pertaining to both model micro watersheds and to Sub watersheds under Part B of the respective atlases

**Data products of hydrological atlas:**

The data products are developed and attributed under the category of a) rainfall pattern b) runoff pattern c) available soil moisture d) ground water status f) water balance components g) and summary and interpretation of the data products.

The location in terms of latitude, longitude and respective geopolitical location, micro watersheds with their code, types of soil texture inventorised, crops grown and scale of the spatial data used are mentioned in the introduction. The location down the line from state to the sub watersheds has been shown pictorially. The rainfall index derived for annual, *Kharif, Rabi a*nd *Summer* rainfall depths recorded and analysed for the period of available length of period (2010-2018). The rainfall data with temporal interval of 15 min accrued to for the length of period of annual (Jan – Dec), *Kharif* (June – October), *Rabi* (Nov – Feb) and *Summer* (March – May). The respective period of rainfall depths is represented and compared with “average rainfall of the period of assessment” and “long term average of the station” attributable to the sub watershed under the question. The relevant rain gauge station and relevant 15 min interval rainfall of the years of consideration are identified and shortlisted following suitable procedure. The comparison of the rainfall depth in given period has compared with respect to averages. In case of model micro watersheds, the data measured through automatic weather station established in the micro watershed has been used.

The runoff has been estimated through the distributed model which uses hydrologic as the difference rainfall intensity and infiltration rate of each soil phase unit. The infiltration rate of the soil phase has been derived from measurement using double ring infiltrometer. The potential runoff as the difference of the average intensity of individual rainfall event and infiltration rate expressed as depth (mm) highlights the instantaneous runoff generated. The potential runoff is assumed to be subjected to deduction due to runoff depth absorbed across the intermediatory "bunds" built within soil phase using the concept of runoff interrupted within "water spread area" received from its own "contributing area". The difference of runoff depth between "potential runoff" and "absorbed across water spread area of each bund" of specific length and orientation is referred as "runoff excess". The details are worked on excel sheet format and transferred as map representation using GIS platform. The efforts are being done to execute the model on spatial mode on GIS platform. In case of model micro watersheds, the measured runoff data has been used for comparison with that of estimated quantity.

The micro wave remote sensing has been used to estimate the surface soil moisture using appropriate algorithm only after vetting with measured surface soil moisture across the identified model watersheds discretely established across the Karnataka State. The typical variability soil moisture (vol/vol) curve over the requisite time period (2015-2018) has been given in the atlas. The annual quantity of Potential Evapotranspiration (PET, mm) and Actual Evapotranspiration (AET, mm) has been worked out and ratios of AET/ P and PET/P where P is annual rainfall quantity (mm). The comparison between graphical point derived from aforesaid AET/P (evaporative index) and PET/P (dryness index) ratios *vis* a *vis* Budyko curve is used to identify the usage of water as restricted within and out of receivable rainfall (below the curve) during period of observation (2014-2018) or inferring as excessive water usage beyond receivable rainfall (above the curve). The methodology helps to assess the quantity of evapotranspiration (mm) realised a) only within the rainfall quantity available b) or external source in the form of bore well/ open well/ tanks/ ponds are put to use as additional source (irrigation) to save the crop from the abiotic stress.

The ground water status has been analysed through using the fluctuations (given length of period) of identified bore well that fairly representing the sub watershed. The graphical representation of the fluctuations emphasise ground water variability and inferences are drawn based on the data analytics. In case of model micro watersheds, the status has been derived from the data that being monitored in the representing well(s). The ground water rechargeable quantity has been estimated in case of model watershed.

The water balance sheet summarises the accountability of input as rainfall and its distribution among other components as runoff, ground water, soil moisture and evapotranspiration. The water balance and distribution of components on annual basis has been worked out for year with maximum rainfall and the year near to median rainfall. The runoff quantity thus estimated also givens some degree of understanding about "runoff availability (excess)" due to "existing topographic manipulations" and with "proposed topographic manipulations". The balance sheet earmarks component of "environmental flow" as 20 per cent of "runoff availability (excess)" for the purpose of harvesting (80% of the runoff availability as excess).

## Decision criteria for selection of water harvesting structures based on hydrology output; water budgeting and water balance

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).

**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

**Table 1: Calculating cost of Farm Ponds based on cubic meter rate (Amount in Rs./$m^3$)**

| *South Zone* | | *North Zone* | | *North Zone (Shimoga & Chithradurga)* | | *North East Zone* | |
|---|---|---|---|---|---|---|---|
| *Clayey/ black soil* | *Loamy /red soil* | *Clayey/ black soil* | *Loamy/red soil* | *Clayey/ black soil* | *Loamy /red soil* | *Clayey/ black soil* | *Loamy/ red soil* |
| **172** | **164** | **186** | **179** | **173** | **164** | **183** | **206** |
| **Districts** | | **Districts** | | **Districts** | | **Districts** | |
| Kodagu | | Dharwad | | Shimoga | | Bellary | |
| Udupi | | Gadag | | Chithradurga | | Raichur | |
| South Canara | | Haveri | | | | Koppal | |
| Hassan | | Belagavi | | | | Kalburgi | |
| Chikkamagalore | | Uttara Kannada | | | | Yadgir | |

| | | | |
|---|---|---|---|
| Mysore | Bijapur | | Bidar |
| Mandya | Bagalakote | | |
| Chamarajanagara | Davanagere | | |
| Ramanagaram | | | |
| Tumkur | | | |
| Chikkaballapur | | | |
| Bangalore (Urban) | | | |
| Bangalore (Rural) | | | |
| Kolar | | | |
| 1) Without smoothening of segments<br>2) Costing as per WDD schedule of rate- 2018-19 | | | |

**The application decides the farm pond size based on following steps**

Slide Slope Consideration:

For Black Soil: 1.5:1

For Red Soil: 1:1

Depth needs to be considered as 3 m.

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

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

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

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

Top Area = Top Width * Top Length

Since its square Top width = Top Length

Bottom Area = Bottom Width * Bottom Length

Since its square Bottom width = bottom Length

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

Example:

Depth of Farm Pond : 3 m

70% Surface Runoff : 1500 $m^3$

Soil Type : Black Soil, Slide Slope consider as 1.5:1

Top Width = √ (1500/3) + 4.5 = 26.8608 (Round off the Top width to = 27 m)

Top Area = Top Width X Top Length = 27 * 27 = 729 $m^2$

Bottom Width = √ (1500/3) - 4.5 = 17.8608 (Round off the Bottom width to = 18 m)

Bottom Area = Bottom Width X Bottom Length = 18 * 18 = 324 $m^2$

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

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

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

- Further, the application will check for the Storage Capacity ($m^3$) by considering the 70% Runoff for the purpose of harvesting (from DSS 5.2 – Infiltration method)
- Depending on the standard rates of farm pond construction, cost of construction (rupees) is estimated
- Total Surface runoff (mm/year) is displayed in the final output table along with the farm pond size and the cost of construction. Display the Farm owner details based on the data f*etc*hed 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 o**f the Runoff from the Total runoff towards Environmental flow. (Out of estimated runoff average **70 per cent** of water to be targeted for harvesting within watershed boundary and rest amount to be allowed to flow at downstream location such that it will not significantly affect riverine ecosystem)
2. If net runoff (available for storage) is sufficient (Minimum of **850 $m^3$)** Check dam can be proposed at the point where quantity of runoff is sufficient for Check dam. It can be in 1st, 2nd, or 3rd order stream or if the runoff is not enough at any point in the Micro watershed, then there is no need to construct a Check dam & runoff can be allowed to run into the stream. (Option should be given to enter the Storage Capacity of the Check Dam anything greater than 850),

   Number of Check Dams = Net Runoff / Minimum Storage

3. Based on the quantity of Net runoff available, number and storage capacity of the Check Dam, cost of the structure is decided based on the cost for per Cum (Approximately, South Zone Rs. 502/-, North Zone Rs. 464/-, North East Zone Rs.601/-) as per the prevailing rates in the districts
4. Type of the check dam is decided based on the shape of the nala banks as per ground truth or with the help of DEM data wherever available & availability of the stones nearby
5. Design of Check dam [Impounding height(h), Spillage/depth of flow over the crest(d) and free board depth(f)], type of the check dam and its components are decided based on the spot selected after Field survey/verification

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

**Table 2: Criteria for deciding crest height and cost of check dam**

| *Sl. No.* | *Storage capacity ($m^3$)* | *Cost (Rs.)* | *Check dam-apron type* | *Catchment area (ha)* | *Gully depth (m)* | *Crest height (h) (m)* |
|---|---|---|---|---|---|---|
| 1 | 859 | 342328 | Sloping Apron Type | 25 | 2.4 | 1.25 |
| 2 | 859 | 302989 | Solid Apron type | 25 | 2.3 | 1.25 |
| 3 | 703 | 227782 | Stilling basin type | 25 | 2.5 | 1.25 |
| 4 | 859 | 397132 | Sloping Apron Type | 50 | 2.6 | 1.25 |
| 5 | 859 | 336306 | Solid Apron type | 50 | 2.4 | 1.25 |
| 6 | 859 | 426703 | Sloping Apron Type | 75 | 2.7 | 1.25 |
| 7 | 859 | 378050 | Solid Apron type | 75 | 2.5 | 1.25 |
| 8 | 703 | 293227 | Stilling basin type | 75 | 2.8 | 1.25 |
| 9 | 859 | 464677 | Sloping Apron Type | 100 | 2.8 | 1.25 |
| 10 | 859 | 417877 | Solid Apron type | 100 | 2.6 | 1.25 |
| 11 | 703 | 316668 | Stilling basin type | 100 | 2.9 | 1.25 |
| 12 | 859 | 497115 | Sloping Apron Type | 125 | 2.9 | 1.25 |
| 13 | 859 | 460812 | Solid Apron type | 125 | 2.7 | 1.25 |
| 14 | 703 | 341135 | Stilling basin type | 125 | 2.9 | 1.25 |
| 15 | 859 | 538132 | Sloping Apron Type | 150 | 3 | 1.25 |
| 16 | 859 | 507143 | Solid Apron type | 150 | 2.8 | 1.25 |
| 17 | 703 | 373284 | Stilling basin type | 150 | 3 | 1.25 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 18 | 859 | 580771 | Sloping Apron Type | 175 | 3.1 | 1.25 |
| 19 | 859 | 507143 | Solid Apron type | 175 | 2.8 | 1.25 |
| 20 | 703 | 399675 | Stilling basin type | 175 | 3.1 | 1.25 |
| 21 | 859 | 580771 | Sloping Apron Type | 200 | 3.2 | 1.25 |
| 22 | 859 | 562328 | Solid Apron type | 200 | 2.9 | 1.25 |
| 23 | 703 | 434107 | Stilling basin type | 200 | 3.2 | 1.25 |
| 24 | 1088 | 449349 | Sloping Apron Type | 25 | 2.6 | 1.50 |
| 25 | 1088 | 399529 | Solid Apron type | 25 | 2.6 | 1.50 |
| 26 | 863 | 264090 | Stilling basin type | 25 | 2.7 | 1.50 |
| 27 | 1088 | 513982 | Sloping Apron Type | 50 | 2.8 | 1.50 |
| 28 | 1088 | 440895 | Solid Apron type | 50 | 2.7 | 1.50 |
| 29 | 863 | 287183 | Stilling basin type | 50 | 2.8 | 1.50 |
| 30 | 1088 | 548469 | Sloping Apron Type | 75 | 2.9 | 1.50 |
| 31 | 1088 | 462223 | Solid Apron type | 75 | 2.8 | 1.50 |
| 32 | 863 | 336222 | Stilling basin type | 75 | 3 | 1.50 |
| 33 | 1088 | 592776 | Sloping Apron Type | 100 | 3 | 1.50 |
| 34 | 1088 | 520044 | Solid Apron type | 100 | 2.9 | 1.50 |
| 35 | 863 | 362125 | Stilling basin type | 100 | 3.1 | 1.50 |
| 36 | 1088 | 629983 | Sloping Apron Type | 125 | 3.1 | 1.50 |
| 37 | 1088 | 520044 | Solid Apron type | 125 | 2.9 | 1.50 |
| 38 | 863 | 389018 | Stilling basin type | 125 | 3.2 | 1.50 |
| 39 | 1088 | 629983 | Sloping Apron Type | 150 | 3.1 | 1.50 |
| 40 | 1088 | 582070 | Solid Apron type | 150 | 3 | 1.50 |
| 41 | 863 | 389018 | Stilling basin type | 150 | 3.2 | 1.50 |
| 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 |

| | |
|---|---|
| | **Note**: 1. Gully bed width considered is 5m.<br>2. Gully bed slope considered is 1%<br>3. Cost is as per WDD SOR: 2018-19 - South Zone (PWP&ILWTD) |

**Table 3: Type of check dam**

| *Shape of nala banks* | *Stone availability* | *Nala bed condition* | *Type of check dam* |
|---|---|---|---|
| 'V' Shape<br>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<br>Nala bank with side slope milder than 1:1 | Available at more than 5km distance | Clayey/ lateritic soil | Solid Apron Type |
| 'U' Shape<br>Nala bank with side slope steeper than 1:1 | | Hard strata at a depth more than1.0m | Stilling Basin Type |

**Location of check dams in MWS/SWS area:**

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

**Estimation of soil water (moisture) 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.

Soil Water (moisture) balance equation can be defined as:
Change in soil moisture storage = Rainfall + Irrigation - Surface runoff - Evapotranspiration - Deep percolation

**Table 4: 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 | Texture, organic carbon, bulk density | (Calculated using *pedo-transfer* function |

| | | | |
|---|---|---|---|
| | from LRI database through PTF models) | | 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 ET |
| 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 | |

**Table 5: Step-by-step process for estimating soil water (moisture) balance**

| *Sl. 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, Eta, runoff and deep percolation) at individual field scale | |
| 4 | Estimate runoff on daily time scale based on selected model (SCS Method) | Runoff model based on IR and precipitation-not done |
| 5 | Calculate balance water by subtracting runoff from rainfall | |
| 6 | Distribute balance water into soil by following one-dimensional model | |
| 7 | Excess balance water beyond soil depth may be assumed as deep percolation | |
| 8 | Estimate crop water requirement on daily time scale | As per the DSS on Crop water requirement |
| 9 | Estimate available moisture content in soil up to root zone depth | |

| | | |
|---|---|---|
| 10 | Estimate soil water storage by subtracting crop water requirement from available moisture content up to root depth | |
| 11 | Repeat step 4-11 at daily scale for entire crop growth period | |
| 12 | Display water balance component at land parcel scale | |

**Water budgeting for watershed planning:**

Water budgeting is critical for the sustainable mangement of available water resoureces 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 of time. 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 livlihood activities to bring in additional and sustainable benefits to the scociety as a whole. Though water budgets can be worked out at any sclae, 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 watsershed scale under Suajal III project.

**Table 6: 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 | |

**Table 7: 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<br>1. Measured capacities of surface water bodies<br>2. Runoff generated through watershed based on runoff from Infiltration method<br>3. Amount of water percolation in soil-ground water (deep percolation component in water balance) | |
| 3 | Estimate water required for irrigation based on the crop water requirement and irrigation requirement | |
| 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 | |

## Common land and drainage line treatment plan

**Common land:** It is land owned by a person or collectively by a number of persons, over which other persons have certain common rights, such as to allow their livestock to graze upon it, to collect wood, or to cut turf for fuel.

**Common land/Non-arable land treatments:**

Treatment of non-arable land has been inevitable to reduce the runoff and to create water storage at field level. They help to distribute moisture uniformly on slopping land so that natural vegetation grows successfully and restores the bio-diversity (Sarvade *et al*., 2019). A brief description of suggested measures is indicated below.

