THE WORLD BANK

Application of LRI Approaches for Watershed Management

Special Officer

WATERSHED MANAGEMENT
UAS BANGALORE

Promote science based approach in watershed management

University of Agricultural Sciences, Bangalore

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Centre of Excellence on Watershed Management

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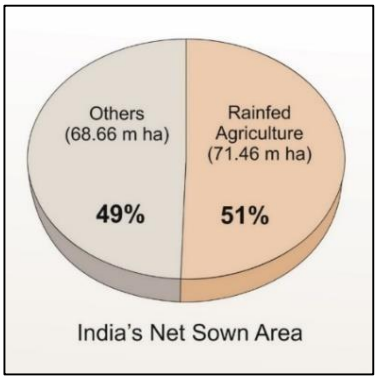
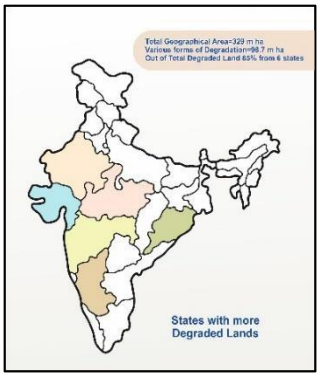
CONTENTS

1. An overview of REWARD program

A. Watershed Development and its importance

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





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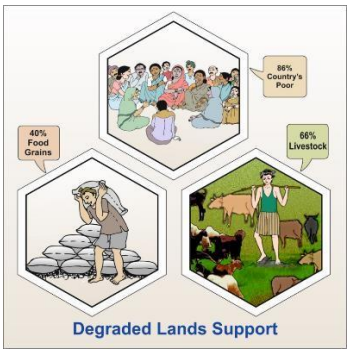
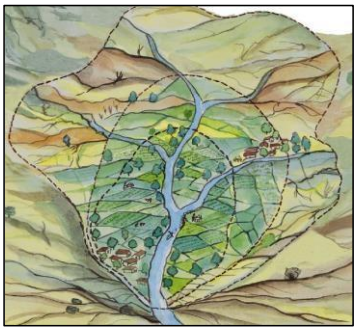


The degraded land is the home to 86% of the country's poor, produce 40% of the food grains, and support 66% of the livestock population. Among the various forms of degradation, soil erosion is the major cause for the declining factor of productivity followed by salinity and alkalinity. The situation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

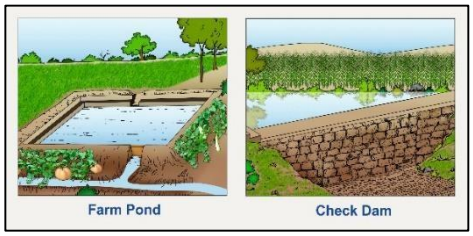
3. A watershed, is as an area in which all water flowing into it goes to a common outlet. All lands on earth are part of one watershed or the other. Watershed Development (WSD) is the preservation, renewal, and wise use of all natural resources, particularly those related to the land, the water, the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

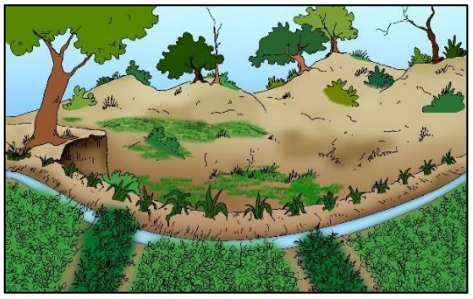


4.

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

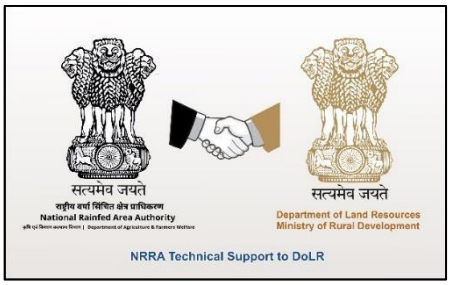
5. The objective of watershed development is maximizing the productivity and income per unit area, per unit time and per unit of water thereby improving the socio-economic status of the farmers. The objective of watershed development can be achieved through implementation of a series of systematic approaches,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





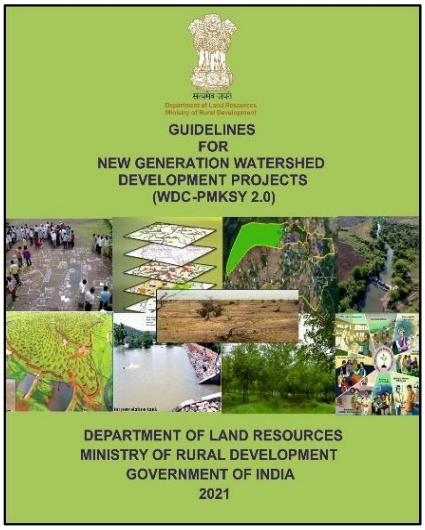
6. 

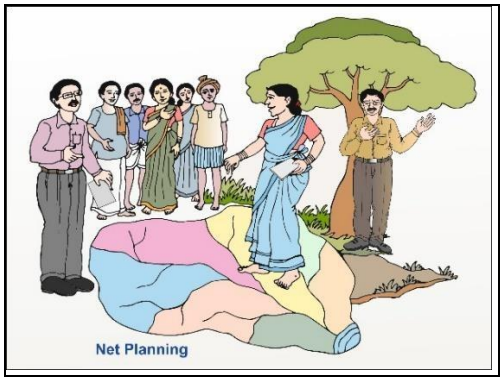
In 1970's Soil and water conservation was taken up with a focus on engineering structures mainly for protecting dams. In 1983, the Operation Research Projects (ORPs) were established in 47 watersheds spread over 16 states covering an area of 35739 ha under the technical guidance of Indian Council of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



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

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

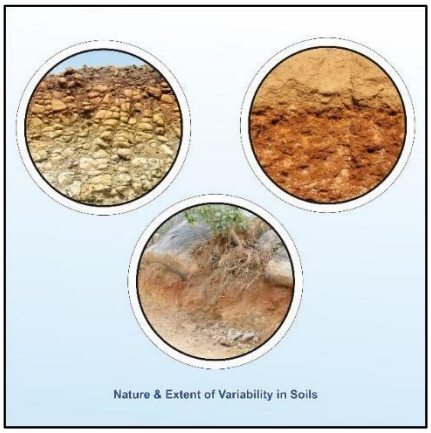


8. 

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

B. Emergence of Sujala-3 project

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



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

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

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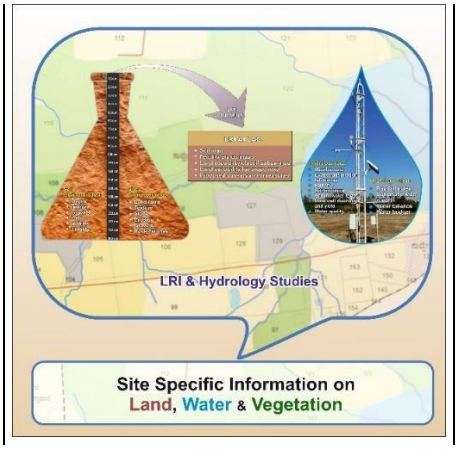
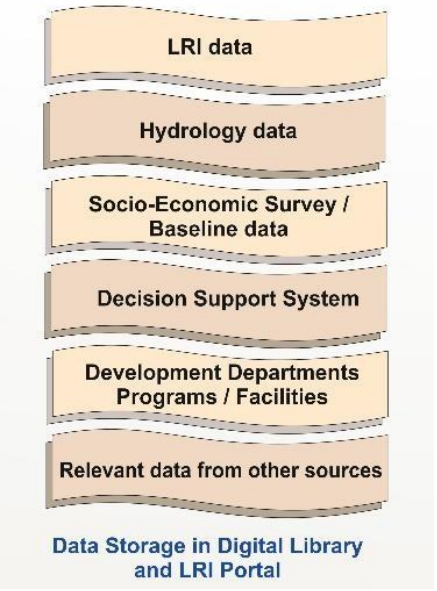


The advanced approaches in Sujala-3 have helped to take up site-specific soil and water conservation interventions, selection of crops as per their suitability, nutrient management as per the fertility status and crop requirement, construction of water harvesting structures as per the available excess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

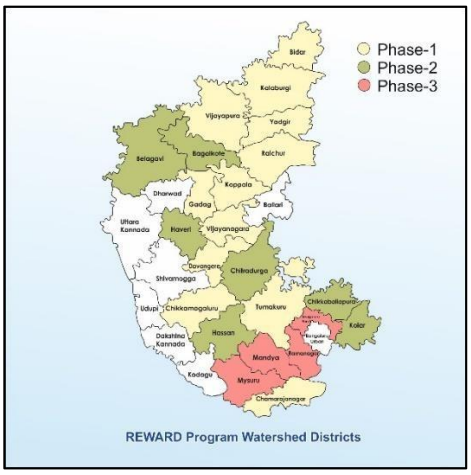
13. To carryout LRI and hydrological studies under Sujala-3 project, 15 scientific consortium partners were involved. Development of Decision Support System (DSS), to improve watershed planning, by integrating the data base generated with decision criteria, models and algorithms is one of the noteworthy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



C. Emergence of REWARD program

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

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



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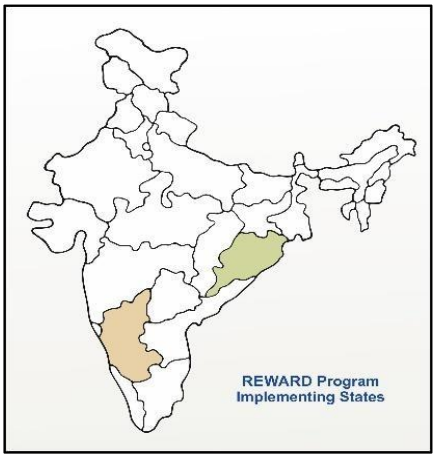
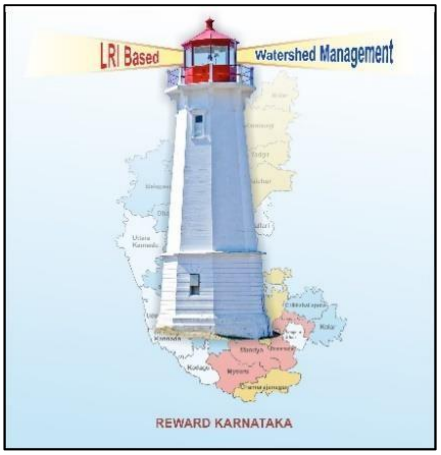
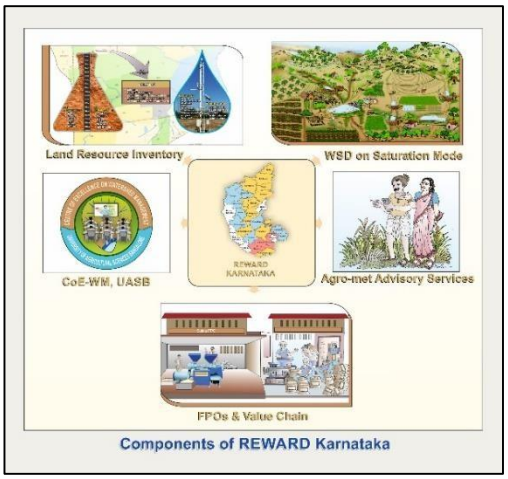


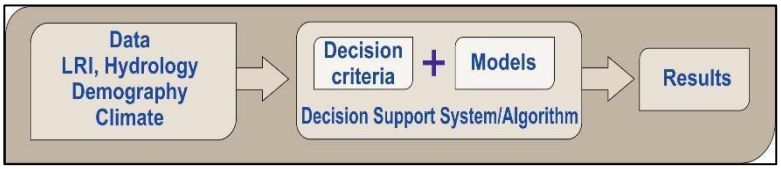


The REWARD-Rejuvenating Watersheds for Agricultural Resilience through Innovative Development program, will create a path for adoption of LRI (including hydrology) based scientific watershed management by all the States through WDC –PMKSY. Karnataka is identified as a light house partner to provide technical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

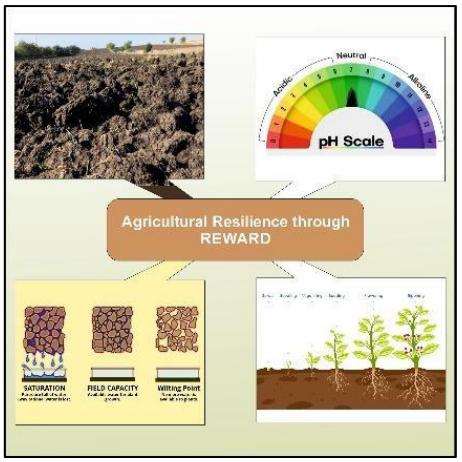
17. The major Components of REWARD program are (a) Land resource inventory (LRI) in 19 lakh ha of rainfed watershed areas spread over in 21 districts, (b) watershed development on Saturation mode covering an area of one lakh ha in 20 sub watersheds based on LRI & Hydrology recommendations, (c) FPO and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



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



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



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

21. The committees for smooth implementation of the REWARD program

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

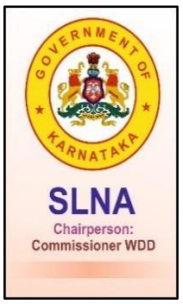
Responsibilities of NLSC: (a) To improve convergence between agriculture, watershed, water resources, rural development and other related ministries and (b) provide high level oversight and guidance for the implementation of the Program

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

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

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

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



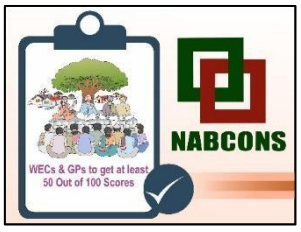
e. District and Block Level (PIA): Officers of Karnataka's DoA will supervise the implementation of the Program Implementing Agency's Respective Part of the Program at the District and Block levels

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

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

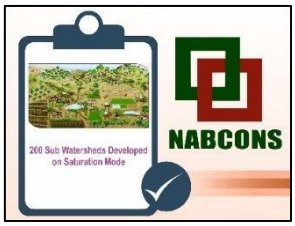
23. The World Bank financing for the REWARD program is "P for R" (Program for Results) mode and disbursement of funds by the World Bank is based on achievements of the results (a) strengthened institutions and supportive policy for watershed development and (b) scientific watershed development and enhanced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

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



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

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



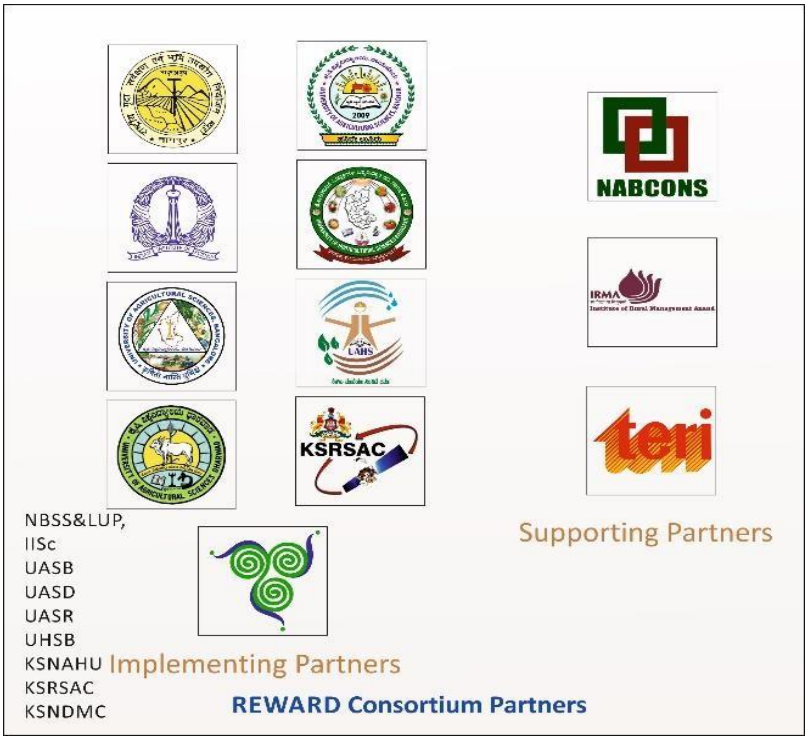
According to the third indicator, 27000 farmers to adopt and practice resilient agriculture technologies.

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

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

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

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



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

2. An overview of LRI outputs and their application in watershed management

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

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

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

Data products of LRI atlas

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

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

b. **Satellite image:** Satellite images are images of earth collected by imaging satellites. At present for survey (inventory), we (Karnataka) are using maps in the False Colour Composite (FCC) form at 1: 8000 scale from Karnataka State Remote Sensing and Application Centre (KSRSAC), Bengaluru.

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

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

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

7. **Geology:**

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

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

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

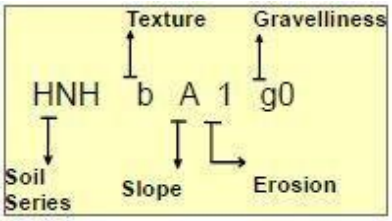
9. **Location of wells map:** The total number of wells (open wells and bore wells) existing in the particular watershed area will be indicated in the maps along with their location.

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

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

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

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



13. **Soil fertility description:** It represents the status and distribution of different soil fertility parameters like pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium, sulphur, exchangeable calcium, magnesium, DTPA extractable iron, manganese, copper, zinc and hot water soluble boron in the particular watershed area, which will be further helpful to correct the deficit nutrient through proper nutrient management techniques.

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

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

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

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

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

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

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

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

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

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

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

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

3. An overview of hydrology outputs and their application in watershed management

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

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.

Preparation of hydrologic atlas:
Integrated Hydrological Assessment & Monitoring involves hydrological data gathering, behavior mapping & processes understanding at micro-watersheds scale. 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, 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 maps.

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,

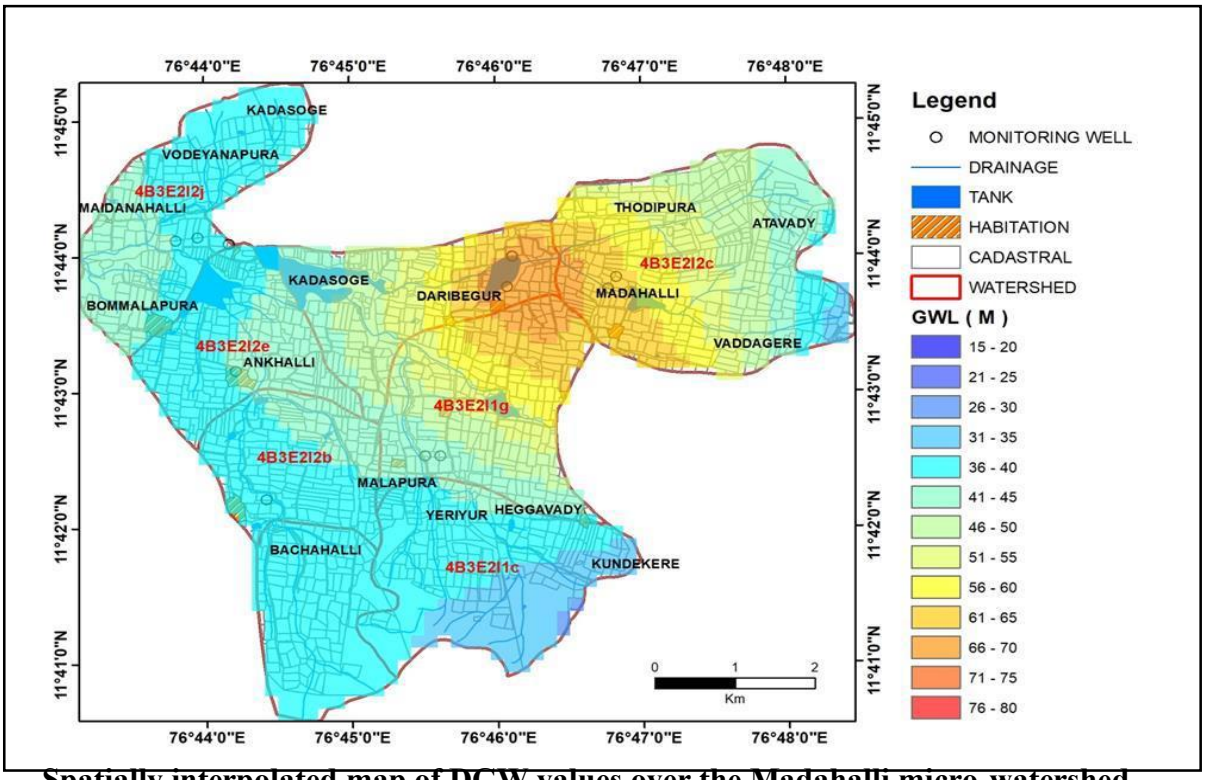
$$P=Q+AET+R+S$$

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:

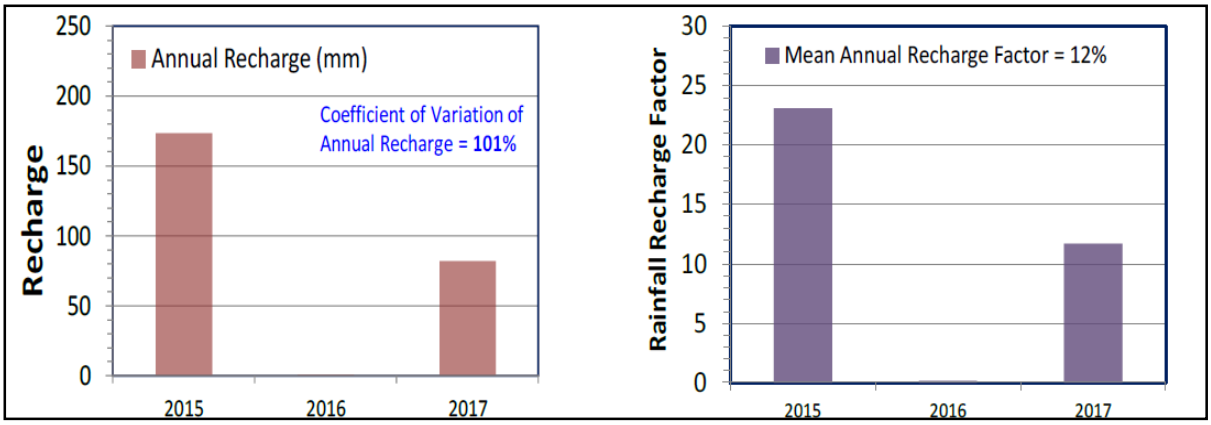
DGW is point data and needs to be interpolated to prepare the spatial maps. Any of the following approaches can be used to convert the point data into spatial maps:

- 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:



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:

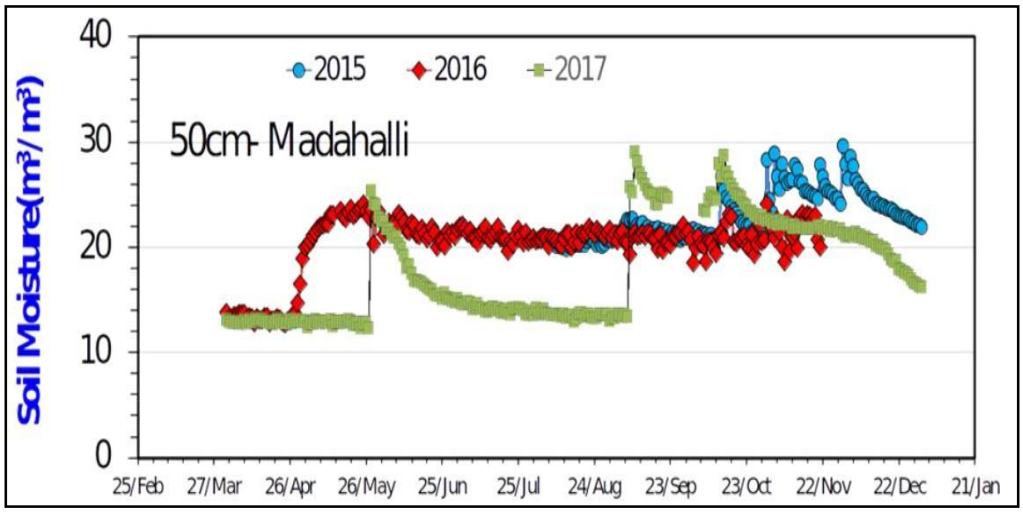
These maps are prepared using satellite remote sensing products. The following facts are to be noted:

- 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.

4. An overview of DSS modules

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 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 were 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.

4.1 Delineation of watershed area according to land capability classification

Delineation of watershed area into arable and non-arable land is essential to select appropriate conservation and crop production systems within the watershed. The capability grouping is based on inherent soil characteristics, external land features and environmental factors that limit the use of land for different purposes. Among the inherent soil characteristics soil depth, texture, gravelliness, soil reaction, water holding capacity, calcareousness, salinity/ alkalinity etc., are considered. The external land features considered are slope, erosion, rock outcrops and drainage. The climate factors include rainfall amount and distribution. Based on this, classified as humid with well distributed rainfall, humid with occasional dry spells, sub humid, semi-arid and arid.

The capability classes are designated by roman numerals I to VIII. The numerals indicate progressively greater limitations and narrow choices for practical use. The classes I to IV are arable lands and classes V to VIII are non-arable lands. The mapping units falling under Class-I will have few or very few limitations that restrict their use. The Class-II mapping units will have moderate limitations that reduce the choice of the crops or that require moderate conservation practices. Class-III mapping units will have severe limitations that reduce the choice of the crops or that require special conservation practice, or both. Class-IV mapping units have very severe limitations that reduce the choice of the crops or that require very careful management, or both. Class-V soils in the mapping units are not likely to erode, but they have other limitations, impractical to remove that limit their use. Class-VI the land area has severe limitations that make them generally unsuitable for cultivation. Class-VII the land area has very severe limitations that make them unsuitable for cultivation. Class-VIII soils and miscellaneous areas have limitations that nearly prevent their use for any commercial crop production.

Further, capability subclasses are formed based on the dominant limitations observed within the capability class. Sub classes are designated by adding a lower-case letter like e, w, s, or c, to the class numeral. For example, in subclass IVe, the letter ‘e’ shows that the main hazard in class IV land is the risk of erosion. Similarly, the symbol ‘w’ indicates drainage or wetness as a limitation for plant growth; ‘s’ indicates soil limitation such as depth, calcareousness, salinity and sodicity and graveliness; ‘c’ indicates climate or rainfall with short growing period as a limitation for plant growth.

Classification of the soil phase KBTmB3g1 is explained as follows: KBT is soil series which mainly gives depth and drainage, m is texture (clay), B is slope (1-3%), 3 is erosion (severe), g1 is graveliness (15-35%). This soil phase is classified as IIIes as per Liebig’s Law of the Minimum.

Exercise - 1

Delineation of arable and prime lands based on land capability assessment

Based on the soil characters presented in the atlas, group each soil phase into various land capability classes and sub classes.

The parameters to be considered are given below and the criteria's to be used in grouping the land parcels into land capability units are given in DSS book (Table 4.1, Page: 110). To understand soil characteristics and soil-site characteristics, refer Annexure-2 page: 219.

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

Climate, soil and site parameters/features affecting LCC		*Land capability ratings*							
		Suitable for Agriculture				*Suitable for forestry, silvipasture, wildlife etc.*			
		Class I	*Class II*	*Class III*	*Class IV*	*Class V*	*Class VI*	*Class VII*	*Class VIII*
Erosion	Slight (e_1)								
	Moderate (e_2)								
	Severe (e_3)								
	Very Severe (e_4)								
Drainage	Excessive								
	Well drained								
	Mod.WD								
	Imperfect								
	Poor								
	Very Poor								
Soil depth	> 100 cm								
	50 –100 cm								
	25-50 cm								
	10-25 cm								
	< 10 cm								
Texture	sl, scl, cl, loam, silty clay loam								
	sandy clay, silty clay								
	clay								
	loamy sand								
	sand								
Gravels	< 15 %								
	15-35 %								
	35-60 %								
	> 60 %								

Climate, soil and site parameters/features affecting LCC		*Land capability ratings*							
		Suitable for Agriculture				*Suitable for forestry, silvipasture, wildlife etc.*			
		Class I	*Class II*	*Class III*	*Class IV*	*Class V*	*Class VI*	*Class VII*	*Class VIII*
Rockout crops (%)	<2								
	2-10								
	10-50								
	50-90								
	>90								
Salinity EC	<2								
	2-4								
	4-8								
	8-16								
pH	Favorable Reaction (6.5-7.5)								
	Unfavorable reaction (easy to modify) (5.5-6.5 & 7.5-8.5)								
	Unfavorable reaction (difficult to modify) (4.5-5.5 & 8.5-9.5)								
	Unfavorable reaction (exceedingly difficult to modify) (<4.5 & >9.5)								
Permeability	Very slow								
	Slow								
	Mod. slow								
	rapid								
	Very rapid								

4.2. DSS on Soil & water conservation

The soil and water conservation measures constitute a major activity in the watershed management. The Watershed Development Department has is issued a technical manual on soil and water conservation measures to be considered in planning for the watershed management with technical specifications. However, in the annexure, the information on soil and water conservation measures is furnished in this reference book for the benefit of the trainees.

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.

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.

Exercise – 2

Soil and Water conservation for arable and non-arable lands

Step-by-step execution of Conservation Plan

Steps	***Description***
1	Select two distinct soil phases and study their land characteristics
2	Select treatment for land characteristics based on decision rules (Table 2.6: Page No. 14 of DSS book)
3	Select vertical and horizontal interval based on decision rules (Table 2.9: Page No. 29 of DSS book)
4	Select cross-section of structure based on the decision rules (Table 2.10: Page No. 30 of DSS book)
5	Estimate length of Bunding per hectare (m) = 10000 x S/(VI x 100)
6	Estimate cost of conservation structure based on decision rules (Table-2.11: Page No. 31 of DSS book for Contour Bunding, Table 2.12: Page No. 33 of DSS book for TCB and Table 2.13: Page No. 34 of DSS book for Graded bunds.

4.3 DSS on Crop suitability

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

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

Land evaluation procedures

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

The main activities in a land evaluation are as follows:

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

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

Data set requirements for land evaluation

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

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

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

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

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

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

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

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

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

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

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

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

Land Evaluation Approaches

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

A. Qualitative evaluation

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

B. Quantitative evaluation

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

Land Suitability Evaluation

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

This assessment is based on the model proposed by the FAO (1976 and 1983) for land evaluation and suggested the classification of land in different categories: Orders, Classes, Sub-classes and Units. The soil-site characteristics are expressed in terms of degree of limitation (0, 1, 2, 3 or 4); the limitation of 2 is considered critical at which the expected yield declined significantly and the cultivation is considered marginally economical. The final soil-site evaluation/suitability is based on the number and degree of limitation (s). Modern approaches involve simulation model predicting yield as a measure of suitability. Although very well refined, yet these approaches are largely based on local experience of farmers or of the researchers.

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

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

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

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

Matching of crop requirements consists of comparing existing climate, soil and physiographic conditions with the soil-site criteria with respect to individual crop. On the basis of the degree and the number of limitations identified, the suitability class is established, *viz*., highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable land (N1 & N2) for specific kind of land use. Land suitability subclasses are divided into land suitability units based on specific

management requirements. The ratings used for defining each class are based on the number and degree of limitations present. The S1 classes correspond to areas, which have a yield potential above 80% of the maximal attainable harvest within the climatic region of the area. This figure drops to 60% and 40% for classes S2, and S3, respectively.

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

Order S (Suitable)	
Class S1 Highly suitable	Land unit having no limitation for sustainable use or with not more than three slight limitations.
Class S2 Moderately suitable	Land with more than three slight limitations but with not more than three moderate limitations.
Class S3 Marginally suitable	Land with more than three moderate limitations but with not more than two severe limitations.
Order N (Not Suitable)	
Class N1 Currently not suitable	Land with severe or very severe limitations that may be overcome in time but cannot be corrected with existing knowledge at current acceptable cost
Class N2 Permanently not suitable	Land having limitations that will be very difficult to correct and us

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

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

Limitations are indicated in lower case letters after the suitability class symbol. For example,

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

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

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

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

Example:

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

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

Red gram: 15S1 + 0S2 + 0S3 ~ will be placed in to S1 (Since there is no limitation for the crop)

Maize S2, Groundnut S2-Selection of the most suitable crop among the two will be based on B:C Ratio as the score for both crops are same.