A. **Continuous Contour V trenches:** Contour trenches made in non-agricultural land for providing adequate moisture conditions in order to raise trees and grass species. The size of the trench varies with slope, rainfall and depth of soil available. The trenches are usually of 60 cm X 48 cm in size. The spacing varies from 10 to 30 m. the trenches are half refilled diagonally with excavated material and remaining half of the soil forms the spoil bank. The trenches are not continuous, but broken at intervals of 60 m. rainwater is held in these trenches for some time and facilitate growth of vegetation. Planting is done on the spoil bank.

B. **Staggered Contour V trenches:** These are the 'V' shaped trenches dug on contour in non-arable lands of more than 3 % slope to hold run off for conservation and reducing erosion. They are established for development of trees and grass species and are adoptable in areas with annual rainfall of up to 950 mm per annum.

C. **Pits with crescent-shaped bunds:** Consists of staggered rows of pits with crescent (half-moon) shaped bunds for planting trees and are adoptable in non-arable lands having less than 3 % slope, in areas with annual rainfall of less than 950 mm (Singh and Sharma, 2010)

**Specifications**: Pit: 0.5 X 0.5 X 0.5 m for forest areas, 1 X 1 X 1 m for horticultural areas

Crescent shaped bund: 1 m on either side of the upstream side of the pit.

**Forestry measures:**

Forestlands located at higher elevation where the slopes are steep and uneven, soil is less stable and highly erodible and precipitation is high. The vegetation and dried leaves on the floor intercept the rain and reduce the impact of raindrops. However, overgrazing and felling of unessential to avoid serious erosion and to maintain ecological balance (Schuler *et al*., 2006) and the re-establishment of forest trees or shrubs is difficult. The survival percentage of transplanted samplings ranges from 37 to 57 percent. So, the species suitable for the region with high survival rate should be selected. In addition, contour terracing and afforestation is recommended for improving the productivity of forests. Rainwater stored in this trench facilitates the growth of vegetation besides acting as a potential groundwater recharge structure.

**Agrostological measures:**

Grasses prevent soil erosion by intercepting rainfall, by binding the soil particles and by improving soil structures. A grass legume association is ideal for soil conservation. Legumes

built up soil fertility by fixing atmospheric nitrogen in their root nodules. Grasses have multiplicity of uses in soil conservation. They are used for stabilizing the surfaces of waterways (Gupta *et al*., 2018).

Suitability of a grass for using in soil and water conservation in a watershed is decided based on their perennial nature, drought resistance rhizomniferous, develop good canopy, deep root system, prostate in habit, and useful for cottage industries. Best-suited grasses are, *Cenchrus ciliaris, Cynodon doctylon, Dicanthium annulatum, Heteropogan contortus, Iseilema laxum, panicum antidotale, Panicum virgatum, Eragrostis curvula etc*. and best-suited leguminous species are, *Atylosia scarabaeoides*, *Styloxanthus species* and *Siratro species*.

**Drainage line treatments:**

The basic approach of drainage line treatment involves controlling the formation of gullies due to peak flow rates and provision of stable channel for flow that has to be handled (Meena *et al*., 2020). The first one, reducing the proneness to gully formation is accomplished by diverting the runoff, retention of runoff on the watershed by adoption of techniques lie contour cultivation, strip cropping, vegetative strip cropping, cover crops, mulching *etc*. Second one, i.e. provision of stable channel for the flow is accomplished by stabilizing the gully slides and bed by establishing vegetation and reducing the gradient of the channel to maintain velocities below erosive level by temporary and permanent structures such as check dams, drop-spillways and chutes, *etc*. Common drainage line treatments are classified into vegetative and mechanical methods based on the technique on which treatments are made.

**Vegetative measures:**

Strips of suitable vegetation planted across the drainage line or nala to check the velocity of water flow and to arrest silt.

1. **Sod strips:** These are taken up in gullies up to 1 m depth and with three ha catchments and 4 % bed slope. Three staggered rows of agave or other crop planted with 1 m width, 0.5 m height, refilling 0.35 m and 1 m interval between the rows.
2. **Sodded earthen strips:** These are taken up in gullies of 1 to 1.5 m depth and with 3 to 10 ha catchments and bed slope less than 4 %. The crest height 0.6 – 1.5 cm, slope upstream side 2:1, downstream side 3:1, a bund with concave crest 0.3 m higher than at the middle is constructed across the gully and stabilized by sodding and planting suitable vegetation.
3. **Shrub checks:** These are taken up in gullies with more than 10 ha catchment. Shrub checks planted in a staggered way in three rows across the gully at intervals of 1 m to form a strip.
4. **Brush wood checks:** are porous checks constructed across the gully with wooden pegs and brush wood and are adoptable in all areas.

**Mechanical measures:**

1. **Loose boulder checks:** These are porous checks across the nala constructed using loose boulders to check water velocity and to arrest slit.

2. **Gabions:** Dams made of wire-woven baskets filled with stones placed in trench of suitable size across steep-sloped gullies to trap erosion debris during rains. They are adoptable in all areas of high slopes and high rainfall.

3. **Drop spill way:** Masonry structures constructed across the gully with a spill way to serve as gully control and water harvesting structure, where in water flow is not blocked.

4. **Chute spill way:** Chute spill way or flumes are concrete of masonry structures constructed across the flow in channels or nalas to transmit the flow in a safe manner over the elevation differences in the flow course.

5. **Ravine reclamation structure:** This is a masonry structure consisting of a body wall, apron and header. The banks are protected by stone revetment to further scouring. They are constructed to control head movement of gullies, avoid further widening and deepening of ravine, reduce sedimentation of tanks/reservoirs, provide protective irrigation, drinking water for the cattle and wild life, increase moisture regime and recharge underground water table. They are constructed in ravines with depth of 2.5 to 3.5 m., width 8 to 15 m., and catchment area 15 to 25 ha.

6. **Sunken ponds/ Farm ponds:** These are small storage structures made across waterways and/ or gullies to collect inevitable runoff for subsequent use as supplemental irrigation, to recharge ground water and for improving availability of water for agricultural and other uses, in cultivate areas where slope is less than 5%. The most economical earthwork and desired water storage are the two guiding factors for locating the structure. The catchment should be large enough to yield sufficient runoff for filling the pond. They are preferably located in areas with impervious substratum.

7. **Nala bunds:** This structure taken up with the objective of controlling runoff water, reducing sedimentation of tanks/reservoirs, providing protective irrigation, drinking water for the cattle and wild life, increase moisture regime and recharge underground water table. Consists of homogeneous earthen embankment-inner core bund and the outer main bund-constructed across the nalas or valleys which have distinct banks with width of about 5 to 15 m and depth of about 1 to 3 m. and the slope of the nala bund should be 1 to 3 %. A cut outlet also provided at one end of the nala bund where bank strata are hard and non-erosive. The catchment area of a nala bund would be 80 to 500 ha, where rainfall is below 750mm per year and 40 to 250 ha, where rainfall is more than 750 mm per year.

8. **Check dams:** Check dams constructed across gullies to reduce the velocity of runoff, heal the gully, store water for use by livestock and recharge groundwater in wells lower down. Depending on the size of the gully, the check dam constructed with earth, rocks, boulders, masonry or concrete. A series of check dams constructed from top towards bottom for their efficiency in conservation. The dams should be so spaced so that the crest level of one coincides with the base level of the next dam upstream. Generally, a grade of 0.1 to 0.5% is provided. While preparing the treatment plan for a given micro watershed by using LRI and hydrology outputs and decision criteria for water harvesting structures indicate appropriate treatments using the following format

**Common land activities/Drainage line treatment**

a. Boulder Check / Gully Plug
b. Rubble Check
c. Check Dam / Drop Structure
d. Cattle Pool (Gokatte)
e. Institution Plantation
f. Nala Revetment
g. Nala Plantation
h. Tank Development
i. Water Way
j. Block Plantation - Burial Ground
k. RRS- Ravine reclamation structure
l. RTW
m. Nala Bund
n. Diversion Channel

**Table 8: Details of common land activities**

**Sub watershed:** **MWS:**

| *Sl. No. (1)* | *Activity (2)* | *Location of site (3)* | *Dimension (4)* | *Quantity (5)* | *Unit cost (Rs.) (6)* | *Total cost (Rs.) (7)* |
|---|---|---|---|---|---|---|
| 1 | Boulder Check / Gully Plug | | | | | |
| 2 | Rubble Check | | | | | |
| 3 | Check Dam / Drop Structure | | | | | |
| 4 | Cattle Pool (Gokatte) | | | | | |
| 5 | Institution Plantation | | | | | |
| 6 | Nala Revetment | | | | | |
| 7 | Nala Plantation | | | | | |
| 8 | Tank Development | | | | | |
| 9 | Water Way | | | | | |
| 10 | Block Plantation - Burial Ground | | | | | |
| 11 | RRS | | | | | |
| 12 | RTW | | | | | |
| 13 | Nala Bund | | | | | |
| 14 | Diversion Channel | | | | | |

| *Survey No. (8)* | *Village (8)* | *Location (9)* | *Expected No. of Beneficiaries* | | | |
|---|---|---|---|---|---|---|
| | | | *SC (10)* | *ST (11)* | *Others (12)* | *Total (13)* |
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Land management in a watershed involves any practice, which, carried out to halt runoff and soil erosion induced thereafter so that the land gets better ability to supply moisture and nutrients to the crops cultivated in the watershed. Therefore, the aspect of land management in a watershed involves agronomic, mechanical, forestry and agrostological measures (Eswaran *et al*., 2001).

Following is the description about some of the measures to be taken up in both arable and non-arable lands.

**Agronomic measures:**

Though most of the dryland crops are able to produce satisfactory yield in a rainfall ranging between 400-450 mm per annum, it is the amount of rainfall which gets infiltrated or stored in the soil which determines the yielding ability of crops (Manivannan *et al*., 2017). Therefore, for effective conservation of rainwater between the bunds is essential, which achieved through various *'in-situ'* soil and moisture conservation practices also called as inter-terrace land management practices. Which involves following aspects (Gachene *et al*., 2019).

**A. Modifying land configuration for better distribution of rain water:** Rainwater falls uniformly over the land surface in a locality, but does not get uniformly absorbed due to undulations in the field. The depressions hold more while the humps remain dry (Quinton *et al*., 2010). Some amount of land smoothing is essential even in flat lands to ensure uniformity in infiltration. Practices like general smoothing, graded border strips, conservation bench terraces or Zingg terraces, *etc*.

**a. Inter terrace management:** Inter terrace management includes all operations undertaken within the bunded area for controlling erosion (particularly in slopy lands), enhancing infiltration (particularly in black soils), conserving rain water and safe disposal of surplus water. Common inter terrace management practices are,

**b. Small section bunds (interceptor bunds) and vegetative barriers:** When the distance between bunds is greater than 30 meters, there can be uncontrolled flow within the bunded area. To avoid this damage, small bunds of 0.2 to 0.3 $m^2$ section are to be constructed at 10-15 m interval across the slope with the help of a bund former. Such barriers can also be vegetative in nature formed by establishing grasses like *Vetiver, Pennisetum, etc*.

**B. Tillage:** In watersheds, tillage is required to improve moisture conservation, break hard pan and help root penetration, control weeds, provide better aeration and to form a good seed bed (Blanco and Lal, 2008). Tillage methodologies like off season tillage/ fall ploughing, contour cultivation, scooping, compartment bunding, ridges and furrows formation, tied and graded ridges, graded furrows and dead furrows, mulching (surface/vertical), *etc*. will help in proper conservation and supply of moisture throughout the growth period of crops (Singh *et al*., 2020).

**C. Other agronomic practices:** Early sowing, Optimum plant population repeated intercultural operations, disease and pest management aid the crop growth thereby improving crop production in cultivated watersheds (Guo *et al*., 2019).

**Mechanical measures:**

Mechanical measures are adopted to supplement the agronomical measures when the latter alone are not adequate. These measures differ with respect to suitability of land to cultivate the crops (arable or non-arable). Common mechanical measures to conserve rainfall and soil moisture are classified into two components as arable land treatments and non-arable land treatments.

**Decision criteria for selection of conservation measures based on LRI output**

**Table 9: 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 |
| 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 |
| 52 | 1 to 3 | <50 | Loam | Clay | >35% | 750-950 | Contour bund/TCB |
| 53 | 3 to 5 | <50 | Loam | Clay | >35% | <750 | Contour bund/TCB |
| 54 | 3 to 5 | <50 | Loam | Clay | >35% | 750-950 | Contour bund/TCB |
| 55 | 5 to 10 | <50 | Loam | Clay | >35% | <750 | Contour bund/TCB |
| 56 | 5 to 10 | <50 | Loam | Clay | >35% | 750-950 | Contour bund/TCB |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 57 | <1 | 50-100 | Loam | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 58 | <1 | 50-100 | Loam | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 59 | 1 to 3 | 50-100 | Loam | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 60 | 1 to 3 | 50-100 | Loam | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 61 | 3 to 5 | 50-100 | Loam | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 62 | 3 to 5 | 50-100 | Loam | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 63 | 5 to 10 | 50-100 | Loam | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 64 | 5 to 10 | 50-100 | Loam | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 65 | <1 | >100 | Loam | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 66 | <1 | >100 | Loam | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 67 | 1 to 3 | >100 | Loam | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 68 | 1 to 3 | >100 | Loam | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 69 | 3 to 5 | >100 | Loam | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 70 | 3 to 5 | >100 | Loam | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 71 | 5 to 10 | >100 | Loam | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 72 | 5 to 10 | >100 | Loam | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 73 | <1 | <50 | Clay | Clay | >35% | <750 | Contour bund/TCB |
| 74 | <1 | <50 | Clay | Clay | >35% | 750-950 | Contour bund/TCB |
| 75 | 1 to 3 | <50 | Clay | Clay | >35% | <750 | Contour bund/TCB |
| 76 | 1 to 3 | <50 | Clay | Clay | >35% | 750-950 | Contour bund/TCB |
| 77 | 3 to 5 | <50 | Clay | Clay | >35% | <750 | Contour bund/TCB |
| 78 | 3 to 5 | <50 | Clay | Clay | >35% | 750-950 | Contour bund/TCB |
| 79 | 5 to 10 | <50 | Clay | Clay | >35% | <750 | Contour bund/TCB |
| 80 | 5 to 10 | <50 | Clay | Clay | >35% | 750-950 | Contour bund/TCB |
| 81 | <1 | 50 to 100 | Clay | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 82 | <1 | 50 to 100 | Clay | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 83 | 1 to 3 | 50 to 100 | Clay | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 84 | 1 to 3 | 50 to 100 | Clay | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 85 | 3 to 5 | 50 to 100 | Clay | Clay | >35% | <750 | Contour bund/$^2$TCB |
| 86 | 3 to 5 | 50 to 100 | Clay | Clay | >35% | 750-950 | Contour bund$^2$/TCB |

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|---|---|---|---|---|---|---|---|
| 87 | 5 to 10 | 50 to 100 | Clay | Clay | >35% | <750 | Contour bund$^2$/TCB |
| 88 | 5 to 10 | 50 to 100 | Clay | Clay | >35% | 750-950 | Contour bund$^2$/TCB |
| 89 | <1 | >100 | Clay | Clay | >35% | <750 | Graded bund |
| 90 | <1 | >100 | Clay | Clay | >35% | 750-950 | Graded bund |
| 91 | 1 to 3 | >100 | Clay | Clay | >35% | <750 | Graded bund |
| 92 | 1 to 3 | >100 | Clay | Clay | >35% | 750-950 | Graded bund |
| 93 | 3 to 5 | >100 | Clay | Clay | >35% | <750 | Graded bund |
| 94 | 3 to 5 | >100 | Clay | Clay | >35% | 750-950 | Graded bund |
| 95 | 5 to 10 | >100 | Clay | Clay | >35% | <750 | Graded bund |
| 96 | 5 to 10 | >100 | Clay | Clay | >35% | 750-950 | Graded bund |
| 97 | <1 | <50 | Loam | Loam | <35% | <750 | Contour bund/TCB |
| 98 | <1 | <50 | Loam | Loam | <35% | 750-950 | Graded bund |
| 99 | 1 to 3 | <50 | Loam | Loam | <35% | <750 | Contour bunding/TCB |
| 100 | 1 to 3 | <50 | Loam | Loam | <35% | 750-950 | Graded bund |
| 101 | 3 to 5 | <50 | Loam | Loam | <35% | <750 | Contour bunding/TCB |
| 102 | 3 to 5 | <50 | Loam | Loam | <35% | 750-950 | Graded bund |
| 103 | 5 to 10 | <50 | Loam | Loam | <35% | <750 | Graded bund |
| 104 | 5 to 10 | <50 | Loam | Loam | <35% | 750-950 | Graded bund |
| 105 | <1 | 50-100 | Loam | Loam | <35% | <750 | Contour bunding$^2$/TCB |
| 106 | <1 | 50-100 | Loam | Loam | <35% | 750-950 | Graded bund |
| 107 | 1 to 3 | 50-100 | Loam | Loam | <35% | <750 | Contour bunding$^2$/TCB |
| 108 | 1 to 3 | 50-100 | Loam | Loam | <35% | 750-950 | Graded bund |
| 109 | 3 to 5 | 50-100 | Loam | Loam | <35% | <750 | Contour bunding$^2$/TCB |
| 110 | 3 to 5 | 50-100 | Loam | Loam | <35% | 750-950 | Graded bund |
| 111 | 5 to 10 | 50-100 | Loam | Loam | <35% | <750 | Graded bund |
| 112 | 5 to 10 | 50-100 | Loam | Loam | <35% | 750-950 | Graded bund |
| 113 | <1 | >100 | Loam | Loam | <35% | <750 | Contour bunding$^2$/TCB |
| 114 | <1 | >100 | Loam | Loam | <35% | 750-950 | Graded bund |
| 115 | 1 to 3 | >100 | Loam | Loam | <35% | <750 | Contour bunding$^2$/TCB |
| 116 | 1 to 3 | >100 | Loam | Loam | <35% | 750-950 | Graded bund |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 117 | 3 to 5 | >100 | Loam | Loam | <35% | <750 | Contour bunding[2]/TCB |
| 118 | 3 to 5 | >100 | Loam | Loam | <35% | 750-950 | Graded bund |
| 119 | 5 to 10 | >100 | Loam | Loam | <35% | <750 | Graded bund |
| 120 | 5 to 10 | >100 | Loam | Loam | <35% | 750-950 | Graded bund |
| 121 | <1 | <50 | Clay | Loam | <35% | <750 | Graded bund |
| 122 | <1 | <50 | Clay | Loam | <35% | 750-950 | Graded bund |
| 123 | 1 to 3 | <50 | Clay | Loam | <35% | <750 | Graded bund |
| 124 | 1 to 3 | <50 | Clay | Loam | <35% | 750-950 | Graded bund |
| 125 | 3 to 5 | <50 | Clay | Loam | <35% | <750 | Graded bund |
| 126 | 3 to 5 | <50 | Clay | Loam | <35% | 750-950 | Graded bund |
| 127 | 5 to 10 | <50 | Clay | Loam | <35% | <750 | Graded bund |
| 128 | 5 to 10 | <50 | Clay | Loam | <35% | 750-950 | Graded bund |
| 129 | <1 | 50 to 100 | Clay | Loam | <35% | <750 | Graded bund |
| 130 | <1 | 50 to 100 | Clay | Loam | <35% | 750-950 | Graded bund |
| 131 | 1 to 3 | 50 to 100 | Clay | Loam | <35% | <750 | Graded bund |
| 132 | 1 to 3 | 50 to 100 | Clay | Loam | <35% | 750-950 | Graded bund |
| 133 | 3 to 5 | 50 to 100 | Clay | Loam | <35% | <750 | Graded bund |
| 134 | 3 to 5 | 50 to 100 | Clay | Loam | <35% | 750-950 | Graded bund |
| 135 | 5 to 10 | 50 to 100 | Clay | Loam | <35% | <750 | Graded bund |
| 136 | 5 to 10 | 50 to 100 | Clay | Loam | <35% | 750-950 | Graded bund |
| 137 | <1 | >100 | Clay | Loam | <35% | <750 | Graded bund |
| 138 | <1 | >100 | Clay | Loam | <35% | 750-950 | Graded bund |
| 139 | 1 to 3 | >100 | Clay | Loam | <35% | <750 | Graded bund |
| 140 | 1 to 3 | >100 | Clay | Loam | <35% | 750-950 | Graded bund |
| 141 | 3 to 5 | >100 | Clay | Loam | <35% | <750 | Graded bund |
| 142 | 3 to 5 | >100 | Clay | Loam | <35% | 750-950 | Graded bund |
| 143 | 5 to 10 | >100 | Clay | Loam | <35% | <750 | Graded bund |
| 144 | 5 to 10 | >100 | Clay | Loam | <35% | 750-950 | Graded bund |
| 145 | <1 | <50 | Loam | Loam | >35% | <750 | Contour bund/TCB |
| 146 | <1 | <50 | Loam | Loam | >35% | 750-950 | Contour bund/TCB |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 147 | 1 to 3 | <50 | Loam | Loam | >35% | <750 | Contour bund/TCB |
| 148 | 1 to 3 | <50 | Loam | Loam | >35% | 750-950 | Contour bund/TCB |
| 149 | 3 to 5 | <50 | Loam | Loam | >35% | <750 | Contour bund/TCB |
| 150 | 3 to 5 | <50 | Loam | Loam | >35% | 750-950 | Contour bund/TCB |
| 151 | 5 to 10 | <50 | Loam | Loam | >35% | <750 | Contour bund/TCB |
| 152 | 5 to 10 | <50 | Loam | Loam | >35% | 750-950 | Contour bund/TCB |
| 153 | <1 | 50-100 | Loam | Loam | >35% | <750 | Contour bund$^2$/TCB |
| 154 | <1 | 50-100 | Loam | Loam | >35% | 750-950 | Contour bund$^2$/TCB |
| 155 | 1 to 3 | 50-100 | Loam | Loam | >35% | <750 | Contour bund$^2$/TCB |
| 156 | 1 to 3 | 50-100 | Loam | Loam | >35% | 750-950 | Contour bund$^2$/TCB |
| 157 | 3 to 5 | 50-100 | Loam | Loam | >35% | <750 | Contour bund$^2$/TCB |
| 158 | 3 to 5 | 50-100 | Loam | Loam | >35% | 750-950 | Contour bund$^2$/TCB |
| 159 | 5 to 10 | 50-100 | Loam | Loam | >35% | <750 | Contour bund/TCB |
| 160 | 5 to 10 | 50-100 | Loam | Loam | >35% | 750-950 | Contour bund/TCB |
| 161 | <1 | >100 | Loam | Loam | >35% | <750 | Contour bund$^2$/TCB |
| 162 | <1 | >100 | Loam | Loam | >35% | 750-950 | Contour bund$^2$/TCB |
| 163 | 1 to 3 | >100 | Loam | Loam | >35% | <750 | Contour bund$^2$/TCB |
| 164 | 1 to 3 | >100 | Loam | Loam | >35% | 750-950 | Contour bund$^2$/TCB |
| 165 | 3 to 5 | >100 | Loam | Loam | >35% | <750 | Contour bund$^2$/TCB |
| 166 | 3 to 5 | >100 | Loam | Loam | >35% | 750-950 | Contour bund$^2$/TCB |
| 167 | 5 to 10 | >100 | Loam | Loam | >35% | <750 | Contour bund/TCB |
| 168 | 5 to 10 | >100 | Loam | Loam | >35% | 750-950 | Contour bund/TCB |
| 169 | <1 | <50 | Clay | Loam | >35% | <750 | Contour bund/TCB |
| 170 | <1 | <50 | Clay | Loam | >35% | 750-950 | Contour bund/TCB |
| 171 | 1 to 3 | <50 | Clay | Loam | >35% | <750 | Contour bund/TCB |
| 172 | 1 to 3 | <50 | Clay | Loam | >35% | 750-950 | Contour bund/TCB |
| 173 | 3 to 5 | <50 | Clay | Loam | >35% | <750 | Contour bund/TCB |
| 174 | 3 to 5 | <50 | Clay | Loam | >35% | 750-950 | Contour bund/TCB |
| 175 | 5 to 10 | <50 | Clay | Loam | >35% | <750 | Contour bund/TCB |
| 176 | 5 to 10 | <50 | Clay | Loam | >35% | 750-950 | Contour bund/TCB |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 177 | <1 | 50 to 100 | Clay | Loam | >35% | <750 | Contour bund/TCB |
| 178 | <1 | 50 to 100 | Clay | Loam | >35% | 750-950 | Contour bund/TCB |
| 179 | 1 to 3 | 50 to 100 | Clay | Loam | >35% | <750 | Contour bund/TCB |
| 180 | 1 to 3 | 50 to 100 | Clay | Loam | >35% | 750-950 | Contour bund/TCB |
| 181 | 3 to 5 | 50 to 100 | Clay | Loam | >35% | <750 | Contour bund/TCB |
| 182 | 3 to 5 | 50 to 100 | Clay | Loam | >35% | 750-950 | Contour bund/TCB |
| 183 | 5 to 10 | 50 to 100 | Clay | Loam | >35% | <750 | Contour bund/TCB |
| 184 | 5 to 10 | 50 to 100 | Clay | Loam | >35% | 750-950 | Contour bund/TCB |
| 185 | <1 | >100 | Clay | Loam | >35% | <750 | Contour bund/TCB |
| 186 | <1 | >100 | Clay | Loam | >35% | 750-950 | Contour bund/TCB |
| 187 | 1 to 3 | >100 | Clay | Loam | >35% | <750 | Graded bund |
| 188 | 1 to 3 | >100 | Clay | Loam | >35% | 750-950 | Graded bund |
| 189 | 3 to 5 | >100 | Clay | Loam | >35% | <750 | Graded bund |
| 190 | 3 to 5 | >100 | Clay | Loam | >35% | 750-950 | Graded bund |
| 191 | 5 to 10 | >100 | Clay | Loam | >35% | <750 | Graded bund |
| 192 | 5 to 10 | >100 | Clay | Loam | >35% | 750-950 | Graded bund |

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

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

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

**Table 10: 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**: [1]As per the criteria, the recommended conservation measure is contour bunding, but in practice, TCB is commonly adopted by the department in the field. However, the cost of bunding for both remains the same.

**Table 11: 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 |
| 3 | >5 | <25 | Loam | Clay | <35% | <=750 | Contour trenching (continuous/staggered contour trench) |
| 4 | >5 | <25 | Loam | Clay | <35% | 750-950 | Graded trenching |
| 5 | <5 | >25 | Loam | Clay | <35% | <=750 | Contour trenching (continuous/staggered contour trench) |
| 6 | <5 | >25 | Loam | Clay | <35% | 750-950 | Graded trenching |
| 7 | >5 | >25 | Loam | Clay | <35% | <=750 | Contour trenching (continuous/staggered contour trench) |
| 8 | >5 | >25 | Loam | Clay | <35% | 750-950 | Graded trenching |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | <5 | <25 | Clay | Clay | <35% | <=750 | Graded trenching |
| 10 | <5 | <25 | Clay | Clay | <35% | 750-950 | Graded trenching |
| 11 | >5 | <25 | Clay | Clay | <35% | <=750 | Graded trenching |
| 12 | >5 | <25 | Clay | Clay | <35% | 750-950 | Graded trenching |
| 13 | <5 | >25 | Clay | Clay | <35% | <=750 | Graded trenching |
| 14 | <5 | >25 | Clay | Clay | <35% | 750-950 | Graded trenching |
| 15 | >5 | >25 | Clay | Clay | <35% | <=750 | Graded trenching |
| 16 | >5 | >25 | Clay | Clay | <35% | 750-950 | Graded trenching |
| 17 | <5 | <25 | Loam | Clay | >35% | <=750 | Contour trenching (continuous/staggered contour trench) |
| 18 | <5 | <25 | Loam | Clay | >35% | 750-950 | Graded trenching |
| 19 | >5 | <25 | Loam | Clay | >35% | <=750 | Contour trenching (continuous/staggered contour trench) |
| 20 | >5 | <25 | Loam | Clay | >35% | 750-950 | Graded trenching |
| 21 | <5 | >25 | Loam | Clay | >35% | <=750 | Contour trenching (continuous/staggered contour trench) |
| 22 | <5 | >25 | Loam | Clay | >35% | 750-950 | Graded trenching |
| 23 | >5 | >25 | Loam | Clay | >35% | <=750 | Contour trenching (continuous/staggered contour trench) |
| 24 | >5 | >25 | Loam | Clay | >35% | 750-950 | Graded trenching |
| 25 | <5 | <25 | Clay | Clay | >35% | <=750 | Graded trenching |
| 26 | <5 | <25 | Clay | Clay | >35% | 750-950 | Graded trenching |
| 27 | >5 | <25 | Clay | Clay | >35% | <=750 | Graded trenching |
| 28 | >5 | <25 | Clay | Clay | >35% | 750-950 | Graded trenching |
| 29 | <5 | >25 | Clay | Clay | >35% | <=750 | Graded trenching |
| 30 | <5 | >25 | Clay | Clay | >35% | 750-950 | Graded trenching |
| 31 | >5 | >25 | Clay | Clay | >35% | <=750 | Graded trenching |
| 32 | >5 | >25 | Clay | Clay | >35% | 750-950 | Graded trenching |
| 33 | <5 | <25 | Loam | Loam | <35% | <=750 | Contour trenching (continuous/staggered contour trench) |
| 34 | <5 | <25 | Loam | Loam | <35% | 750-950 | Graded trenching |
| 35 | >5 | <25 | Loam | Loam | <35% | <=750 | Contour trenching (continuous/staggered contour trench) |
| 36 | >5 | <25 | Loam | Loam | <35% | 750-950 | Graded trenching |
| 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 |

**Table 12: 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 | VI = Width x Slope/(100-Slope) for Black soil (batter slope 1:1; horizontal:vertical)<br>VI = 2 x Width x Slope/(200-Slope)-for Red and lateritic soils (batter slope 0.5:1)<br>HI = Width /VI<br>Note: For designing the Width = 200 x depth of cut/slope<br>Depth of cut* = Profile depth x (1-(slope/100))<br>*minimum depth of cut = 0.3 m or (Profile depth - (VI/2))<br>Note: Volume of earth excavation for Terrace strips are estimated using the formula: Q = L x W x D/8<br>Where, l = Length of the Terrace strip, W = Designed Terrace width, D = Fall between two Terrace strips | | | | | |