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

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

Exercise - 3

Crop wise soil characteristics for deciding suitability of crops

Description		*Ragi*	*Redgram*	*Mango*	*Areca*
Depth (cm)					
Very shallow	<25	N	N	N	N
Shallow	25-50	S3	N	N	N
Moderately shallow	50-75	S2	S3	N	S3
Moderately deep	75-100	S1	S2	S3	S2
Deep	100-150	S1	S1	S2	S1
Very deep	>150	S1	S1	S1	S1
Gravels (%)					
g0	<15	S1	S1	S1	S1
g1	15-35	S2	S2	S2	S2
g2	35-60	S3	S3	S3	S3
g3	60-80	N	N	N	N
Slope (%)					
A	0-1	S1	S1	S1	S1
B	1-3	S1	S1	S1	S1
C	3-5	S2	S2l	S2	S2
D	5-10	S3	S3l	S3l	S3
E	>10	N	N	N	N
Texture					
Loamy sand (b)	ls	S3	S3	N	S3
Sandy loam (c)	sl	S1	S2	S2	S2
Sandy clay loam (h)	scl	S1	S2	S1	S1
Clay loam (f)	cl	S1	S2	S1	S1
Sandy clay (i)	sc	S1	S1	S1	S1
Clay Red (m)	c	S1	S1	S1	S2
Clay Black (m)	c	S3	S2	S3	S3
Drainage					
Well		S1	S1	S1	S1
Moderately well		S1	S2	S2	S2
Poorly		S3	S3	S3	N
Very poorly		N	N	N	N

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

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

4.4. DSS on nutrient management

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

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

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

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

Available Nutrients mapping

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

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

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

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

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

Step by Step Process

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

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

Exercise - 4

Nutrient Management Plan

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

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

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

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

Item	Crops	
	1.	2.
Nutrients recommendation (RDF) (table - 5.3a to 5.3h Page No. 119-142 of DSS book)		
Adjusted nutrient as per soil nutrient status (table - 5.4: Page 143 of DSS book)		
Type and quantity of fertilizers recommended		
Combination 1		
Urea		
SSP		
MOP		
Combination 2		
DAP		
17-17-17		
Urea		
MOP		
Cost of fertilizers (Rs.) (table - 5.7: Page 148 of DSS book)		

4.5 DSS on runoff estimation

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. The runoff estimation is done by (a) SCS curve number method, (b) rational method, (c) infiltration method. Under REWARD program, infiltration method is considered as important because of its strengths in accurate assessment of the runoff.

While accessing DSS on estimation of runoff through infiltration method, the information on extent of vegetative cover to be mentioned by the user. Further, the assessments indicate runoff available with existing conditions and with proposed conservation measures. The assessments also indicate runoff excess available for harvesting by construction of new water harvesting structures and runoff to be allowed as environmental flow at the outlet. Normally, it is 30 per cent of the available runoff.

An example of runoff estimation for a sub-watershed which has received annual rainfall of 806.00 mm during 2014 is illustrated for better clarity. Out of the total rainfall, the runoff availability with existing conditions is estimated as 154.10 mm. The runoff available after execution of appropriate conservation measures is 68.20 mm. Out of harvestable runoff of 68.20 mm, 30% of it has to be allowed as environmental flow at the outlet which is 20.46 mm. The remaining 47.74 mm runoff will be available for harvesting by construction of new structures.

Exercise - 5

DSS for estimating runoff and designing of water harvesting protocol

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

4.6 DSS on designing size of farm ponds and check dams

The farm ponds are manmade ponds normally constructed in the arable lands owned by the farmers. These are constructed in relatively level regions across the runoff by excavating the soil, by depositing the soil on the bunds. Farm ponds are preferably located in areas with impervious substratum. The ponds will be lined with impermeable membrane like HDPE sheet to avoid infiltration. Unlined ponds are suitable for groundwater recharge. These ponds are constructed for storing rain water to provide lifesaving irrigation to crop during water scarce conditions for uninterrupted physiological activities of crops.

To decide the size of the farm pond, it is required to know the extent of catchment area or land parcel owned by farmer and quantity of excess runoff available for that parcel/ catchment based on infiltration method. Based on the runoff available, decide the size of the pond to capture the runoff quantity.

The decision criteria for deciding size of pond in red soils are:

a. side slope=1:1,

b. depth=3m,

c. $\text{top width} = \sqrt{\left(\frac{\text{Runoff volume}}{3}\right)} + 3$,

d. $\text{bottom width} = \sqrt{\left(\frac{\text{Runoff volume}}{3}\right)} - 3$,

e. top area=top width x top length,

f. bottom area=bottom width x bottom length,

g. $\text{total volume} = \left(\frac{\text{top area} + \text{bottom area}}{2}\right) \text{x depth}$

To calculate the harvestable volume of water, the catchment area to be multiplied with the runoff. If catchment area is 1 ha and the runoff available is 30 mm, the harvestable volume of water will be 10000 m^2 x 0.03 m = 300 m^3. 1 cubic meter is equivalent to 1000 liters

To store 300 m^3 of runoff as per the decision criteria, the size of the farm pond required is 13m (top width) x 13m (top length) x 3m (depth) as indicated below.

a. $\text{Top width} = \sqrt{\left(\frac{300}{3}\right)} + 3 = 13 \text{ m}$

b. $\text{Bottom width} = \sqrt{\left(\frac{300}{3}\right)} - 3 = 10\text{m}$

c. Top width and length =13 m

d. Bottom width and length = 10 m

e. Depth = 3m

Exercise - 6

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

1. Suggest the size of the farm pond for a given condition with cost estimates - Refer page - 181 in DSS book for details
   Catchment area -1ha
   Runoff - 30mm
   Soil type - Red

4.7 Crop water requirement and water budgeting

Water is a basic and most essential natural resource for existing of life. Although, 70% of the earth is covered with water, 0.3% is only available for human welfare satisfying domestic, agricultural and industrial needs. The per capita water availability of water in India is reduced from 5177 m^3 during 1951 to 2500 m^3 during 1980 to the present (2020) 1700 m^3 and expecting to decline further to 1140 m^3 by 2050 against the safe limit of 1800 m^3. NITI Aayog (2018) report 'Composite water management index' mentions that India is undergoing the worse water crisis in its history and nearly 600 million people are facing high to extreme water stress. The report also mentions that India is placed in 120th position among 122 countries in water quality index, with nearly 70% of available water being contaminated.

In India, agriculture being the major sector consuming around 82% of the fresh water, will lose its share with increasing demand from domestic and industrial share. Sustaining agriculture production to achieve food security of the burgeoning population in the country demand efficient use of available water, necessitating water budgeting.

Water budgeting at watershed scale is essential in the present context in India considering its greater dependence on rainfed farming. The purpose of water budgeting at watershed scale is

- To promote sustainable water management (Surface & groundwater) through participation of stake holders for higher water productivity.
- To create awareness among the water users within the watershed.
- To facilitate a shift in cropping systems considering water availability.
- To develop wise water use protocols.

Steps in Water Budgeting

Water balance is the difference between source / supply and utilization / demand. The source of water / supply side in the watershed include rainfall, surface water if available (canal / lift irrigation / tanks) and ground water. The demand side of water in the watershed includes domestic, agricultural and industrial (if exist in watershed) needs besides water subjected for evaporation from the storage structures. The steps involved in working water budget are

1. Estimation of water availability (rainfall, surface, groundwater etc) within the watershed.
2. Estimation of storage potential of rainfall in different forms (Soil moisture, Runoff, Surface and Ground water storage)
3. Estimation of total water use demand for human, livestock, crop and industries with in the watershed Area.
4. Finding out Water Balance (Available Water – Water Requirement as per proposed water use pattern).

Step 1: Water supply Assessment.

Rainfall: The quantity of rain water received in a watershed is calculated by multiplying the amount of rainfall with the geographical area

$$\text{Rain water availability } (m^3) = \text{Total Rainfall (mm)} \times \text{Watershed area (acre)} \times$$

Eg: The quantum of water received in a watershed with 500 ha area (1250 acre) with 700 mm annual rainfall is

Rain water availability (m^3) = 700 X 1250 X 4

= 35,00,000 m^3

= 350,00,00,000 ltr (**Note** 1 m^3 = 1000 ltr)

Other sources: If the watershed receives water from other surface (Canal, lift irrigation, runoff from the upper catchment etc.) or groundwater (to be calculated based on the number of bore wells and their water yield) also to be considered.

Step 2: Assessment of Stored Water (existing) using GEC (Groundwater Estimation Committee) Norms

As per GEC guidelines, the rainfall proportion utilized for different components include

A. Soil moisture and evaporation : 70%
B. Runoff : 20%
C. Ground water storage : 10%

Step 3: Water Demand Assessment (based on water use pattern)

The data on Human and Livestock population including birds for calculating domestic needs, crop are data for calculating agricultural needs and Industrial needs if any within the watershed area to be considered in demand analysis using the following information.

Domestic demand: The total water demand for domestic needs to be calculated using the per capita water demand (ltr per day) for different population as detailed below

Human: 135 ltr	Local cows: 100 ltr	Crossbreed cows: 150 ltr
Buffalo: 150 ltr	Sheep & Goat: 10 ltr	Horse: 32.5 ltr
Donkey: 20 ltr	Pig: 10 ltr	Poultry: 0.25 ltr
Dog: 5 ltr	Rabits: 0.64 ltr	

Agricultural crop water demand: The area under different crops in the watershed need to multiply with the crop water requirement to workout agricultural demand, the water requirement of crops is detailed below for the said calculation

Sl. No.	Name of the crop	Water requirement					
		Irrigated			Rainfed		
		cm	Ltr / acre	m^3 / acre	cm	Ltr / acre	m^3 / acre
1	Paddy	150	6000000	6000	100	4000000	4000
2	Jowar	55	2200000	2200	50	2000000	2000
3	Bajra	40	1600000	1600	35	1400000	1400
4	Maize	60	2400000	2400	55	2200000	2200
5	Ragi	45	1800000	1800	40	1600000	1600
6	Wheat	55	2200000	2200	45	1800000	1800
7	Minor Millets	35	1400000	1400	30	1200000	1200