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

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

**Table 13: Criteria for deciding cross-section of contour bund and TCB under field crops**

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Clay | >35% | 100-150 | 0.6 | 3.1 | 0.7 | 1.78:1 | 1.29 |
| Loam | <35% | >150 | 0.3 | 2.1 | 0.6 | 1.5:1 | 0.72 |
| Loam | >35% | >150 | 0.3 | 2.1 | 0.6 | 1.5:1 | 0.72 |
| Clay | <35% | >150 | 0.5 | 3.0 | 0.85 | 1.47:1 | 1.49 |
| Clay | >35% | >150 | 0.5 | 3.0 | 0.85 | 1.47:1 | 1.49 |
| *Graded bunding* | | | | | | | |
| Clay | <35 | 50-100 | 0.3 | 1.2 | 0.5 | 0.9:1.0 | 0.375 |
| 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<br>d/s 1.5:1 | 2.06 |
| Clay | >35 | 100-150 | 0.3 | 5.175 | 0.75 | u/s 5:1<br>d/s 1.5:1 | 2.06 |
| Clay | <35 | >150 | 0.3 | 5.175 | 0.75 | u/s 5:1<br>d/s 1.5:1 | 2.06 |
| Clay | >35 | >150 | 0.3 | 5.175 | 0.75 | u/s 5:1<br>d/s 1.5:1 | 2.06 |
| *For Plantation crops* | | | | | | | |
| Loam | >35% | <50 | 0.3 | 1.2 | 0.5 | 0.9;1 | 0.375 |

**Note**: Length of side bund = 10% of main bund length
**Source**: Technical Manual for Integrated Watershed Development, 2006, (Sponsored by Watershed Development Department, Government of Karnataka), Institution of Agricultural Technologists (IAT), Queen's Road, Bengaluru-560 052

**Table 14: Criteria for selecting the cost rate for contour bund/TCB**

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

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Waste weir | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 |
| | | Sowing of grass seeds | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| | Total | | 53.52 | 60.77 | 69.31 | 87.71 | 116.12 | 127.66 | 156.09 | 174.77 |
| *b) Lateritic Soils* | | | | | | | | | | |
| Machinery-WDD SOR | | Main bund | 33.55 | 38.80 | 44.86 | 58.15 | 77.56 | 95.73 | 110.48 | 126.58 |
| | | Side bund | 23.69 | 27.65 | 31.63 | 41.35 | 54.91 | 54.91 | 71.99 | 81.38 |
| | | Waste weir | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 |
| | | Sowing of grass seeds | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| | Total | | 62.74 | 71.96 | 81.98 | 105.00 | 137.96 | 156.13 | 187.97 | 213.46 |
| *a) Black Soils/Red Soils* | | | | | | | | | | |
| Manual-MGNREGS | <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 | | 156.89 | 187.17 | 223.51 | 296.18 | 376.92 | 437.48 | 526.30 | 607.04 |
| | >35% gravel | Main bund | 90.66 | 108.79 | 130.54 | 174.06 | 222.41 | 258.67 | 311.85 | 360.20 |
| | | Side bund | 60.74 | 72.89 | 87.46 | 116.62 | 149.01 | 173.31 | 208.94 | 241.34 |
| | | Waste weir | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 |
| | | Sowing of grass seeds | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| | Total | | | | | | | | | |
| *b) Lateritic Soils* | | | | | | | | | | |
| Manual-MGNREGS | - | Main bund | 90.66 | 108.79 | 130.54 | 174.06 | 222.41 | 258.67 | 311.85 | 360.20 |
| | | Side bund | 60.74 | 72.89 | 87.46 | 116.62 | 149.01 | 173.31 | 208.94 | 241.34 |
| | | Waste weir | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 |
| | | Sowing of grass seeds | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| | Total | | 156.89 | 187.17 | 223.51 | 296.18 | 376.92 | 437.48 | 526.30 | 607.04 |
| *a) Black Soils/Red Sandy Soils* | | | | | | | | | | |
| Manual-WDD SOR | <35% gravel | Main bund | 31.13 | 37.35 | 44.82 | 59.76 | 76.36 | 88.81 | 107.07 | 123.67 |
| | | Side bund | 20.85 | 25.02 | 30.03 | 40.04 | 51.16 | 59.50 | 71.74 | 82.86 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Waste weir | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 |
| | | Sowing of grass seeds | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| | Total | | 57.48 | 67.87 | 80.35 | 105.30 | 133.02 | 153.81 | 184.31 | 212.03 |
| | >35% gravel | Main bund | 34.13 | 40.95 | 49.14 | 65.52 | 83.72 | 97.37 | 117.39 | 135.59 |
| | | Side bund | 22.86 | 27.44 | 32.92 | 43.90 | 56.09 | 65.24 | 78.65 | 90.85 |
| | | Waste weir | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 |
| | | Sowing of grass seeds | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| | Total | | 62.49 | 73.89 | 87.56 | 114.92 | 145.31 | 168.11 | 201.54 | 231.94 |
| *b) Lateritic Soils* | | | | | | | | | | |
| Manual-WDD SOR | - | Main bund | 42.75 | 51.30 | 61.56 | 82.08 | 104.88 | 121.98 | 147.06 | 169.86 |
| | | Side bund | 28.64 | 34.37 | 41.25 | 54.99 | 70.27 | 81.73 | 98.53 | 113.81 |
| | | Waste weir | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 | 5.22 |
| | | Sowing of grass seeds | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| | Total | | 76.89 | 91.17 | 108.31 | 142.57 | 180.65 | 209.21 | 251.09 | 289.17 |

**Source**: SoR-2018-19

**Table 15: Criteria for selecting the cost rate for construction of contour bund with zing terrace (summary of rates as per SoR 2018-19)**

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

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

**Table 16: Criteria for selecting the cost rate for graded bund**

| *Soil type* | *Gravel* | *Soil texture* | *Mode of execution* | *SoR* | *Cost of earth work per metre bund length (Rs.) as per bund sections ($m^2$) given below* | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 0.375 | 0.45 | 0.72 | 2.06 |
| a) Black soils/Red Sandy soils | <35% | Loam | Machinery | WDD | 25.11 | 28.61 | 42.49 | 78.02 |
| | | Clay | Machinery | WDD | 25.11 | 28.61 | 42.49 | 78.02 |
| | >35% | Loam | Machinery | WDD | 27.81 | 31.79 | 47.54 | 0.00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Clay | Machinery | WDD | 27.81 | 31.79 | 47.54 | 0.00 |
| b) Lateritic soils | <35% | Lateritic | Machinery | WDD | 33.55 | 38.80 | 58.15 | 187.46 |
| | >35% | Lateritic | Machinery | WDD | 33.55 | 38.80 | 58.15 | 187.46 |
| a) Black soils/Red Sandy soils | <35% | Loam | Manual | MGNREGS | 90.66 | 108.79 | 174.06 | 498.00 |
| | | Clay | Manual | MGNREGS | 90.66 | 108.79 | 174.06 | 498.00 |
| | >35% | Loam | Manual | MGNREGS | 90.66 | 108.79 | 174.06 | 498.00 |
| | | Clay | Manual | MGNREGS | 90.66 | 108.79 | 174.06 | 498.00 |
| b) Lateritic soils | <35% | Lateritic | Manual | MGNREGS | 90.66 | 108.79 | 174.06 | 498.00 |
| | >35% | Lateritic | Manual | MGNREGS | 90.66 | 108.79 | 174.06 | 498.00 |
| a) Black soils/Red Sandy soils | <35% | Loam | Manual | WDD | 31.13 | 37.35 | 59.76 | 170.98 |
| | | Clay | Manual | WDD | 31.13 | 37.35 | 59.76 | 170.98 |
| | >35% | Loam | Manual | WDD | 34.13 | 40.95 | 65.52 | 187.46 |
| | | Clay | Manual | WDD | 34.13 | 40.95 | 65.52 | 187.46 |
| b) Lateritic soils | <35% | Loam | Manual | WDD | 42.75 | 51.30 | 82.08 | 234.84 |
| | >35% | Clay | Manual | WDD | 42.75 | 51.30 | 82.08 | 234.84 |

**Source**: SoR-2018-19

**Table 17: Criteria for selecting the cost rate for channel weir in graded bunds**

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

**Criteria for selection of costing for bench terraces**

**Table 18: Sloping inward terrace-riser 0.5:1.0; H:V in red and lateritic soils (mostly loamy soils)**

| *Sl. No.* | *Land slope (%)* | *Profile depth (cm)* | *Total cost of terracing (Rs./ha)* |
|---|---|---|---|
| 1 | 10 to 15 | 25-50 | 107450 |
| 2 | 15 to 25 | 25-50 | 121591 |
| 3 | >25 | 25-50 | 136389 |
| 4 | 10 to 15 | >50 | 281957 |
| 5 | 15 to 25 | >50 | 276907 |
| 6 | >25 | >50 | 271622 |

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

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

**Table 19: Sloping inward terrace-riser 1:1; H:V in black soils (clayey soils) and rainfall >750 mm**

| *Sl. No.* | *Land Slope (%)* | *Profile depth (cm)* | *Total cost of terracing (Rs./ha)* |
|---|---|---|---|
| 1 | 10 to 15 | 25-50 | 101470 |
| 2 | 15 to 25 | 25-50 | 111228 |
| 3 | >25 | 25-50 | 120846 |
| 4 | 10 to 15 | >50 | 266329 |
| 5 | 15 to 25 | >50 | 253435 |
| 6 | >25 | >50 | 240726 |

**Note**: 1. Costing is as per WDD SOR 2018-19
2. Cost of terracing includes 0.06m$^2$ Lip Bund, 0.3m thick stone pitching of the riser, waterways with drops, survey and alignment charges

**Table 20: Sloping outward terrace-riser 1:1; H:V in loamy (red)/clayey soils**

| *Sl. No.* | *Land Slope (%)* | *Profile Depth (cm)* | *Total cost of terracing (Rs./ha)* |
|---|---|---|---|
| 1 | 10 to 15 | 25-50 | 505561 |
| 2 | 15 to 25 | 25-50 | 704397 |
| 3 | >25 | 25-50 | 900386 |
| 4 | 10 to 15 | >50 | 516473 |
| 5 | 15 to 25 | >50 | 548703 |
| 6 | >25 | >50 | 580470 |

**Note**: 1. Costing is as per WDD SoR 2018-19
2. Cost of terracing includes 0.54 m$^2$ Lip Bund, 0.3m thick stone pitching of the riser, waterways with drops, survey and alignment charges

**Table 21: Plantation terraces with 1:1; H:V riser**

| *Sl. No.* | *Land slope (%)* | *Profile depth (cm)* | *Total cost of terracing (Rs./ha)* |
|---|---|---|---|
| 1 | 10 to 15 | 25-50 | 117106 |
| 2 | 15 to 25 | 25-50 | 192055 |
| 3 | >25 | 25-50 | 276371 |
| 4 | 10 to 15 | >50 | 71481 |
| 5 | 15 to 25 | >50 | 117228 |
| 6 | >25 | >50 | 168 |

**Note**: 1. Costing is as per WDD SoR 2018-19
2. Cost of terracing includes 0.54 m$^2$ Lip Bund, 0.3m thick stone pitching of the riser, waterways with drops, survey and alignment charges

**Table 22: Criteria for selecting the dimensions for opening of trenches**

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

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

**Table 23: Criteria for selecting the quantity of earth excavation for opening of trenches**

| *Sl. No.* | *Slope (%)* | *Horizontal interval (m)* | *Volume of earth excavation ($m^3$) per ha* | |
|---|---|---|---|---|
| | | | *Continuous contour trenches* | *Staggered contour trenches* |
| 1 | 5 | 10.0 | 218.7 | 169.8 |
| 2 | 5 to 10 | 7.5 | 291.6 | 222.2 |
| 3 | 10 to 15 | 5.0 | 434 | 321.4 |

**Table 24: Criteria for selecting the cost rate for trenching**

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

**Private land activities and sub activities plan for individual farmers under each LMU**

**Arable/private land treatments**

Following are some of the treatments suggested for private/arable lands. Understanding of these activities will be helpful to choose appropriate measures for a given condition in addition to decision criteria indicated for each measures.

**A. Contour Bunding:** The contour represents the envelope of the normal drawn at any given level to the lines of the greatest slope of a given watershed. Since runoff from any given surface is along the lines of the greatest slope and the velocity of runoff increases inter alia with the vertical distance through which it is moved. Contour bunding is the best means for arresting runoff from the watershed (Liu *et al*., 2014). These are applicable in areas receiving an annual rainfall of less than 750 mm and successfully practiced in all soils having infiltration rate of more than 8 mm per hour and slope less than 6 %.

**B. Graded-Bunding:** In situations where rainfall is not readily absorbed due to high rainfall or low intake of the soil, graded bunding recommended (Shinde *et al*., 2019). Graded bunds are trapezoidal earthen embankments constructed on a grade across the major slope to lead excess runoff through a wide and relatively shallow channel formed on 0.2 to 0.4 % grade on the upstream side of the bund. These are suitable for areas receiving annual rainfall more than 750 mm, where runoff is high, surplussing are essential and having infiltration rate less than 8 mm per hour Slope is 5 to 10 %.

**C. Contour border strips (CBS):** These are levelled strips of land constructed across the major slope at a vertical interval of 0.3 m with suitable drop structure in the waterways at the end of each strip (Singh *et al*., 2007). Each strip separated from the next bund of 0.24 $m^2$ cross section. CBS are most suitable in moderately to deep soils with infiltration rate of more than 8 mm per hour and where the rainfall is not more than 750 mm annually.

**D. Broad Base Terrace:** Recommended in deep black soils with high clay content develop deep cracks in summer and bunds in these soils breach extensively during rainy season, especially when the rains are of high intensity (Singh and Meena, 2020). A terrace is a combination of ridge and channel built across the slope on a controlled grade.

**E. Zing terracing:** Adopted in lands with 3 to 10 percent slopes and bench terracing is recommended on steeper slopes (Zingg and Hauser, 1959). Zing terraces are constructed in medium to deep soils in moderate to high rainfall areas. The length of the field is divided into donor area and receiving area in the ratio 2:1 to 5:1, but usually 2:1. The donor area is not levelled whereas the lower receiving area is levelled and provided with bund of cross- section area 0.3 to 1.5 $m^2$.

**F. Bench terracing:** On steeply sloping and undulated land, intensive farming is possible only with bench terracing (Meena and Meena, 2017). It is usually practicing on slopes ranging from 16 to 33 percent. Bench terracing consists of principally transforming relatively steep land into a series of level strips or platforms across the slope of the land. The field is made into a series of benches by excavating the soil from upper part of the

terrace and filling in the lower part. A good soil depth is required to avoid exposure of unproductive soil during levelling. The vertical drop may vary from 60 to 180 cm, depending on the slope and soil conditions and width required for easy cultural operations.

**Types of terraces for different soil and rainfall conditions:**

| Type | Suitability |
|---|---|
| Level and table-top | Area receiving medium rainfall (750mm) of even distribution with highly permeable deep soils. |
| Sloping outwards | Low rainfall (<750) area with permeable soil of medium depth. |
| Sloping inwards | Heavy rainfall areas (>750mm) with soil of poor infiltration rate. |

**G. Vegetative Barriers:** Closely spaced plantations, few rows of grasses or shrubs grown along the contour lines for erosion control in agricultural lands.

**H. Grassed waterways:** Waterways dug to a shallow depth of 0.15 to 0.5 m with flat side slopes of 4:1. Based on the gradient decided by the existing slope of the land. Suitable perennial grass (not edible by the cattle, deep rooted and of spreading type) established subsequently for the stability of the waterway (*Panicum repens, Brachiaria mutica, Cynodon plectostahyus, Cynodon dactylon and Paspalum notatum, etc*.) (Meena *et al*., 2018).

While planning the activities for individual farmers in the micro watershed all the activities like conservation measures in the land owned by them, crop plan, nutrient plan, animal husbandry, livelihood activities *etc*., are to be prepared. To prepare the activities as a first step survey number wise details of farmers to be collected. The farmer details should include identifying information like name, father's name, gender, land holding and caste category, village *etc*. Referring to LRI and hydrology atlases, the activities proposed to be taken are soil conservation and their technical specifications need to be mentioned along with the unit cost and total cost. Likewise, it should be detailed for all the farmers in the micro watershed. Following format will be useful to capture the required information.

**Table 45: Details of beneficiary-wise activities**

**Sub watershed:** **Micro watershed:**

| *Sl. No. (1)* | *G.P name (2)* | *Village name (3)* | *Survey No. (4)* | *Hissa No. (5)* | *Area* | | |
|---|---|---|---|---|---|---|---|
| | | | | | *Acre (6)* | *Gunta (7)* | *Hectare (8)* |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |

| *Farmer Name with Father/ Husband Name (9)* | *Gender (M/F) (10)* | *Code (11)* | *Caste (12)* | *LMU (13)* | *Activity (14)* | *Unit (Rmt/ ha/ No.) (15)* | *Size/ Section (16)* |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

| *Quantity per ha (17)* | *Actual Quantity (18)* | *Unit Cost (Rs.) (19)* | *Waste Weir (Rs.) (20)* | *Total Activity Cost (Rs.) (21)* |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

## Decision criteria for selection of crops based on LRI output

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 is done based on certain principles.

**Principles of land evaluation:**

Certain principles are fundamental to the approach and methods employed in land evaluation. These basic principles are as follows:

1. Land suitability assessment and classification with respect to specified kinds of use (Ramamurthy *et al*., 2018)

2. Evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land

3. A multidisciplinary approach is required (Niranjan *et al*., 2011; Das and Sudhakar, 2014; Gautam *et al*., 2017)

4. Evaluation is made in terms relevance to the physical, economic and social context of the area concerned (Niranjan *et al*., 2011; Das and Sudhakar, 2014; Gautam *et al*., 2017; Ramamurthy *et al*., 2018)

5. Suitability refers to use on a sustained basis (Ramamurthy *et al*., 2018)

6. Evaluation involves comparison of more than a single kind of use (Narayana Swamy, 2017)

**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 (*Rabi*a 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 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.

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

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

2. Finalisation of suitability criteria for the crop or crops to be assessed. The criteria table developed for each crop will show the soil-site and other land characteristics on one side and the range of values assigned to each of the land characteristics for different suitability classes like Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), Currently Not Suitable (N1) and Not Suitable (N2) on the other side

3. Match the crop suitability criteria with LRI, Hydrology and other resource information pertaining to the farm/survey number stored in the system

4. Law of Minimum/Limitation approach in assigning the degree of suitability

5. Internal prioritization among crops with same rank

6. Displaying the suitable crops (on prioritization basis) with all limiting factors as sub-script

7. 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.

**Table 25: Land suitability criteria for Maize**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 30-34 | 35-38<br>26-30 | 38-40<br>26-20 | |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. temp. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Moderately well drained | Poorly drained | Very poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | scl, cl, sc | c (red),<br>c (black) | ls, sl | - |
| | pH | 1:2.5 | 5.5-7.8 | 5.0-5.5<br>7.8-9.0 | >9.0 | - |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds $m^{-1}$ | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | 5-10 | 10-15 | >15 | - |
| Erosion hazard | Slope | % | 0-3 | 3-5 | 5-10 | >10 |

**Table 26: Land suitability criteria for Sorghum**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 26–30 | 30–34; 24–26 | 34–40; 20–24 | >40; <20 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Moderately well drained | Poorly drained | Very poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | sc, c (red), c (black) | scl, cl | ls, sl | - |
| | pH | 1:2.5 | 5.5-7.8 | 5.0-5.5 7.8-9.0 | >9.0 | - |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | 10-15 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | 5-10 | 10-15 | >15 | |
| Erosion hazard | Slope | % | 0-3 | 3-5 | 5-10 | >10 |

**Table 27: Land suitability criteria for Bajra (Pearl millet)**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 28-32 | 33-38<br>24-27 | 39-40<br>20-23 | <20 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | 500-750 | 400-500 | 200-400 | <200 |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | Length of growing period for short duration | Days | | | | |
| | Length of growing period for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Moderately well drained | Poorly drained | Very poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | sl, scl, cl, sc, c (red) | c (black) | ls | - |
| | pH | 1:2.5 | 6.0-7.8 | 5.0-5.5<br>7.8-9.0 | 5.5-6.0<br>>9.0 | |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | 15-35 | 35-60 | >60 | |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | 5-10 | 10-15 | >15 | |
| Erosion | Slope | % | 1-3 | 3-5 | 5-10 | >10 |

**Table 28: Land suitability criteria for Red gram**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 30-35(G)<br>20-25(AV)<br>15-18 (F&PS)<br>35-40(M) | 25-30(G)<br>20-25 (AV)<br>12-15 (F&PS)<br>30-35(M) | 20-25(G)<br>15-20(AV)<br>10-12 (F&PS)<br>25-30(M) | < 20<br><15<br><10<br><25 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration crop | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. Well drained | Poorly drained | Very Poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | sc, c (red) | c (black), sl, scl, cl | ls | - |
| | pH | 1:2.5 | 6.0-7.8 | 5.5-6.0<br>7.8-9.0 | 5.0-5.5<br>>9.0 | - |
| | CEC | c mol ($P^+$) $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >100 | 75-100 | 50-75 | <50 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <1.0 | 1.0-2.0 | >2.0 | |
| | Sodicity (ESP) | % | 5-10 | 10-15 | >15 | |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 29: Land suitability criteria for Bengal gram**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 20–25 | 25–30; 15–20 | 30–35; 10–15 | >35; <10 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | Length of growing period for short duration | Days | | | | |
| | Length of growing period for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. Well drained | Poorly drained | Very Poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | c (black) | - | c (red), scl, cl, sc | ls, sl |
| | pH | 1:2.5 | 6.0-7.8 | 5.0-6.0 7.8-9.0 | >9.0 | - |
| | CEC | c mol ($P^+$) $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | 5-10 | 10-15 | >15 | - |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 30: Land suitability criteria for Field bean**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 20-35 | 18-20<br>35-40 | 15-18<br>40-45 | <15<br>>45 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. Well drained | Poorly drained | Very Poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | c (red), sl, scl, cl, sc | c (black) | ls | - |
| | pH | 1:2.5 | 6.0-7.8 | 5.5-6.0<br>7.8-8.4 | 5.0-5.5<br>8.4-9.0 | >9.0 |
| | CEC | c mol $(P^{+})$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | 5-10 | 10-15 | >15 | |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 31: Crop suitability criteria for Groundnut**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 24–33 | 22–24; 33–35 | 20–22; 35–40 | <20; >40 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. Well drained | Poorly drained | Very Poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | scl | sl, cl, sc | c (red), c (black), ls | - |
| | pH | 1:2.5 | 6.0-7.8 | 5.5-6.0 7.8-8.4 | 5.0-5.5 8.4-9.0 | >9.0 |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <35 | 35-60 | >60 | |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | <5 | 5-10 | 10-15 | >15 |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 32: Land suitability criteria for Sesame**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable S1* | *Mod. suitable S2* | *Mar. suitable S3* | *Not suitable N* |
| Climatic regime | Mean temperature in growing season | °C | 30-34 | 30-25<br>34-38 | 25-20<br>38-40 | <20<br>>40 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for varieties | Early | >90 | 70-90 | 60-70 | <60 |
| | | Medium | >120 | 90-120 | 70-90 | <70 |
| | | Late | >150 | 120-150 | 90-120 | <90 |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. well drained | Imp. to poorly drained | Very poorly drained |
| | Water logging | Days | | | | |
| Nutrient availability | Texture | Class | scl, l, sil, cl, sl | sicl, sc c (red) | ls, c (black) | s |
| | pH | 1:2.5 | 5.5-7.5 | 7.5-8.0<br>5.0-5.5 | 8.0-9.0<br>4.9-4.5 | <4.5<br>>9.0 |
| | CEC | c mol $(P^{+})$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | | | |
| | OC | % | High | Medium | Low | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 50-25 | <25 |
| | Stoniness | % | <15 | 15-35 | 25-35 | >35 |
| | Coarse fragments | Vol % | | | | |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <1.0 | 1.0-2.0 | 2.0-4.0 | >4.0 |
| | Sodicity (ESP) | % | <5 | 5-10 | 10-15 | >15 |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 33: Land suitability criteria for Cotton**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Mar. suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 22-32 | >32 | <19 | - |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP period for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well to moderately well | P.drained/ Somewhat ex. drained | - | v.poorly/ ex. drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | sc, c (red and black) | cl | scl | ls, sl |
| | pH | 1:2.5 | 6.5-7.8 | 7.8-8.4 | 5.5-6.5 8.4->9.0 | <5.5 |
| | CEC | c mol ($P^+$) $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >100 | 50-100 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | 5-10 | 10-15 | >15 | |
| Erosion hazard | Slope | % | <3 | 3-5 | - | >5 |

**Table 34: Land suitability criteria for Chillies**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 25-32 | 33-35<br>20-25 | 35-38<br><20 | >38 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Moderately well drained | Poorly drained | Very poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | scl, cl, sc | c (black), sl | ls | - |
| | pH | 1:2.5 | 6.0-7.3 | 5.0-6.0<br>7.3-8.4 | 8.4-9.0 | >9.0 |
| | CEC | c mol ($P^+$) $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | <5 | 5-10 | 10-15 | >15 |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 35: Land suitability criteria for Guava**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 28-32 | 33-36<br>24-27 | 37-42<br>20-23 | |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Moderately well drained | Poorly drained | Very poorly drained |
| | Water logging | Days | | | | |
| Nutrient availability | Texture | Class | scl, cl, sc, c (red) | sl | c (black), ls | - |
| | pH | 1:2.5 | 6.0-7.8 | 5.0-6.0 | 7.8-8.4 | >8.4 |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >100 | 75-100 | 50-75 | <50 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2.0 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | <5 | 5-10 | 10-15 | >15 |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 36: Land suitability criteria for Coconut**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 26–29 | 23–25; 30–32 | 20–22; 32–34 | |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. to poorly drained | - | Very poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | scl, cl, | sl, c (red) | ls, c (black) | - |
| | pH | 1:2.5 | 5.0-7.3 | 7.3-7.8 | 7.8-8.4 | >8.4 |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >100 | 75-100 | 50-75 | <50 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | <5 | 5-10 | 10-15 | >15 |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 37: Land suitability criteria for Jackfruit**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | | | | |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. Well drained | Poorly drained | Very poorly drained |
| | Water logging | Days | | | | |
| Nutrient availability | Texture | Class | scl, cl, sc, c (red) | - | sl, ls, c (black) | - |
| | pH | 1:2.5 | 5.5-7.3 | 5.0-5.5 7.3-7.8 | 7.8-8.4 | >8.4 |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >100 | 75-100 | 50-75 | <50 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | >60 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2.0 | 2-4 | 4-8 | >8.0 |
| | Sodicity (ESP) | % | <5 | 5-10 | 10-15 | >15 |
| Erosion hazard | Slope | % | 0-3 | 3-5 | 5-10 | >10- |

**Table 38: Land suitability criteria for Mango**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 28-32 | 24-27<br>33-35 | 36-40 | 20-24 |
| | Min temp. before flowering | °C | 10-15 | 15-22 | >22 | - |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. well drained | Poorly drained | Very Poorly drained |
| | Water logging | Days | | | | |
| Nutrient availability | Texture | Class | scl, cl, sc, c (red) | - | ls, sl, c (black) | - |
| | pH | 1:2.5 | 5.5-7.3 | 5.0-5.5<br>7.3-8.4 | 8.4-9.0 | >9.0 |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Eff. soil depth | cm | >150 | 100-150 | 75-100 | <75 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2.0 | 2-4 | 4-8 | >8.0 |
| | Sodicity (ESP) | % | <5 | 5-10 | 10-15 | >15 |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 39: Land suitability criteria for Cashew**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 32 to 34 | 28 to 32; 34 to 38 | 24 to 28; 38 to 40 | <20; >40 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. well drained | Poorly drained | Very poorly drained |
| | Water logging | Days | | | | |
| Nutrient availability | Texture | Class | scl, cl, sc, c (red) | - | sl, ls | c (black) |
| | pH | 1:2.5 | 5.5-6.5 | 5.0-5.5 6.5-7.3 | 7.3-7.8 | >7.8 |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >100 | 75-100 | 50-75 | <50 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2 | 2-4 | 4-8 | >8 |
| | Sodicity (ESP) | % | <5 | 5-10 | 10-15 | >15 |
| Erosion hazard | Slope | % | <3 | 3-10 | >10 | - |

**Table 40: Land suitability criteria for Potato**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 16-25 | 26-30<br>13-15 | 31-32<br>10-12 | >32<br><10 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP- short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Moderately well drained | - | Poorly to very poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | scl, cl, sl, sc | ls (red) | s, c (black) | - |
| | pH | 1:2.5 | 5.5-6.5 | 5.0-5.5<br>6.5-7.8 | 7.8-8.4 | >8.4 |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2.0 | 2-4 | 4-8 | >8.0 |
| | Sodicity (ESP) | % | | | | |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 41: Land suitability criteria for Tomato**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 25-28 | 29-32<br>20-24 | 15-19<br>33-36 | <15<br>>36 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LPG for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Moderately well drained | Poorly drained | Very poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | sl, scl, cl, sc, c (red) | - | ls, c (black) | - |
| | pH | 1:2.5 | 6.0-7.3 | 5.0-6.0<br>7.3-8.4 | 8.4-9.0 | >9.0 |
| | CEC | c mol $(P^+)$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2.0 | 2-4 | 4-8 | >8.0 |
| | Sodicity (ESP) | % | <5 | 5-10 | 10-15 | >15 |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 42: Land suitability criteria for Marigold**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 18-23 | 17-15<br>24-35 | 35-40<br>10-14 | >40<br><10 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Moderately well drained | Poorly drained | Very Poorly drained |
| | Water logging in growing season | Days | | | | |
| Nutrient availability | Texture | Class | sl,scl, cl, sc, c (red) | c (black) | ls | - |
| | pH | 1:2.5 | 6.0-7.3 | 5.0-6.0<br>7.3-8.4 | 8.4-9.0 | >9.0 |
| | CEC | c mol $(P^{+})$ $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Eff. soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2.0 | 2-4 | 4-8 | >8.0 |
| | Sodicity (ESP) | % | | | | |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 43: Land suitability criteria for Chrysanthemum**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | 18-23 | 17-15<br>24-35 | 35-40<br>10-14 | >40<br><10 |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Moderately well drained | Poorly drained | V.Poorly drained |
| | Water logging | Days | | | | |
| Nutrient availability | Texture | Class | sl,scl, cl, sc, c (red) | c (black) | ls | - |
| | pH | 1:2.5 | 6.0-7.3 | 5.0-6.0<br>7.3-8.4 | 8.4-9.0 | >9.0 |
| | CEC | c mol ($P^+$) $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity (EC saturation extract) | ds/m | <2.0 | 2-4 | 4-8 | >8.0 |
| | Sodicity (ESP) | % | | | | |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Table 44: Land suitability criteria for Crossandra**

| *Land use requirement* | | | *Rating* | | | |
|---|---|---|---|---|---|---|
| *Characteristics* | | *Unit* | *Highly suitable (S1)* | *Moderately suitable (S2)* | *Marginally suitable (S3)* | *Not suitable (N1)* |
| Climatic regime | Mean temperature in growing season | °C | | | | |
| | Mean max. temp. in growing season | °C | | | | |
| | Mean min. tempt. in growing season | °C | | | | |
| | Mean RH in growing season | % | | | | |
| | Total rainfall | mm | | | | |
| | Rainfall in growing season | mm | | | | |
| Moisture availability | LGP for short duration | Days | | | | |
| | LGP for long duration | Days | | | | |
| | AWC | mm/m | | | | |
| Oxygen availability to roots | Soil drainage | Class | Well drained | Mod. well drained | - | Poorly to very poorly drained |
| | Water logging | Days | | | | |
| Nutrient availability | Texture | Class | scl, cl, sc, c(red) | sl, | c (black), ls | - |
| | pH | 1:2.5 | 6.0-7.3 | 5.0-6.0 7.3-8.4 | 8.4-9.0 | >9.0 |
| | CEC | c mol ($P^+$) $kg^{-1}$ | | | | |
| | BS | % | | | | |
| | $CaCO_3$ in root zone | % | | <5 | 5-10 | >10 |
| | OC | % | | | | |
| Rooting conditions | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| | Stoniness | % | | | | |
| | Coarse fragments | Vol % | <15 | 15-35 | 35-60 | 60-80 |
| Soil toxicity | Salinity | ds/m | <2.0 | 2-4 | 4-8 | >8.0 |
| | Sodicity (ESP) | % | | | | |
| Erosion hazard | Slope | % | <3 | 3-5 | 5-10 | >10 |

**Decision criteria for selection of nutrient management based on LRI output**

In watersheds, the flow of water on or beneath the surface (rivers, lakes, estuaries and aquifers) have the tendency to dissolve nutrients (both applied and naturally occurring) and carry them to the distant locations where they may get assimilated or cause other physico-chemical impacts, absorbed by vegetation like weed or crop.