8	Bengal gram	45	1800000	1800	40	1600000	1600
9	Red gram	70	2800000	2800	65	2600000	2600
10	other pulses	40	1600000	1600	35	1400000	1400
11	Groundnut	60	2400000	2400	50	2000000	2000
12	Castor	70	2800000	2800	65	2600000	2600
13	Sunflower	60	2400000	2400	50	2000000	2000
14	Soybean	55	2200000	2200	45	1800000	1800
15	Sesamum	45	1800000	1800	35	1400000	1400
16	Mustard	45	1800000	1800	35	1400000	1400
17	Safflower	45	1800000	1800	35	1400000	1400
18	Linseed	50	2000000	2000	40	1600000	1600
19	Niger	40	1600000	1600	30	1200000	1200
20	Sugar cane	200	8000000	8000	170	6800000	6800
21	Cotton	85	3400000	3400	75	3000000	3000
22	Tobacco	50	2000000	2000	45	1800000	1800
24	Mulberry	120	4800000	4800	80	3200000	3200
25	Mango	60	2400000	2400	60	2400000	2400
26	Banana	220	8800000	8800	220	8800000	8800
27	Lemon	90	3600000	3600	90	3600000	3600
28	Guava	60	2400000	2400	60	2400000	2400
29	Sapota	50	2000000	2000	50	2000000	2000
30	Pomogranate	60	2400000	2400	90	3600000	3600
31	Papaya	90	3600000	3600	60	2400000	2400
32	Grapes	90	3600000	3600	90	3600000	3600
33	Other fruits	60	2400000	2400	60	2400000	2400
34	Potato	60	2400000	2400	50	2000000	2000
35	Tomato	70	2800000	2800	70	2800000	2800
36	Brinjal	70	2800000	2800	70	2800000	2800
37	Beans	50	2000000	2000	50	2000000	2000
38	Onion	60	2400000	2400	50	2000000	2000
39	Green chillies	60	2400000	2400	60	2400000	2400
40	Ladies finger	50	2000000	2000	50	2000000	2000
41	Radish	30	1200000	1200	30	1200000	1200
42	Carrot	40	1600000	1600	40	1600000	1600
43	Water melon	30	1200000	1200	30	1200000	1200
44	Leafy vegetables	30	1200000	1200	30	1200000	1200
45	Total gaurds	40	1600000	1600	40	1600000	1600
46	Other vegetables	45	1800000	1800	45	1800000	1800
47	Pepper	100	4000000	4000	100	4000000	4000
48	Cardamum	100	4000000	4000	100	4000000	4000
49	Dry Ginger	90	3600000	3600	90	3600000	3600
50	Turmeric	90	3600000	3600	90	3600000	3600

51	Garlic	60	2400000	2400	60	2400000	2400
52	Dry chilli	50	2000000	2000	65	2600000	2600
53	Coriander	60	2400000	2400	60	2400000	2400
54	Coconut	-	700000	700	-	700000	700
55	Cashew	50	2000000	2000	50	2000000	2000
56	Total flower crops	70	2800000	2800	70	2800000	2800
57	Medicinal plants	70	2800000	2800	70	2800000	2800
58	Coffee	100	4000000	4000	100	4000000	4000

Industrial demand: The annual water demand for industries in water watershed to be accounted if they exist.

Step 4: Calculation of Water Balance

The difference between water supply and demand gives water balance. If the difference is negative, planning to be made either to source water externally or by adjusting cropping system with low water demanding crops. If positive, alternative means viz., cropping intensification (multiple cropping), high water demanding crops of other activities may be planned to use the excessive water.

For more details, refer the DSS book supplied.

Exercise - 7

Estimation of crop water requirement

Steps in estimation of crop water requirement

#	***Description of the steps involved***
1	Define land use class/ cropping system and its management details
2	Estimate day after sowing
3	Estimate crop coefficient based on days after sowing and crop growth
4	Estimate potential evapotranspiration requirement using measured weather parameters on daily time scale
5	Estimate crop water requirement using crop coefficient (Table 8.3) and potential
6	Display crop-wise water requirement **at parcel level**. (Aggregate crop water requirement at soil unit, MWS and SWS levels based on the crop cultivated)
7	Display crop-wise water requirement to the farmer/other stakeholders

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

Place: Hodekallu micro watershed in Tumkur Taluk

Daily average PET during south-west monsoon is 4.33

Refer table-8.3, page: 194 for crop coefficient (Kc) values compiled for major crops (FAO, 1998)

Crop	***Area (ha)***	***Crop water requirement***
Maize	7	
Sorghum	14	
Soybean	3	
Groundnut	10	
Sunflower	9	
Cotton	12	

5. DPR generation-consolidation of all activities for a micro watershed

A detailed project report (DPR) is the final blueprint of a project after which the implementation and operational process can occur. In REWARD program, more advanced scientific approaches (LRI and hydrological assessments) are followed in assessing the status of natural resources for management of a watershed compared to earlier programs. Further, development of LRI portal with decision support system, automate the preparation of the DPR. Hence, there will be considerable reduction in time required for preparation of DPR leading toshortening 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 decideon 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, pulsesand 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 micronutrientsin soils, (i) crop wise fertilizer recommendation, (j) soil fertility for adjusting major nutrients recommendation. Regarding water harvesting structures, the information on runoff estimationand 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 ofwatershed program and all agriculture related activities by concerned developmentdepartments.

Phases involved in preparation of DPR:

The phases involved in the process of DPR preparation under REWARD are (a) pre-planningactivities 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, DPRPreparation Team at PIA level WDT
11. Roles and responsibilities of all those institutions and teams involved in the project needto 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 theinputs provided in the LRI atlas, reports and digital library

   (Select water harvesting structures based on decision criteria, water budgeting andwater 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 LRIoutput)
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 LevelTechnical Committee (DLTC)
4. Technical review by DLTC, placing before WCDC and WCDC to forward the DPR toPEC for approval
5. Forwarding approved DPR to PIA for implementation

Steps in DPR preparation, validation & community consultation

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

Download DPR from LRI portal

Contents of the DPR for Private lands

1. Sl. No.
2. MWS CODE
3. Hobli
4. G.P Name
5. Village
6. Survey number
7. Hissa
8. Area: acre, gunta
9. Area: ha
10. Owner Name
11. Phone Number
12. Gender (M/F)
13. Caste-SC/ST/OBC/Min./Gen
14. Category (MF/SF/MEF/LF)
15. Farmer code
16. AG Code
17. Fruit ID

18. Soil Phase
19. SWC activity
20. Size / Section (in m^2)
21. Actual field Size/Section (in m^2)
22. Actual RMT (in mtr)
23. Per RMT Cost
24. No. of Waste Weir
25. Per WW cost
26. WW Cost
27. SWC Cost
28. Farm Pond size
29. Farm pond cost
30. S1 Crops
31. S2 Crops
32. S3 crops
33. Horti. Species 1
34. No of Plants
35. Per Plant Cost
36. Horti. Species1 total cost
37. Horti. Species 2
38. No of Plants
39. Per Plant Cost
40. Horti. Species 2 cost
41. Total Hort Plants
42. Total Hort. Cost
43. Forestry
44. No of Plants
45. Per Plant Cost
46. Forestry cost
47. Total Beneficiary Cost

Community consultation

Need for community consultation

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

Community Consultation Process

- Using the MWS map, form AG groups – may be 5-10 AGs
- Bifurcate MWS plan AG wise in Excel format
- Carry the same during transect walk along with different thematic maps generated through LRI data
- Fix AG wise responsibility of mobilizing the farmers to FNGO staff

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

Suggested Modifications / deletions Recording Format

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

Precaution to be taken while recording the modifications or deletions

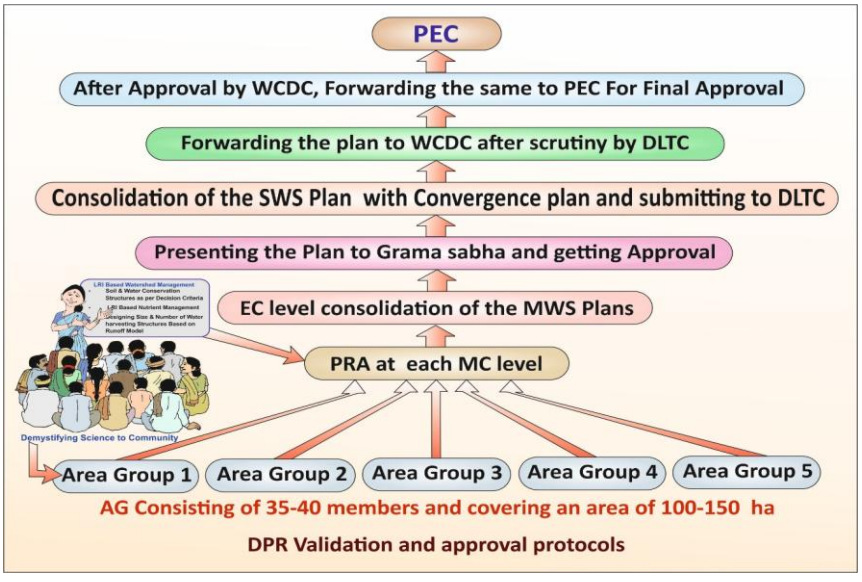
1. Suggested modifications should not lead to altering the entire plan
2. Concerted efforts to be made to convince the beneficiary about the plan prepared keeping in view of existing condition of the soil and topography
3. Ensure complying key recommendations of LRI and ESSA principles

PRA exercises for cross verification and finalisation

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

Consolidation and approval protocols

- Include if any modifications suggested in the PRA and prepare revised MWS plans. Once the MWS plans are vetted in the PRA exercise, then generate farmer wise and survey number wise details in the form of net planning
- Convene a General Body/ Gram Sabha meeting of the WEC and present the overall MWS plans, budgets, contributions, mode of implementation (manual labour, machinery, contracts, etc.), common land and drainage line treatments, post management strategies, inter linkages between individual lands and common lands, etc.
- Present entire plan along with Budget before the General Body and get its approval. WDT, FNGO team and WEC committee members should play major role in getting the approval. Proceedings should be recorded with photo/video documentation
- After General Body approval, the plans are to be finalized by PIA along with a summary of SWS plan for technical scrutiny
- Taluk PIA office will verify component wise project allocations, unit costs, contribution and total budget allocation for all the MWS plans received from different WECs and prepare a component wise consolidated plan for the SWS and submit to DLTC headed by district JDA for technical scrutiny
- DLTC go through the individual MWS plans for technical feasibility and prepare a convergence plan wherever possible and recommend the same to WCDC headed by district Deputy Commissioner for approval
- WCDC will verify the consolidated SWS DPR as well as convergence plan and recommends to the Project Empowered Committee (PEC) for approval. Upon approval of the WCDC, district JDA will submit the same along with minutes of DLTC and WCDC to State PIA to place before PEC
- State PIA will submit the SWS DPRs before the PEC and upon approval forward to district JDA
- JDA will forward the approved DPRs to Taluk PIA and in turn to field staff, FNGO & WECs to take up implementation
- Funds will be transferred to WECs for work implementation



Note: For further details refer DPR guidelines issued by WDD soft copy of which is given in the pendrive

6. LRI based Nutrient Management

Need for LRI based fertilizer application: Land Resource Inventory (LRI) provides site and crop specific fertilizer recommendations based on the fertility status of the soils, but still, most of the farmers follow blanket recommendation. This has led to either over or sub optimal application of fertilizers in most of the situations, thereby increasing the input costs and reducing the profit margin or may result in lower yields. This can be avoided if the fertilizer applications are made based on the LRI recommendations. Therefore, aligning soil fertility status with nutrient requirement of crops assumes greater importance. The extension functionaries of the State Department of Agriculture especially those who are working in Raitha Samparka Kendras have to influence fertilizer purchase decisions of farmers to align them to the soil fertility status to avoid inappropriate use and overuse of chemical fertilizers. Under the REWARD program, LRI cards have been distributed to each parcel of land and given to the concerned farmers with training on how to use information provided in the LRI card for nutrient management as per the soil fertility status and the crops under consideration. In this chapter details are presented for the benefit of Extension Staff to promote this approach.