In an undeveloped watershed, hydrologic and nutrient loads are commonly low, and surface water quality is very good. When new techniques like soil and water conservation techniques are adopted along with the nutrient application in order to develop the watershed for its suitability to grow crops, there may be chance of nutrient contamination and eutrophication of the waterbodies. As nutrient loads increase due to development and land use, surface waters become eutrophic (an increase in algal productivity, causing poorer water quality) and are commonly listed as "impaired" on state lists. A surface water segment is listed as impaired when the measured water quality exceeds the state standard. The nutrient producing the impairment may be phosphorus, nitrogen, or both. The primary nutrient causing water quality impairment in a given water body is termed the "limiting" nutrient. Freshwaters are commonly phosphorus-limited, while brackish and salt waters are commonly nitrogen limited. Certain types of algae present in surface waters can actually fix, or capture, nitrogen from the atmosphere.

Raising environmental awareness among stakeholders is the key for successful nutrient management in watersheds, which aims at improving crop yields besides affecting the environment. Among the various techniques available for gathering the information on the existing soil nutrient status, the technique, which involves realistic, on-site information, serves the best purpose of maximal crop productivity without affecting the environment. One among such methods is Land Resource Inventory (LRI), which involves analysis of site and soil characteristics, which can be used to assess the health of the soil directly in the field along with fertility or nutrient status of the soil based on laboratory analysis.

LRI outputs generated in the form of soil fertility thematic maps/data in atlas forms the base for taking decision for selection of nutrient management strategy

**Table 46: Soil fertility criteria for adjusting the recommended fertilizer doses for macro nutrient application (NPK)**

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

**Note:** For example, if the recommended dose of N for irrigated maize is 150 kg $ha^{-1}$ and if the nutrient content of the soil is very low, then we need to add 250 kg $ha^{-1}$ (150 x 1.67), for low 200 kg $ha^{-1}$ (150 x 1.33), for medium 150 kg $ha^{-1}$ (150 x 1.0), for high 100 kg $ha^{-1}$ (150 x 0.67)

and for very high 50 kg $ha^{-1}$ (150 x 0.33). Similarly, for phosphorus and potassium, the fertilizer requirements are calculated using the above formula.

**Table 47: General recommended doses of micronutrients and sulphur fertilisers**

| *Micro nutrients* | *Critical limits (ppm)* | *Dry/ Irrigated* | *Elemental form recommended (kg $ha^{-1}$)* | *Micronutrient fertiliser and quantity for application (*kg $ha^{-1}$*)* | |
|---|---|---|---|---|---|
| | | | | *Soil application* | *Foliar spray* |
| Zinc | 0.6 | Dry | 3.15 | Zinc Sulphate $7H_2O$ 10 | 0.5% Zinc Sulphate $7H_2O$ + 0.25% lime |
| | | Irrigated | 5.25 | 25 | |
| Iron | 4.5 | Dry | 1.90 | Ferrous Sulphate 10 | 1% Ferrous Sulphate + 0.5% Lime |
| | | Irrigated | 4.75 | 25 | |
| Copper | 0.2 | Dry | 1.20 | Copper Sulphate 5 | 0.1% Copper Sulphate + 0.05% Lime |
| | | Irrigated | 2.40 | 10 | |
| Manganese | 2.0 | Dry | 3.05 | Manganese Sulphate 10 | 1% Manganese Sulphate + 0.25% Lime or 0.5% Manganese Sulphate 3 sprays |
| | | Irrigated | 7.62 | 25 | |
| Boron | 0.5 | Dry | 0.53 | Borax 5 | 0.25% Borax |
| | | Irrigated | 1.05 | 10 | |
| Sulphur | 10.0 | Dry | 20 | Sulphates 20 | - |
| | | Irrigated | 20 | 40 | |

**Note**: Critical limits for micronutrient fertiliser is as per DTPA extractable content. Land ranging lower than the critical limits are to be supplemented with recommended dose in the suitable form

## DPR generation-consolidation of all activities for a micro watershed

Consolidation of DPR

Format for consolidation of DPR is presented below:

Name of the Project: Rejuvenating of Watersheds for Agriculture Resilience through Innovative Development (REWARD) Program

Detailed Project Report (DPR)

for …… (code) Sub watershed of

…… Taluka/Block

……..…District

Name and Address of the Department
Watershed Development Department

# Certificate

**Sub watershed Name……..**
**Micro watershed Name……..**
**Village……**
**Total Area……**

## Certificate

This is to certify that the action plan was developed for the micro watershed……through active participation of the people. In the Grama sabha, budget for different components, project share for the activities on the individual farmer's land their share of contribution, works on common lands were presented and consent of the concerned persons was obtained.

**CONTENTS**

| | | | |
|---|---|---|---|
| | | characterization and mapping of soil (soil map),<br>water, and other resources of the area)<br>**(Source : LRI report, …..)** | |
| | 4.2 | **Profile study details**<br>(Details of the profile study, grid survey, soil and water samples collected - include major landscape, soil photos)<br>**(Source : LRI report, …..)** | |
| | 4.3 | **Land use**<br>(major crops and other land uses identified and mapped with their area and distribution- with the map and data in tables)<br>**(Source : LRI report, …..)** | |
| | 4.4 | **Soils**<br>(describe the major soils identified and their characteristics-include soil map of the MWS with units described)<br>**(Source : LRI report, …..)** | |
| | 4.5 | **Soil fertility status**<br>(indicate the fertility status of the area-both micro and macro nutrients with maps and data in a tabular form) | |
| | 4.6 | **Location of waterbodies, wells, existing conservation, and harvesting structures *etc*.,**<br>(include maps)<br>**(Source : LRI report, …..)** | |
| | 4.7 | **Water quality and status of ground water in the area**<br>(with maps)<br>**(Source : LRI report, …..)** | |
| **5** | **Constraints and potentials of the watershed** | | |
| | 5.1 | **Major constraints / potentials**<br>(Describe the major constraints/potentials like severity and status of soil erosion, slope, texture, soil depth, presence of gravels, acidity/alkalinity, drainage, rate of runoff *etc* and include maps to highlight the same and show the unit wise soil-site constraints/potentials of the MWS in a tabular form)<br>**(Source : LRI report, …..)** | |
| | 5.2 | **Water balance and categorization of the MWS** (sufficient/deficient one as per the water balance arrived)<br>**(Source : LRI report, …..)** | |
| | 5.3 | **Water budget for the micro watershed** (by taking into consideration the requirements of the population (human and cattle), irrigation needs, industries, mandated or minimum environmental flow to be allowed *etc*)<br>**(Source : LRI report, …..)** | |
| **6** | **Land capability grouping and identification of arable and non-arable lands** | | |
| | 6.1 | **Capability classes identified**<br>(Describe the capability classes identified, arable and non-arable lands and their distribution-classes shown in a tabular form with LCC map of the MWS area)<br>**(Source : LRI report, …..)** | |
| **7** | | **Soil conservation and water harvesting plan** | |
| | 7.1 | **Criteria used to prepare the plan** | |

| | | | |
|---|---|---|---|
| | | (Describe briefly about the criteria/expert system/DSS used to prepare the plan)<br>**(Source : LRI report, …..)** | |
| | 7.2 | **Conservation plan for arable lands**<br>(with map)<br>**(Source : LRI report, …..)** | |
| | 7.3 | **Conservation plan for non- arable lands**<br>(with map)<br>**(Source : LRI report, …..)** | |
| | 7.4 | **Drainage line treatment details**<br>(map and table)<br>**(Source : LRI report, …..)** | |
| **8** | **Development of crop plan**<br>(Productivity improvement plan)<br>**(Source : LRI report, …..)** | | |
| | 8.1 | **Suitability assessment, suitability classes identified for major crops and land uses**<br>(Describe briefly about the suitability assessment, suitability classes identified for major crops and land uses (cereals, pulses, oil seeds, commercial crops, horticulture, fodder, forestry *etc*))<br>**(Source : LRI report, …..)** | |
| | 8.2 | **Unit wise suitability classes identified for major crop cultivated in the area**<br>(Prepare map unit wise suitability classes identified for major crop cultivated in the area in a tabular form along with maps)<br>**(Source : LRI report, …..)** | |
| **9** | **Development of nutrient management plan** | | |
| | 9.1 | **Sequence of activities involved in preparing nutrient management plan**<br>(Describe the sequence of activities involved in preparing nutrient management plan for the crop or crops selected by the farmer / WDD -this will capture the present nutrient status of the farm/parcel, amount of fertilizer required, dosage at different growth periods, package of practices to be followed *etc*.)<br>**(Source : LRI report, …..)** | |
| **10** | **Plan for taking up other interventions** | | |
| | 10.1 | **Identification of areas**<br>(Identification of areas for taking up agro-forestry, animal husbandry, fisheries *etc*. and preparation of plans for the same with maps)<br>**(Source : LRI report, …..)** | |
| **11** | | **Plan for livelihood activities**<br>(to be elaborated in this section.) | |
| **12** | | **Development of water balance and water budget for the area** | |
| | 12.1 | **Water balance and water budget**<br>(Indicate the water balance components like precipitation, runoff, soil moisture, ground water recharge, prepare budget based on the consumption/allocation as it exists and indicate the surplus or deficit at the MWS level.) | |
| **13** | | **Any other intervention relevant for the area** | |

| | | | |
|---|---|---|---|
| **14** | | **Finalization of detailed project report (DPR)** | |
| **15** | | **Convergence plan with other departments/schemes** | |
| **16** | | **Details of community contribution to be mobilized** | |
| **17** | | **DPR Implementation-Annual action plan (Physical and Financial)** | |
| **18** | | **Action plan for post project management** | |
| **19** | | **Annexure** | |
| | 1 | Cadastral Map of the MWS<br>**(Source : LRI report, …..)** | |
| | 2 | HR Imagery of the area<br>**(Source : LRI report, …..)** | |
| | 3 | Cadastral Map overlaid on Imagery<br>**(Source : LRI report, …..)** | |
| | 4 | Land Use and Cover map<br>**(Source : LRI report, …..)** | |
| | 5 | Existing conservation structures map<br>**(Source : LRI report, …..)** | |
| | 6 | Well inventory map<br>**(Source : LRI report, …..)** | |
| | 7 | Existing water bodies map<br>**(Source : LRI report, …..)** | |
| | 8 | Soil map<br>**(Source : LRI report, …..)** | |
| | 9 | Unit wise soil<br>(site characteristics, nutrient status, suitability *etc* in tabular form)<br>**(Source : LRI report, …..)** | |
| | 10 | Thematic maps<br>(slope, erosion, soil depth, soil texture, soil reaction, nutrient status *etc*.-include only the important/critical maps of the area)<br>**(Source : LRI report, …..)** | |
| | 11 | Soil and water conservation plan map of the MWS<br>**(Source : LRI report, …..)** | |
| | 12 | Drainage line treatment map<br>(Check dams, other structures planned for each MWS)<br>**(Source : By Traversing)** | |
| | 13 | Proposed crop plan<br>(Crop suitability maps of the dominant crops)<br>**(Source : LRI report, …..)** | |
| | 14 | Proposed Horticulture, agro forestry<br>(forestry, Animal husbandry and other interventions plan with maps)<br>**(Source : LRI report, …..)** | |
| | 15 | Proposed Nutrient Management plan<br>**(Source : LRI report, …..)** | |
| | 16 | Abstract - Micro Watershed plan | |
| | 17 | Abstract – Soil & Water Conservation plan | |
| | 18 | Abstract – Horticulture activity | |
| | 19 | Abstract – Forestry activity | |
| | 20 | Abstract - Animal Husbandry and other activities | |

| | | | |
|---|---|---|---|
| | 21 | Farmer wise action plan for soil and water conservation, and other interventions with cost. This is to be prepared village wise for each micro watershed of the project area (SWS) | |
| | 22 | Action plan for Common land | |
| | 23 | Documents of Agreements, Approval forms *etc*. | |
| | 24 | Proceedings of Gram Sabha/PRIs for DPR Approval | |
| | 25 | List SHGs/AG Members, FPOs, NGOs *etc*. | |
| | 26 | Environmental and Social Safeguards Assessment Screening Checklist | |

**Formats for consolidation of all sectors programs in a DPR**

**Table 1: Treatable and Non-Treatable Area in a Micro Watershed**

District :
Taluk :
Sub Watershed :
Micro Watershed :
Name of the G.Ps Covered :
Name of the Villages Under Each G.P :

| *Sl. No.* | *Particulars* | *Area (ha)* |
|---|---|---|
| 1 | Total Geographic Area | |
| 2 | Reserved Forest Area | |
| 3 | Program Area | |
| 4 | Area Not Available for Treatment | |
| | a) Quarry | |
| | b) Water Spread Across Tanks | |
| | c) Settlement | |
| | d) Rocky-Hillocks Which Cannot be Treated | |
| | e) Others | |
| 5 | Total Area Not Available for Treatment | |
| 6 | Total Rain fed Agricultural Area | |
| 7 | Total Treatable Wasteland Area | |
| 8 | Total Area Proposed for Treatment (7=5+6 or 7=3-4) | |

**Table 2: Land Holding Size Wise Class and Caste-Wise Distribution of Farmer**

District :
Taluk :
Sub Watershed :
Micro Watershed :

| *Sl. No.* | *Category* | *Area (ha)* | | | | *Number of Farmers* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Land Holding Size Class* | *Others* | *SC* | *ST* | *Total* | *Others* | *SC* | *ST* | *Total* |
| 1 | Big Farmer | | | | | | | | |
| 2 | Marginal Farmer | | | | | | | | |
| 3 | Small Farmer | | | | | | | | |
| 4 | *Total* | | | | | | | | |

**Table 3: Micro Watershed Reach Wise/Location/Caste Distribution**

District :
Taluk :
Sub Watershed :
Micro Watershed :

| *Sl. No.* | *Reach/Location* | *Number of Farmers* | | | |
|---|---|---|---|---|---|
| | | *Others* | *SC* | *ST* | *Total* |
| 1 | Upper | | | | |
| 2 | Middle | | | | |
| 3 | Lower | | | | |
| 4 | *Total* | | | | |

**Table 4: Micro Watershed Wise Action Plan (Overview)**

District :
Taluk :
Sub Watershed :
Micro Watershed :

| *Sl. No.* | *Particulars* | *Proposed Treatment Area (ha)* | *Proposed Cost (Rs. lakhs)* | *Contribution (Rs. lakhs)* |
|---|---|---|---|---|
| 1 | Private Land | | | |
| 2 | Common Land | | | |
| | *Total* | | | |

**Table 5: Micro Watershed Wise Action Plan (Abstract)**

District :
Taluk :
Sub Watershed :
Micro Watershed :

| *Sl. No.* | *Particulars* | *Total Cost (Rs. lakhs)* | *Total Contribution (Rs. lakhs)* |
|---|---|---|---|
| 1 | *Private Land Treatment* | | |
| | Soil & Water Conservation | | |
| | Horticulture | | |
| | Forestry | | |
| | *Private Land Total* | | |
| 2 | *Common Land* | | |
| | Soil & Water Conservation | | |
| | Drainage Line Treatment | | |
| | Horticulture | | |
| | Forestry | | |
| | *Common Land Total* | | |
| 3 | Animal Husbandry Activities | | |

| | | | |
|---|---|---|---|
| 4 | Production System | | |
| 5 | Capacity Building and Training | | |
| 6 | Administrative Expenses | | |
| | *Grand Total* | | |

Extent of Private Land Proposed for Treatment (ha) :
Extent of Common Land Proposed for Treatment (ha) :
*Total* (ha) :

**Table 6: Micro Watershed Wise Action Plan**

District :
Taluk :
Sub Watershed :
Micro Watershed :

| *Sl. No.* | *Sector/ Activity Name/ Sub Activity* | *Unit* | *Quantity* | *Total Cost (Rs. lakhs)* |
|---|---|---|---|---|
| | *Private Land Treatment* | | | |
| | *Soil and Water Conservation* | | | |
| 1 | Trench Cum Bund | Rmt | | |
| 2 | Vegetative Bund | Rmt | | |
| 3 | Pebble Bund | Rmt | | |
| 4 | Crescent Bund | Rmt | | |
| 5 | Boulder Checks | No. | | |
| 6 | Farm Ponds | No. | | |
| | *Sector Total* | | | |
| | *Horticulture* | | | |
| 1 | Bund Sowing | ha | | |
| 2 | Block Plantation | ha | | |
| 3 | Vegetable Minikit | No. | | |
| 4 | Homestead Garden | No. | | |
| | *Sector Total* | | | |
| | *Forestry* | | | |
| 1 | Bund Planting and Agro Forestry | ha | | |
| 2 | Seed Dibbling | ha | | |
| 3 | Road Side Planting | km | | |
| | *Sector Total* | | | |
| | *Private Land Treatment Total* | | | |
| | *Common Land Treatment* | | | |
| | *Soil and Water Conservation* | | | |
| 1 | | | | |

| | | | | |
|---|---|---|---|---|
| 2 | | | | |
| | *Sector Total* | | | |
| | *Drainage Line treatment* | | | |
| 1 | | | | |
| 2 | | | | |
| | *Sector Total* | | | |
| | *Horticulture* | | | |
| 1 | | | | |
| 2 | | | | |
| | *Sector Total* | | | |
| | *Forestry* | | | |
| 1 | | | | |
| 2 | | | | |
| | *Sector Total* | | | |
| | *Common Land Treatment Total* | | | |
| | *Animal Husbandry* | | | |
| 1 | | | | |
| 2 | | | | |
| | *Sector Total* | | | |
| | *Production System* | | | |
| 1 | Demo | | | |
| 2 | Integrated Farming System | | | |
| | *Sector Total* | | | |
| | *Capacity Building and Training* | | | |
| 1 | CBO Training | | | |
| 2 | District Level Workshop | | | |
| 3 | Exposure Visit | | | |
| | *Sector Total* | | | |
| | *Administrative Expenditure and Other* | | | |
| | *Salary of Outsourced Staff* | | | |
| | *Documentation* | | | |
| | *Other Expenses* | | | |
| | *Sector Total* | | | |
| | *Grand Total* | | | |

**Table 7: Convergence of development departments activities**

| *Sl. No.* | *Department* | *Activity* | *Quantity* | *Amount (Rs.)* |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |

**Table 7: Details of Institution and Project Management**

| *Sl. No.* | *Particulars* | *Details* |
|---|---|---|
| 1 | Project Implementing Agency (PIA) | |
| 2 | Office Telephone Number | |
| 3 | Official Email-id | |
| 4 | Contact Officer Name | |
| 5 | Contact Officer Cell Number | |

**Table 8: Details of Staff at Project Implementing Agency (PIA)**

| *Sl. No.* | *Staff Name* | *Designation* |
|---|---|---|
| 1 | | |
| 2 | | |

**Table 9: Details of Watershed Development Team (WDT)**

| *Sl. No.* | *Staff Name* | *Designation* |
|---|---|---|
| 1 | | |
| 2 | | |

**Table 10: Details of NGO**

| *Sl. No.* | *Particulars* | *Details* |
|---|---|---|
| 1 | Name of the NGO | |
| 2 | Name of the Team Leader | |
| 3 | Address | |
| 4 | Phone Number | |

**Table 11: Details of the Institution Carried out LRI & Hydrology Studies**

| *Sl. No.* | *Particulars* | *Details* |
|---|---|---|
| 1 | Name of the Institution | |
| 2 | LRI Nodal Officer | |
| 3 | Phone Number | |
| 4 | Email-id | |
| 5 | Hydrology Nodal Officer | |
| 6 | Phone Number | |
| 7 | Email-id | |

**Table 12: Details of Watershed Committee (WC)**

| *Sl. No.* | *Committee Members Name* | *Designation* |
|---|---|---|
| 1 | | |
| 2 | | |

**Table 13: Details of Self Help Group (SHG)**

| *Sl. No.* | *Particulars* | *Details* |
|---|---|---|
| 1 | Village Name | |
| 2 | SHG Name | |
| 3 | Formation Date | |
| 4 | Number of Males | |
| 5 | Number of Females | |

**Table 13.1: Details of Self Help Group Members**

**Name of the Self Help Group:** **Code:**

**Representatives Name**

**1.**

**2.**

| *Sl. No. (1)* | *G.P Name (2)* | *Village Name (3)* | *Name of the Member (4)* | *Gender (5)* | *Father/ Husband Name (6)* |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |

| *Area* | | | *Landholding Category (Large Farmer/ Marginal Farmer/ Small Farmer) (10)* | *Caste Category (SC/ST/Others) (11)* |
|---|---|---|---|---|
| *Acre (7)* | *Gunta (8)* | *Hectare (9)* | | |
| | | | | |
| | | | | |

**Table 14: Details of Area Group (AG)**

| *Sl. No.* | *Particulars* | *Details* |
|---|---|---|
| 1 | Village Name | |
| 2 | AG Name | |
| 3 | Formation Date | |
| 4 | Number of Males | |
| 5 | Number of Females | |
| | Total Members | |

**Table 14.1: Details of Area Group Members**

**Name of the Area Group:** **Code:**

**Representatives Name**

**1.**

**2.**

| *Sl. No. (1)* | *G.P Name (2)* | *Village Name (3)* | *Name of the Member (4)* | *Gender (5)* | *Father/ Husband Name (6)* |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |

| *Area* | | | *Landholding Category (Large Farmer/ Marginal Farmer/ Small Farmer) (10)* | *Caste Category (SC/ST/Others) (11)* |
|---|---|---|---|---|
| *Acre (7)* | *Gunta (8)* | *Hectare (9)* | | |
| | | | | |
| | | | | |

**Table 15: Details of Farmers Producer Organisation (FPO)**

| *Sl. No.* | *Particulars* | *Details* |
|---|---|---|
| 1 | Village Name | |
| 2 | FPO Name | |
| 3 | Registration Date | |
| 4 | Value Chain | |
| 5 | No. of Share Members | |
| 6 | Paid-up Capital/ Share Collected | |
| 7 | Turnover of Input Business | |
| 8 | Turnover of Output Business | |

**Table 15.1: Details of Famers Producer Organisation (FPO) Members**

| *Sl. No. (1)* | *Village Name (2)* | *FPO Name (3)* | *Name of the Member (4)* | *Gender (5)* | *Father/ Husband Name (6)* |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |

| *Landholding Category (Large Farmer/ Marginal Farmer/ Small Farmer) (7)* | *Caste Category (SC/ST/Others) (8)* | *BPL (Yes/No) (9)* |
|---|---|---|
| | | |
| | | |

**Table 16: Details of Entry Point Activity (EPA)**

District :
Sub Watershed :
Micro Watershed :

| *Sl. No.* | *Village Name* | *Entry Point Activity Name* | *Estimated Cost (Rs. lakhs)* | *Executing Agency* | *Latitude (Degree-Min-Sec)* | *Longitude (Degree-Min-Sec)* | *Months for Work Completion* |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |

**Table 17: Details of Private Land Treatment Beneficiary-Wise Activities**

**Sub Watershed:** **Micro Watershed:**

| *Sl. No. (1)* | *G.P Name (2)* | *Village Name (3)* | *Survey No. (4)* | *Hissa No. (5)* | *Area* | | |
|---|---|---|---|---|---|---|---|
| | | | | | *Acre (6)* | *Gunta (7)* | *Hectare (8)* |
| 1 | | | | | | | |
| 2 | | | | | | | |

| *Farmer Name with Father/ Husband Name (9)* | *Gender (M/F) (10)* | *Code (11)* | *Caste (12)* | *LMU (13)* | *Activity (14)* | *Unit (Rmt/ ha/ No.) (15)* | *Size/ Section (16)* |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |

| *Quantity per ha (17)* | *Actual Quantity (18)* | *Unit Cost (Rs.) (19)* | *Waste Weir (Rs.) (20)* | *Total Activity Cost (Rs.) (21)* |
|---|---|---|---|---|
| | | | | |
| | | | | |

**Table 18: Details of Common Land Activities**

**Sub watershed:** **MWS:**

| *Sl. No. (1)* | *Activity (2)* | *Dimension (3)* | *Quantity (4)* | *Unit Cost (Rs.) (5)* | *Total Cost (Rs.) (6)* |
|---|---|---|---|---|---|
| 1 | Boulder Check / Gully Plug | | | | |
| 2 | Rubble Check | | | | |
| 3 | Check Dam / Drop Structure | | | | |
| 4 | Cattle Pool (Gokatte) | | | | |
| 5 | Institution Plantation | | | | |
| 6 | Nala Revetment | | | | |
| 7 | Nala Plantation | | | | |
| 8 | Tank Development | | | | |
| 9 | Water Way | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 10 | Block Plantation - Burial Ground | | | | |
| 11 | RRS | | | | |
| 12 | RTW | | | | |
| 13 | Nala Bund | | | | |
| 14 | Diversion Channel | | | | |

| *Survey No.* *(7)* | *Village* *(8)* | *Location* *(9)* | *Expected No. of Beneficiaries* | | | |
|---|---|---|---|---|---|---|
| | | | *SC* *(10)* | *ST* *(11)* | *Others* *(12)* | *Total* *(13)* |
| | | | | | | |
| | | | | | | |
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| | | | | | | |

**Table 19: Expected Project Outcomes in Terms of Employment Generation**

| *Sl. No.* *(1)* | *Name of Village* *(2)* | *Wage Employment* | | | | |
|---|---|---|---|---|---|---|
| | | *Number of Man Days* | | | | |
| | | *SC* *(3)* | *ST* *(4)* | *Others* *(5)* | *Women* *(6)* | *Total (3+4+5)* *(7)* |
| 1 | | | | | | |
| 2 | | | | | | |

| *Wage Employment* | | | | | *Self-Employment* |
|---|---|---|---|---|---|
| *Number of Beneficiaries* | | | | | *No. of Beneficiaries* *(13)* |
| *SC* *(8)* | *ST* *(9)* | *Others* *(10)* | *Women* *(11)* | *Total (8+9+10)* *(12)* | |
| | | | | | |
| | | | | | |

**Table 20: Private Land Sectors Wise Summary**

| | | *Trench Cum Bund* | *Vegetative Bund* | *Pebble Bund* | *Crescent Bund* | *Boulder Checks* | *Farm Ponds* | *Grand Total (Rs.)* |
|---|---|---|---|---|---|---|---|---|
| SWC | Unit | | | | | | | |
| | Unit Rate (Rs.) | | | | | | | |
| | Total Quantity | | | | | | | |
| | Total Amount (Rs.) | | | | | | | |
| Agro Forestry | | *Neem* | *Pongamia* | *Melia dubia* | *Teak* | *Tamarind* | | |
| | Unit | | | | | | | |
| | Unit Rate (Rs.) | | | | | | | |
| | Total Quantity | | | | | | | |
| | Total Amount (Rs.) | | | | | | | |
| Horticulture | | *Mango* | *Sapota* | *Guava* | *Lime* | *Amla* | *Custard Apple* | |
| | Unit | | | | | | | |
| | Unit Rate (Rs.) | | | | | | | |
| | Total Quantity | | | | | | | |
| | Total Amount (Rs.) | | | | | | | |

**Table 21: Common Land Sectors Wise Summary**

| | | *Trench Cum Bund* | *Vegetative Bund* | *Pebble Bund* | *Crescent Bund* | *Boulder Checks* | *Farm Ponds* |
|---|---|---|---|---|---|---|---|
| SWC | Unit | | | | | | |
| | Unit Rate (Rs.) | | | | | | |
| | Total Quantity | | | | | | |
| | Total Amount (Rs.) | | | | | | |
| Agroforestry | | *Neem* | *Pongamia* | *Melia dubia* | *Teak* | *Tamarind* | |
| | Unit | | | | | | |
| | Unit Rate (Rs.) | | | | | | |
| | Total Quantity | | | | | | |
| | Total Amount (Rs.) | | | | | | |
| Hortic | | *Mango* | *Sapota* | *Guava* | *Lime* | *Amla* | *Custard Apple* |
| | Unit | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Unit Rate (Rs.) | | | | | | |
| | Total Quantity | | | | | | |
| | Total Amount (Rs.) | | | | | | |

| | | *Check Dam* | *Cattle Pool (Gokatte)* | *RRS* | *Desilting of Nala* | *Grand Total (Rs.)* |
|---|---|---|---|---|---|---|
| SWC | Unit | | | | | |
| | Unit Rate (Rs.) | | | | | |
| | Total Quantity | | | | | |
| | Total Amount (Rs.) | | | | | |
| Agroforestry | | *Silveroak* | *Simaruba* | *Agave on Bunds* | | |
| | Unit | | | | | |
| | Unit Rate (Rs.) | | | | | |
| | Total Quantity | | | | | |
| | Total Amount (Rs.) | | | | | |
| Horticulture | | *Jamun* | *Coconut* | *Banana* | *Jackfruit* | |
| | Unit | | | | | |
| | Unit Rate (Rs.) | | | | | |
| | Total Quantity | | | | | |
| | Total Amount (Rs.) | | | | | |

**Community consultation and validation of DPR generated and approval protocols**

Active involvement of target groups in the planning, implementation and monitoring of development initiatives undertaken as part of watershed development can sustain after outside financial and technical support is withdrawn. Participation of stakeholders at the time of planning a watershed development programme is much needed to take decisions on the proposed activities to understand their relevance to address their need and to improve the natural resources.

In REWARD program, based on the LRI and hydrological inventories, the statuses of the resources are captured and stored in the digital library. Using criteria tables, models, and guidelines, algorithms are written to decide about the appropriate interventions to address the problem observed through inventories. These data are stored in the portal. From the portal, detailed project report can be downloaded for any micro and sub watershed. After downloading the DPR it is to be presented to actual stakeholders to understand about the situation of the natural resources and approaches suggested to improve them. Therefore, community consultation and validation of DPR becomes very important. Following steps are conceived and followed in REWARD, Karnataka.