Land Resource Inventory (LRI) Card interpretation

What is LRI card?

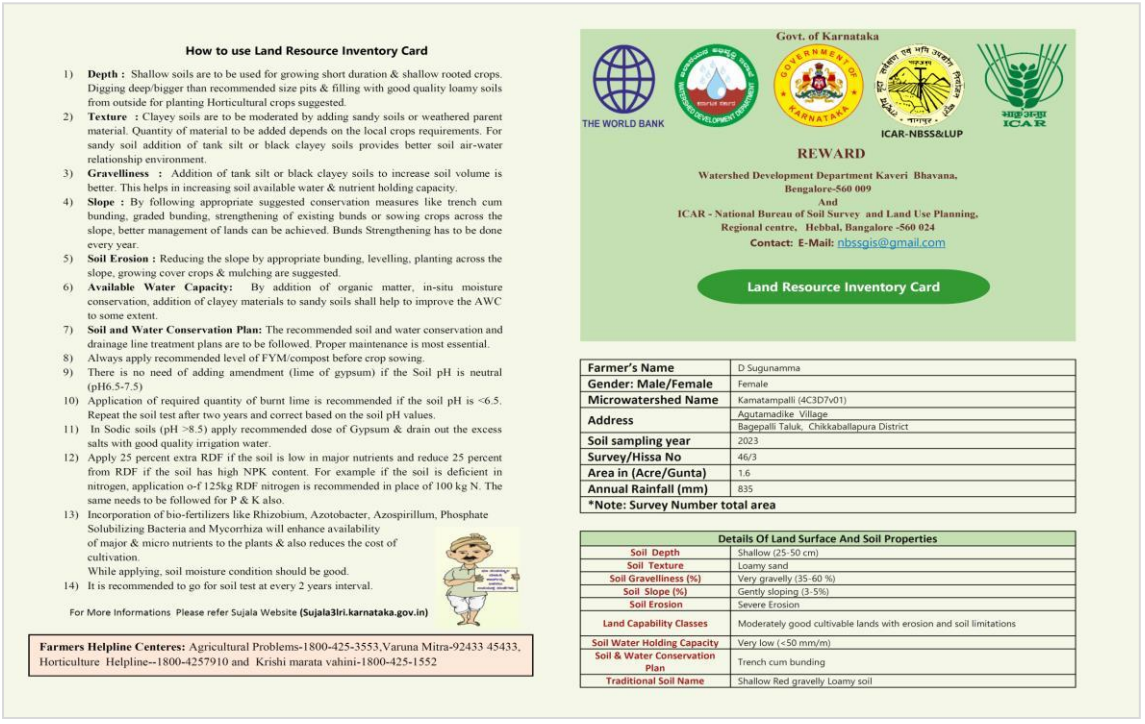
Land resource inventory card is a printed document given to a farmer for each of his land holdings. It provides information about the soil's health condition based on soil physical and chemical properties. It helps farmers assess the quality of their farm soil and improve its productivity in the long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

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

Land resource inventory card contains the following information:

1. Farmers general information
    - Name
    - Gender
    - Micro watershed name
    - Adress
    - Soil sampling year
    - Survey/ Hissa No.
    - Area in (Acre/ gunta)
    - Annual rainfall (mm)

2. Details of land surface and soil properties
    - Soil depth
    - Soil texture
    - Soil gravelliness (%)
    - Soil slope (%)
    - Soil erosion
    - Land capability classes
    - Soil water holding capacity
    - Soil and water conservation plan
    - Traditional soil name
3. Soil test results: pH, Electrical conductivity, Organic carbon, Available nitrogen, Available Phosphorus, Available potassium, Sulphur, iron, manganese, zinc, copper and boron
4. Secondary and micronutrients recommendations for deficient soils
5. Soil nutrient classification for very low, low, medium, high and very high soils
6. Suggested crop plan (Highly suitable, moderately suitable, marginally suitable and not suitable) based on land resource information



How to use Land Resource Inventory Card

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

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

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

Govt. of Karnataka

THE WORLD BANK

ICAR-NBSS&LUP

ICAR

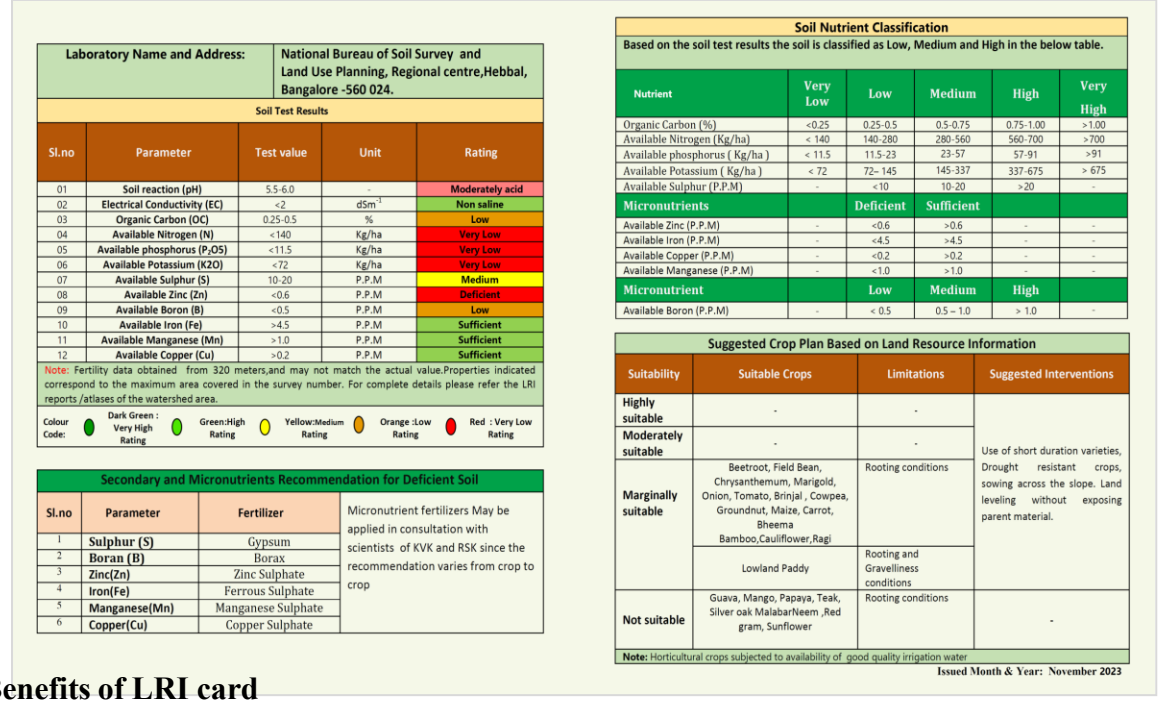
REWARD

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

Land Resource Inventory Card

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

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



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

Soil Test Results

Sl.no	Parameter	Test value	Unit	Rating
01	Soil reaction (pH)	5.5-6.0	-	Moderately acid
02	Electrical Conductivity (EC)	<2	dSm^{-1}	Non saline
03	Organic Carbon (OC)	0.25-0.5	%	Low
04	Available Nitrogen (N)	<140	Kg/ha	Very Low
05	Available phosphorus (P_2O5)	<11.5	Kg/ha	Very Low
06	Available Potassium (K_2O)	<72	Kg/ha	Very Low
07	Available Sulphur (S)	10-20	P.P.M	Medium
08	Available Zinc (Zn)	<0.6	P.P.M	Deficient
09	Available Boron (B)	<0.5	P.P.M	Low
10	Available Iron (Fe)	>4.5	P.P.M	Sufficient
11	Available Manganese (Mn)	>1.0	P.P.M	Sufficient
12	Available Copper (Cu)	>0.2	P.P.M	Sufficient

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

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

Secondary and Micronutrients Recommendation for Deficient Soil

Sl.no	Parameter	Fertilizer
1	Sulphur (S)	Gypsum
2	Boran (B)	Borax
3	Zinc(Zn)	Zinc Sulphate
4	Iron(Fe)	Ferrous Sulphate
5	Manganese(Mn)	Manganese Sulphate
6	Copper(Cu)	Copper Sulphate

Micronutrient fertilizers May be applied in consultation with scientists of KVK and RSK since the recommendation varies from crop to crop

Soil Nutrient Classification

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

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

Suggested Crop Plan Based on Land Resource Information

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

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

Issued Month & Year: November 2023

Benefits of LRI card

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

Adjustment of recommended dose of fertilizer based on soil nutrient status

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

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

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

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

If the soil nutrient status is Very Low

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

If the soil nutrient status is Medium

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

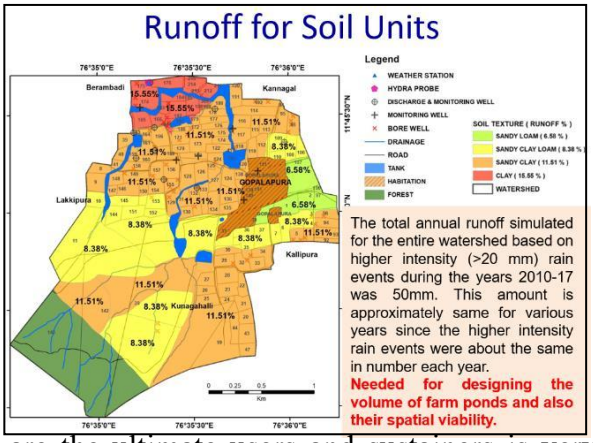
If the soil nutrient status is Very High

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

7. Demystifying Science to the Communities

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

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



Approach to demystify science to communities

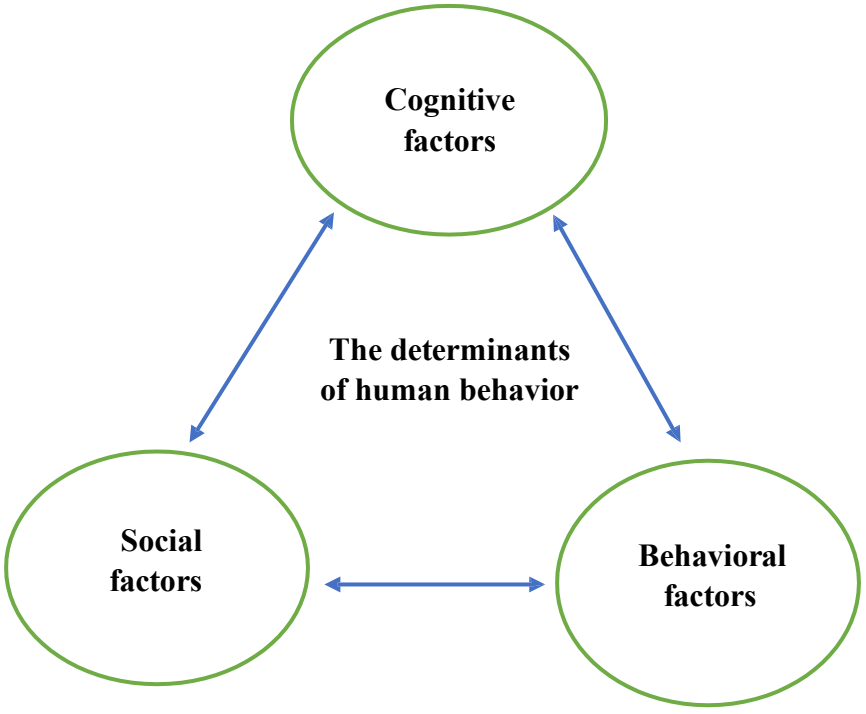
Demystifying science is nothing but, changing the behavior of person/s to accept and act on the scientific outcomes (evidence-based practice) to solve a problem instead of applying existing or traditional approaches. Therefore, for implementation of evidence-based practices, there is a need for behavioral change among the users on the suggested interventions.

For example, through hydrology studies, estimating soil phase wise runoff from a given catchment is an evidence-based fact. To make the communities to accept the number and size of check dams in a drainage line based on the precise quantity of runoff from the catchment

instead of a conventional approach is the behavioral change. Changing the behavior of communities on the evidence-based interventions is not that simple as identifying an evidence-based fact or generating scientific data.

Determinants of behavior:

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



Identifying behaviors of interest

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

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

Identifying whose behavior(s) need to change

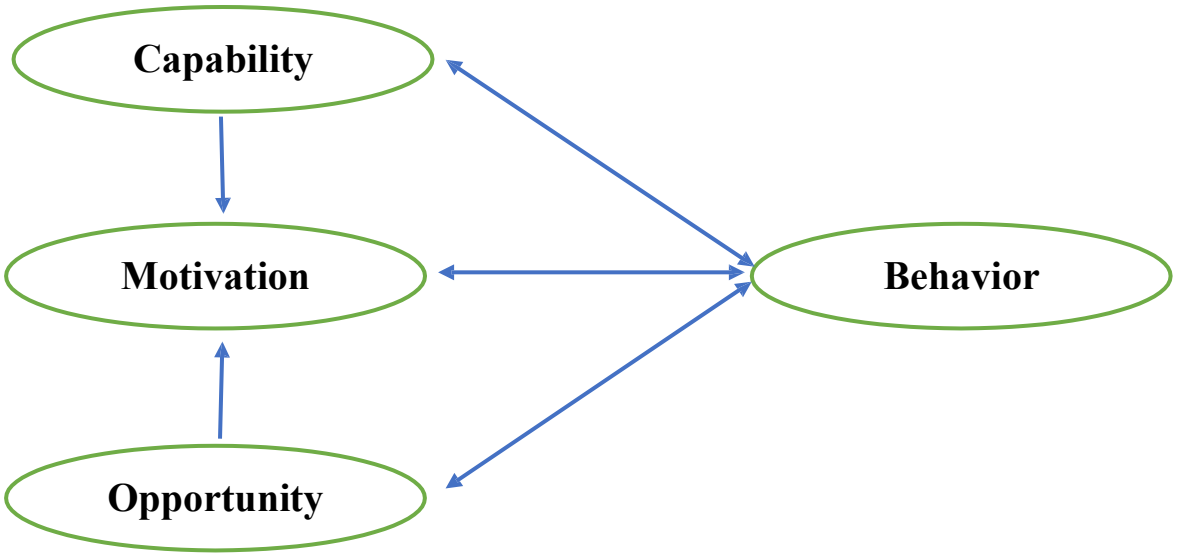
It is important to provide clarity regarding what to change and to specify target behaviors in terms of:

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

Model of Behavioral Change:

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

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



COMB model of behavior change

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

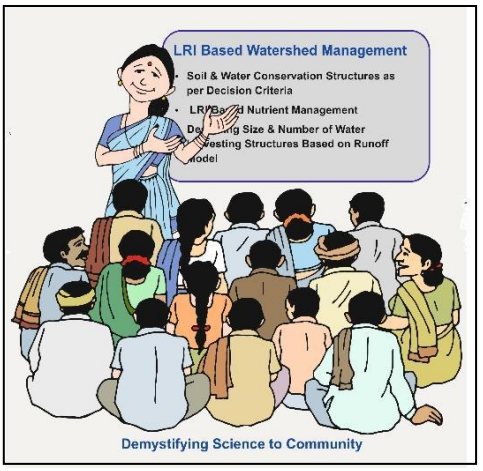
Capability can be achieved through imparting knowledge through educational activities, physical skill development through training which is the focus of training or potentially through enabling interventions such as medication, surgery or prostheses.

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

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

Methods for changing the behavior or demystifying science

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



1. **Education:** Increasing knowledge or understanding through discussions, use of print and electronic methods, interpreting the scientific outputs in a simple and understandable manner
   Example: Providing information on soil phase wise runoff available with the existing conditions and after execution of appropriate conservation measures

2. **Training:** Imparting skills on interpretation of thematic maps, selection of soil and moisture conservation measures based on decision criteria, selection of crops for different soil phases:
   Example: For a given quantity of runoff, deciding on number and size of check dams

3. **Persuasion:** Inducing positive feelings on the LRI based approaches for watershed planning and management. It may be important to identify and use progressive thinking people within the village to persuade others:
   Example: Comparison of Benefits between LRI based approaches and conventional approach in terms of expenditure, time saving, conservation of resources, productivity levels to be prepared and presented to key persons in the village and convince them

4. **Incentivization:** Rewarding for positive behavior on the introduced interventions. by complementing and recognizing the positive outcome. May be allocation of additional money for some important activities
   Example: Recognizing in a mega event and providing additional funds for some important activities

5. **Enablement:** Increasing means/reducing barriers to increase capability or opportunity. This may be possible through constant support from the PIA at various stages of project cycle

6. **Coercion:** Creating expectation of punishment by cost recoveries, if not complied with the scientific recommendations
   Example: Not providing budget from the project if the activities are deviated from approved DPR and if already implemented initiating recovery process from the supervisory staff\

7. **Restriction:** Using rules to reduce the scope for deviation from the expected output. It should be compelling to adhere to the scientific recommendations in selection of interventions, crops etc.
   Example: if farmers do not cultivate crops as per the crop suitability criteria, such farmers will not get Government subsidy

Barriers for changing the behavior

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

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

8. Convergence of programs of Line Departments with REWARD program

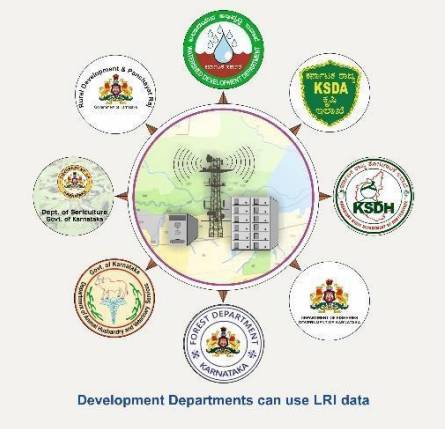
Convergence is the process that results in the achievement of common objectives through value addition, targeted and efficient use of financial and human resources. Coordinated planning and service delivery ensures timely inputs from multiple sources, simultaneously avoiding duplication and redundancies.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

Need for convergence

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

Departments and integration of programs

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



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

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

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

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

Critical levels for Convergence

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

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

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

Watershed Cell Cum Data Centre (WCDC) on the strength of above instructions & in consultation with the concerned authority at the district level would facilitate linkages with relevant programmes of agriculture, horticulture, animal husbandry, rural development etc.

with watershed development projects implemented under REWARD program for enhancement of productivity and livelihoods at the district level. The Convergence potential and modalities would need to be clearly spelt out in the convergence and resultant matrix which would be an integral part of the Detailed Project Report (DPR)

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

Format for convergence of REWARD program activities with other departments activities

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

Inputs available from REWARD for planning line departments activities

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

Application of LRI for planning and implementation of DoA programs

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

Exercise

Format for convergence of REWARD program activities with other departments activities

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

9. Soil and water conservation measures for watershed management

Arable lands treatments

The suitability of a given type of conservation measure in an area depends upon slope, rainfall soil type and depth, water holding capacity location of impervious layer, agricultural practices, power/equipment used and economics. Land having less than 2 % slope do not require any of the structural measures in general. Lands up to 10 % slope may require narrow or broad-based terraces. The broad-based terraces are useful when land holdings are large and machinery is used for farming operations. It is doubtful if narrow based terracing i.e. bunding be of any practical use in lands having slopes more than 6 %. In high rainfall areas, such land slopes will require uneconomically closer spacings resulting in more loss of area. It is difficult to achieve uniformity inbounding practice on lands steeper than 4 % and in any case steeper than 6 %. For lands with slopes above 10 % and upto33 %, bench terracing is an effective measure as it breaks the length and also reduces the degree of slope. It, however, restricts farming operations, is expensive and significant area is lost out of cultivation.

From the point of view of efficient water management, graded terraces are to be adopted in areas where rainfall is more or for areas where in spite of moderate rainfall, runoff disposal is a problem. Level terraces are for drier tracts with scanty or erratic rainfall where moisture conservation if of prime importance. Area lost out of cultivation is highest in bench terracing while under bunding, 5-10 % area is lost which can be alternate land uses.

Important principles for design of structures

- Increasing the time of concentration and thereby allowing more runoff water to be absorbed and stored in the soil profile due to enhanced infiltration opportunity time.
- Intercepting a long slope into several short ones, so as to maintain less than the critical velocity of the runoff water.
- Protection against damage owing to excessive runoff.
- Reducing the steepness of slope.
- Terracing/bunding is the most effective and widely used practice for controlling or preventing erosion on agricultural lands in different agro-ecological regions.

Types of bunds

- Contour bunds are constructed along approximate contours for moisture conservation.
- Side bunds are constructed at extreme ends of the contour bunds running along the slope.
- Lateral bunds are constructed along with the slope in between two side bunds in order to prevent concentration of water along one side and to break the length of contour bund into convenient bits.