1. Download MWS wise DPRs using LRI portal and consolidate the generated plan for selected SWS.

2. Prepare AG wise treatment plan on a brown sheet for each of the MWS and carry them during transect walk.

3. WDT will be divided into three sub-groups and 3 to 4 MWS will be allotted to each group based on number of MWS located in that SWS. Thus, sub-groups can be formed as follows;

   a. AO+WA+FNGO-TL+LRI-EM+2AG Reps+2SHG Reps +1 to 2WEC members+ local FPO President/CEO/Board Member.

   b. AAO1+WA+FNGO-TC+LRI-EM+2AG reps+2SHG reps+1 to 2WEC members + local FPO President /CEO/ Board Member.

   c. AAO2+WA+District Cordinator+LRI-EM+2AG reps+2SHG reps+1 to 2WEC 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.

4. Teams members' involvement in community consultation:

| *Participants* | *Individual / Private lands* | *Common lands and Drainage lines* | *Vulnerable Groups* |
|---|---|---|---|
| Field NGO | • Field Guide and Community organizer<br>• Technical Staff if any | • Field Guide and Community organizer | Field Guide and Community organizer |

| *Participants* | *Individual / Private lands* | *Common lands and Drainage lines* | *Vulnerable Groups* |
|---|---|---|---|
| | | • Technical Staff if any | |
| Assistant Agriculture Officer (AAO) | AAO assigned to that micro-watersheds | AAO assigned to that micro-watersheds | AAO assigned to that micro-watersheds |
| Watershed Development Team (WDT) | Specialist in<br>• Horticulture<br>• Livestock<br>• Agriculture<br>• Forestry | Specialist in<br>• Horticulture<br>• Livestock<br>• Agriculture<br>• Forestry | Optional |
| SWS Executive Committee (WEC) | Preferably the entire committee and<br>• President<br>• Secretary<br>• Treasurer<br>• Gram Panchayat Representatives<br>Compulsorily:<br>Representatives from AGs and SHGs | Preferably the entire committee and<br>• President<br>• Secretary<br>• Treasurer<br>• Gram Panchayat Representatives<br>Compulsorily:<br>Representatives from AGs and SHGs | • President<br>• Secretary<br>• Treasurer<br>• all SHG representatives |
| Area Groups | All members belonging to the area | All members belonging to the area | |
| SHGs | Representatives of the WEC | Compulsorily:<br>All members of the SHGs dependent on CPRs in the mini-micro-catchment and the micro-watershed<br>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 |

**Steps for community consultation and validation of DPR**

a. 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.

b. 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.

c. 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 portal output and mark if any corrections/inclusions required.

d. Compare map of the land showing existing structures, land use, drainage lines *etc*., with actual observations and do necessary corrections.

e. Explain treatment plan generated by the portal to AG and note down the any concern/modification/ feedback of the farmers.

f. Discuss with the community on pros and cons and impact of the proposed activities on social and environment aspects and document the same. Further, also record if any modifications required by the community. For common land treatment opinion of the WEC and neighbour farmers should be recorded.

g. Each group will carry 3 markers of different colour to mark community reaction

Green – recommended intervention agreed
Blue – recommended intervention modified
Red – recommended interventions deleted

h. Any modifications made will be recorded in a note book with following details

Name of the MWS_____Name/no. of the AG_____

| *Sl. No.* | *LMU Code* | *Survey No./Nos.* | *Private Land(PL)/CPR* | *Recommended Intervention* | *Suggestion Modification* |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

i. Precaution to be taken while recording the modifications.

- 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

j. 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.

k. 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.

l. Along with individual farmer wise plan, share the common land and drainage line treatments proposed as per the portal DPR, wherever proposed common land and drainage line treatments falls within the area of each AG.

m. It is expected that on each day, one to two AGs could be completed and in four days' time, one micro watershed can be completed (assuming1000 to 1500 ha. /group).

**Consolidating Area group wise treatment plan into MWS plan**

n. End of the day after completion of transect, group will assemble at a pre-identified place and present summary of treatment plan on private land and Common Property Resources (CPRs) and get the approval by taking signatures of at least 5 to 6 farmers on back side of the DPR map.

o. Photo documentation during transect and at the end of the day, meeting should be conducted. This responsibility should be entrusted to one of the members of the task team having good quality camera in his/her mobile. At least 10-12 good quality photos should be documented. Out of which, minimum of 3 photos should be on planning for CPRs. The photos should be taken in different angles/sides.

p. If possible, display the treatment plan on a tripod stand and take the photo while explaining.

q. On 5th day, PRA exercise will be done as per the guidelines given in section-IV below.

r. 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 up to 20 days.

s. ***While planning for the common lands and drainage line treatments observe the following conditions and compare with the draft DPR***

- Visit these lands with the respective Area Groups and SHG members. Interact with the people to understand the specific issues related to these lands
- Assess the existing conditions and compare it with the maps generated in portal
- Share the details of rainfall, runoff, existing water bodies and potential for water harvesting, extent and type of erosion *etc*., and interventions proposed with estimated budget *etc*
- Observe details of existing structures, treatments already done and compare with map already generated.
- Study the land and land uses in the Common Property Resources
- Estimate the human and animal population dependent on the common property resources
- Take the community's opinion 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.
- 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.

- Along with estimated budget for the interventions discuss the cost sharing arrangements with the community.

t. Take the opinion of the community on impact of activities on social and environment conditions and record if any modifications/suggestions required.

u. 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).

v. 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.

w. Plan any risk management measures together with community and eliminate any activities which seem to be of high risk.

x. Append the ESSA details to the DPR.

y. 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.

z. 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.

**Consolidation and approval of MWS DPR at GP/WEC Level**

The multiple levels of planning at farmers' 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:**

aa. After completing the transect in all the area groups area, on 4$^{th}$ day the Task Team with the lead taken by the FNGO WA, 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 during transect.
- For finalising the activities to be taken in the watershed on individual and common lands.
- For discussing implementation strategies, cost sharing aspects, labour availability for the works, *etc*.
- For carrying ESSA to ensure that there is no adverse effect on environment and social system by implementing the proposed activities.
- To include the suggestions/modifications required in the MWS plan and place before GS.

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

| *Steps* | *Details* |
|---|---|
| **1.** 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*. |
| **2.** Display micro-watershed wise large digital Resource Map of the watershed (size 4X6 feet) | Prepare large micro-watershed wise digital resource map of the watershed marked with proposed structures and display in the PRA.<br>The map should contain the following features:<br>• Drainage lines<br>• Existing soil and water conservation structures<br>• Various types of land with survey boundaries (common lands and individual lands)<br>• Major land features and vegetation *etc*. |
| **3.** 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. |
| **4.** 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 the REWARD and budget coming from the convergence with other schemes *etc*. Technical appropriateness of the intervention need to be discussed. |
| **5.** Discuss broad implementation issues | Discuss the following issues in great detail:<br>• 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?<br>• Will the labour required for all the works come from the vulnerable families in the micro watershed?<br>• Do the land treatment activities accommodate the livelihoods needs of the vulnerable groups?<br>• Are there special activities with usufruct sharing mechanisms to support the vulnerable groups?<br>• 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.<br>• Discuss the mechanisms to collect people's contributions for work and document the same |
| **6.** Environmental and Social Safeguard Strategies | Any physical treatment activity is having any adverse impact on environment and social systems? If yes, how to manage those? |

cc. 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 portal.

dd. 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*.

ee. 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.

ff. After General Body approval, the plans are to be finalised and consolidated for the SWS and submitted to PIA office by the FNGO with field staff.

**Verification and approval of the Consolidated Sub-watershed DPRs:**

a. 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.

b. 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.

c. 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 WDD to place before PEC.

d. WDD will submit the SWS DPRs before the PEC and upon approval forward to District JDA.

e. JDA will forward the approved DPRs to Taluk PIA and in turn to field staff, FNGO & WECs to take up implementation.

f. Funds can now be transferred to the WECs for work implementation based on their requisitions.

**Proposed Training for different Categories under REWARD, Karnataka**

**SHG Training:**

S1-Orientation on REWARD Program, functions, roles and responsibilities, ESSA compliance and participatory planning

S2-Gender and social Inclusion, implementation and Maintenance, accounts and book keeping

S3-Project Withdrawal Strategy, Linkages and Post-Project Maintenance

**Area Group Trainings (AGs):**

AG1-Overview of REWARD, formation, functions, roles and responsibilities, ESSA compliance, gender & social inclusion, participatory planning and DPR preparation

AG2-Environmental and social Screening under REWARD and gender & social inclusion,

AG3-Project Withdrawal Strategy and Post-Project Maintenance

**Watershed Executive Committee (WEC):**

E1-Orientation about REWARD, roles & responsibilities, DPR preparation and community validation

E2-Book Keeping, Accounting, Transparency, reporting, Beneficiary Contribution, Implementation and monitoring and Gender & social Inclusion

E3-Project Withdrawal Strategy and Post-Project Maintenance

E4-Exposure Visit

**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.

**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.

**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.
- Ensure that the vulnerable families are benefited from planning on the common land - in terms of labour availability, sharing of usufructs, *etc*.
- Actively participate role 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.

**Format for collecting environmental baseline data**

| *Sl. No.* | *Criteria / Information to check for* | | | *Details* |
|---|---|---|---|---|
| 1. General information | | | | |
| 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* | *Category/Type* | *Issues or Management Measure in brief* |
|---|---|---|---|---|
| 2. Resource | | | | |
| 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? | | | |
| 2.1.4 | Important/ Sensitive animal (fauna) | | | |
| 2.1.5 | Important/Sensitive plant (flora) | | | |
| 2.1.6 | 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 | | | |

| | | | | |
|---|---|---|---|---|
| 2.2.6 | Major animals grazed in land | | | |
| 2.2.7 | 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 meditational 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<br>Need to check if ground data is aligning 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) | | | |
| 2.4.3 | Details on soil cards | | | |
| 2.4.4 | Pesticides/ fertilizer usage | | | |
| 2.4.5 | Source of irrigation | | | |
| 2.4.6 | Frequency of irrigation in different seasons | | | |
| 2.4.7 | Extent of irrigation (% of sown area which is irrigated) | | | |
| 2.4.8 | Methods of ploughing | | | |
| 2.5 | Soil quality | | | |
| 2.5.1 | Any Soil Quality issue including salinity range of soil | | | |
| 2.5.2 | Major animals found in soil (invertebrates) | | | |
| 2.5.3 | Any heavy metal or pesticide reported in soil. | | | |
| 2.6 | Ground Water | | | |

| | | | | |
|---|---|---|---|---|
| 2.6.1 | Nearest tube wells with no and distance | | | |
| 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) | | | |
| 2.6.4 | Mention Ground water quality issue (like salinity, nitrate, Fluoride, Heavy metals *etc*.,) | | | |
| 2.7 | Surface Water | | | |
| 2.7.1 | Nearest of ponds – if not within the water shed then mention distance | | | |
| 2.7.2 | Details of Wetland with its location with its watershed number | | | |
| 2.7.3 | Details of any canals, streams with location in respect to watershed | | | |
| 2.7.4 | If draining line treatment is done details need to be added about HFL vis a vis bund height and how inundation of agriculture field is been avoided | | | |
| 2.7.5 | Mention any surface water quality issue (pH, Biological Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen, Heavy metals, pesticide, coliform *etc*.) | | | |
| 2.7.6 | Period of water availability in ponds | | | |
| 2.7.7 | 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 | | | |

**Screening format for potential environmental and social issues**

The Screening checklist is applicable to any intervention on watershed treatment. This form is to be used by PIA/District Team to rule out any adverse environment and social impacts due to program intervention under the guidance of the Project Management Unit (PMU) to screen for the potential environmental and social risks and impacts of a proposed subproject.

| | | |
|---|---|---|
| **Site information** | Village | : |
| | Micro Watershed | : |
| | Watershed | : |

Gram Panchayat :
Taluk :
District :

| Sl. No. | Key Question | Answer | | Risk Category | Due diligence/ Actions |
|---|---|---|---|---|---|
| | | Yes | No | | |
| 1 | Is there any risk/impact/ disturbance to forests and/or protected areas because of watershed intervention activities? | | | High | If yes, the intervention activities to be modified to avoid the risk? If not possible, such interventions should be avoided |
| 2 | Is there any risk/impact/ disturbance to designated wetland because of watershed intervention activities? | | | High | If yes, the intervention activities to be modified to avoid the risk? If not possible, such interventions should be avoided |
| 3 | Is the intervention work to be taken up 100 meters from any cultural, historic, religious site/buildings recognized/ designated by ASI? | | | High | If yes, any interventions should be avoided[1] |
| 4 | Is the intervention work to be taken up between 100 - 200 meters from any cultural, historic, religious site/buildings recognized/ designated by ASI? | | | Substantial | If yes, due permission to be taken from ASI for any construction. Where there is no impact, chance finds procedures would be applicable and ASI norms would need to be followed |
| 5 | Will planned physical infrastructure affect any physical and cultural resources e.g. any cultural, religious sites including sacred groves *etc*.? | | | Substantial | If yes, the intervention activities to be modified to avoid any risk? If not possible, such interventions should be avoided |
| 6 | Does the intervention work involve requirement of additional land for up-gradation/ expansion and/ or new construction through land acquisition or direct purchase and/or restrictions on land use? | | | High | If yes. It is not supported by the project and to be avoided. Alternate options to be explored |

[1]Ancient Monuments and Archaeological Sites and Remains (Amendment and Validation) Act, 2010 there is ban on construction within 100 meters of a centrally protected monument and regulated construction within 100-200 meters construction. Any construction activity within 100-200 meters of the monument requires ASI permission.

| Sl. No. | Key Question | Answer | | Risk Category | Due diligence/ Actions |
|---|---|---|---|---|---|
| | | Yes | No | | |
| 7 | Does the intervention work involve requirement of additional land for up-gradation/ expansion through transfer from another government department like forest or even revenue forest? | | | High | If yes. It is not supported by the project and to be avoided. Alternate location to be identified |
| 8 | Is there any chance of flooding of land beyond drainage line due to construction of check dams/ weirs? | | | High | If yes. It is not supported by the project. Alternate options to be explored |
| 9 | Does the intervention work involve requirement of additional land for up-gradation/ expansion through transfer from another government department for lands such as pasture/grazing land, natural habitats or other common use land? | | | High | If yes. It is not supported by the project. Alternate options to be explored |
| 10 | Will any intervention work have chances of increase in salinity by inundating low lying areas? | | | High | If yes, alternate option need to be explored |
| 11 | Will any intervention work use or generate any hazardous chemicals or waste beyond permissible levels specified in Schedule II of Hazardous Waste Handling and Management Rules, 2016? | | | High | If yes. It is not supported by the project. Its fall in excluded activity list |
| 12 | Any activity that would use most toxic pesticides classified as 'Class I' (based on acute toxicity of the active ingredient) by the World Health Organisation | | | High | If yes. It is not supported by the project. Its fall in excluded activity list |
| 13 | Does the project activities as per DPR involve recruitment and use of contract workers for watershed activities? | | | Moderate | If yes, follow the provisions of Contract Labour Act to be followed. |
| 14 | Is the submergence affecting private lands? | | | Substantial | If yes. It is not supported by the project. Alternate location or design |

| Sl. No. | Key Question | Answer | | Risk Category | Due diligence/ Actions |
|---|---|---|---|---|---|
| | | Yes | No | | |
| | | | | | specifications to be changed. If not possible, such interventions should be avoided. |

In-charge of PIA

Name: ……

Designation: ……

Phone number: …….

Signature: …….

Date: …….

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