- Supplemental bunds are constructed between two contour bunds so as to limit a horizontal spacing to the maximum required.
- Marginal bunds are constructed along boundaries of the micro watershed, road margins, river or stream margins, gully margins etc.
- Graded bunds are constructed along a predetermined grade for safe disposal of excess runoff.
- Broad based bunds are adopted for soil and moisture conservation in large land holdings where farming is done by machines.
- Shoulder bunds are constructed on the outer end of bench terraces to contain runoff and soil loss usually in outwardly slopping terraces

1. Contour Bunding (Narrow based terracing)

For slopes ranging between 2-6 % with scanty or erratic rainfall (less than 800 mm annually), contour bunding is practiced to intercept the runoff flowing down the slope by an embankment with either open or closed ends to conserve moisture as well as reduce erosion. The land treatment in between the bunds is desirable for uniform conservation of moisture. In order to dispose off excess runoff from very high intensity storms, surplussing arrangements should invariably be provided. The practice of contour bunding is found to increase crop yield about 15-20 per cent.

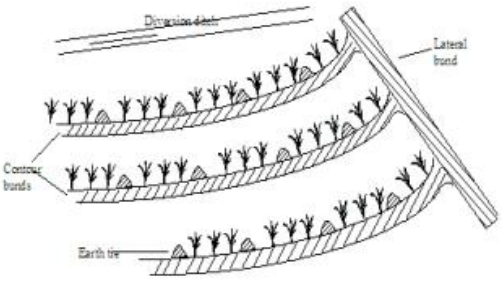


Figure 3.2 (a) Contour earth bunds for runoff farming with field Crops

(a) Contour earth bunds with maize crop *(photo courtesy of MoARD, Ethiopia)*

Soils

Contour bunds can be adopted on most types of relatively permeable soils i.e. alluvial, red, laterite, brown, shallow, medium black except the clayey deep black soils.

Spacing of the contour bunds

Spacing of bunds is usually expressed by vertical interval (VI) between two bunds. The main criteria for spacing of bunds is to intercept the before it attains erosive velocity. It depends on:

- Slope length
- Slope steepness
- Rainfall
- Cropping programme
- Conservation practices to be adopted

Ramsers formula

Based on filed observations (semi-arid climate with good infiltration soils)

$$VI = 0.3(\frac{S}{3} + 3)$$

Where,

VI = Vertical interval between two consecutive bunds, m

S =Degree of slope %

For very high infiltration rates, provide 25 % extra spacing. In case of low infiltration rates, decrease spacing by 15 %

The specifications followed for contour bunds is

Slope percentage	Southern region		Northern region	
	Vertical interval (m)	Corresponding horizontal distance(m)	Vertical interval (m)	Corresponding horizontal distance(m)
<1%	0.6	60	0.9	90
1 – 2%	0.6	39	0.9	60
2 - 3%	0.6	24	1.2	48
3 - 4%	0.9	21	1.5	33
4 - 5%	0.9	21	1.5	33
5 - 6%	1.2	21	1.5	27
6 - 7%	1.2	21	1.5	27
7 - 8%	1.5	18	1.5	27

By knowing the cross-section area of the bund, the volume of earth work per hectare and the cost of earthwork per hectare can be determined.

Bund design: Bunds are designed by determining the base width by considering impounding depth of water on the upstream plus the depth of flow on the weir and free board (20 to 25 % of the above two). Further, side slope ratio is arrived from the angle of repose, being the characteristic feature of a given soil. In general, for light soils 1:1 and for heavy soils 1.5:1 side slopes are adopted. This will ensure that saturation line (hydraulic gradient) falls within the two-thirds of the base width, resulting in bund stability. After knowing the height of the bund and assuming the top width of the bund (considering its usage) the base width is calculated.

The contour plan is brought to the field, and examined whether the proposed bunds are further dissecting the field and / or the length of the bund is crossing the prescribed limit of 300 to 400 m. In such cases adjustments are made in the plan in consultation with land owners. After this, the first bund is located at 1.5 to 2.0 times the contour interval from the top most ridge line. Then drive pegs of longer size to mark top width and pegs of shorter size to mark the base width, after making adjustments in location of the bund while

crossing ridge and valley. Leaving 1.5 m of berm from the upstream line of the bund base, locate borrow pits with equalizers (septum with groove to a depth of 0.15m) of 30 cm width at every 5 m interval of required size to form the designed section of bund. Initially the soil is disturbed in the area where the bund is to be formed without disturbing the pegs used to mark base width and top width. The soil excavated from the borrow pits located preferably on the upstream side is placed between the pegs marked for base width and gradually bund is formed to have the desired top width. Subsequently, the soil is consolidated by breaking clods and shaping to the desired size.

More rain water can be held against the bund by providing deeper and narrow pits of 1.0 m width. However, depth of the pit varies with the section of the bund. This arrangement is more suitable for lands where horticultural crops are grown.

The recommendations of bund section and size of borrow pits is given below:

Top width (m)	**Base width (m)**	**Height (m)**	**Side slope (ratio)**	**Cross section (sq.m)**	**Soil type**
0.3	1.2	0.50	0.9:1	0.375	Red gravelly soil
0.3	1.2	0.6	0.75:1	0.45	
0.3	1.5	0.6	1:1	0.54	Red sandy loam
0.3	2.1	0.6	1.5:1	0.72	Very shallow black soils
0.45	2.0	0.75	1:1	0.92	
0.45	2.4	0.75	1.3:1	1.07	Shallow black soils
0.6	3.1	0.70	1.78:1	1.29	Medium black soils
0.5	3.0	0.85	1.47:1	1.49	

Advantages

The contour ridge system is simple to construct. Construction can be by hand or by machine. It generally is less labour intensive than conventional tillage. This is because the catchment strip that lies ahead of the furrow is left uncultivated, and if possible, compacted so as to generate more runoff. The yield of runoff from the very short catchment lengths can be quite efficient. When designed and constructed correctly, there should be no loss of runoff out of the system, and therefore, no need for spillways. Another advantage is attaining even crop growth because each plant receives runoff from roughly the same size of catchment area.

Limitations

Contour ridges are limited to areas with relatively high rainfall, as the amount of harvested runoff is comparatively small due to the small size of the catchment area. Contour ridges for runoff harvesting are not yet a widespread technique in the region. This is due to the need for leaving a strip uncultivated within the farmland, which some farmers find difficult to accept. Also, the system has to be re-constructed each crop season as it silts up easily.

2. Types of waste weirs

Clear overfall stone weir: It comprises of a masonry wall of a designed length constructed at a suitable place in the bund and the two ends of the bund are stone pitched. A clear overfall weir should be provided along the contour bund, usually with its crest 0.30 m above the contour. This height of 0.30 m is suitable for crops like sorghum and pearl millet ordinarily grown as seasonal crops in the scarcity areas.

Channel weir: A channel weir is provided at one end of the bund to prevent the nose pf the bund from getting breached and the fill of the channel weir is kept 0.30 m above the contour level of bund. It also comprises of a stone wall underground with one end of the bund pitched. Stone work for these walls may be dry rubble.

Cut outlet: It is a channel weir and is cut as an ordinary channel about 1.75 m away from the end of the bund with its fill kept as 0.30 m above contour level. It has an approach and a tail channel to give runoff water proper entrance and exit from the weir, respectively. Usually, such cut outlets are proposed only in hard materials.

Pipe outlet: A pipe outlet comprises of a pipe discharging surplus water. The design consists of a hume pipe of required diameter with one well on the upstream side. A 15 cm diameter pipe is suitable for 4 ha catchment, 22.5 cm diameter pipe up to 6 ha and 30 cm diameter pipe can work up to 10 ha. The well consists of 0.45 m diameter, 0.30 m outlets and the well top is kept 0.30 m above the contour level.

Ramp-cum-waste weir: During the period when scarcity works are in progress, it is not possible to construct outlets immediately. Therefore, ramp-cum-waste weirs are constructed. These are of a temporary nature. The ramp-cum-waste weir consist of an earthen bund with its top 22.5 cm above the contour level and having a slope of 1:10 like a ramp both on the upstream and on the downstream side of the bund. When permanent waste weirs are constructed, they need to be situated by the side of these ramp-sum-waste weirs and should be pitched with grass wherever conditions of rainfall are favorable. They are also constructed as normal waste weirs in parts of Khandesh (Gujarat).

3. Graded bunding

Graded bunds or graded terraces or channel terraces are laid along a predetermined longitudinal grade instead of a contour up to 10% land slope for safe disposal of excess runoff.

Functions

The functions of graded bunds consist of constructing wide and relatively shallow channels across the slope, very near the contour ridges and at suitable vertical intervals. These terraces act primarily as drainage channels for inducing and regulating the excess runoff water and

draining it with a mild and non-erosive velocity. The purpose of these bunds is to make safe disposal of runoff water by slow movements instead of rushing runoff. The graded bunds are laid along a predetermined longitudinal grade.

Suitability

These bunds adopted in areas receiving rainfall exceeding 750 mm particularly in soils having infiltration rate less than 8 mm/hr. graded bunds are also recommended in area receiving less rainfall where rain water is not readily absorbed into the soil due to low infiltration rates such as clayey soils.

The recommended side slope and seepage line slope for graded bund is (Source: Das, 2002)

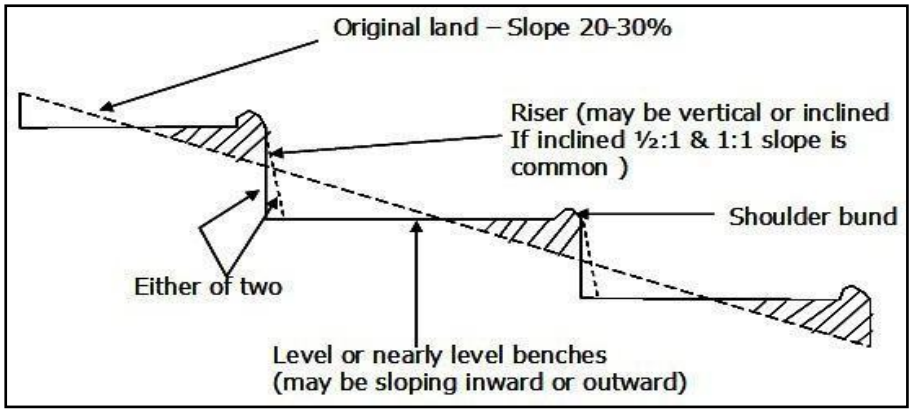
Soil type	**Bund Side slope**	**Seepage line slope**
	Side slope (horizontal: vertical)	
Clayey	1:1	3:1
Loamy	1.5:1	5:1
Sandy	2:1	6:1

The specification for Bund Cross Section in graded bund is

Depth of soil (m)	**Base width (m)**	**Top width (m)**	**Height (m)**	**Side slope (m)**	**Area cross section (sq.m)**
Shallow soils (7.5 – 22.5 cm)	2.67	0.38	0.75	1.5 : 1	1.14
Medium soil (22.5 – 45 cm)	3.12	0.60	0.85	1.5 : 1	1.56
Medium deep soils	4.25	0.60	0.90	2 : 1	2.18

4. Bench Terracing

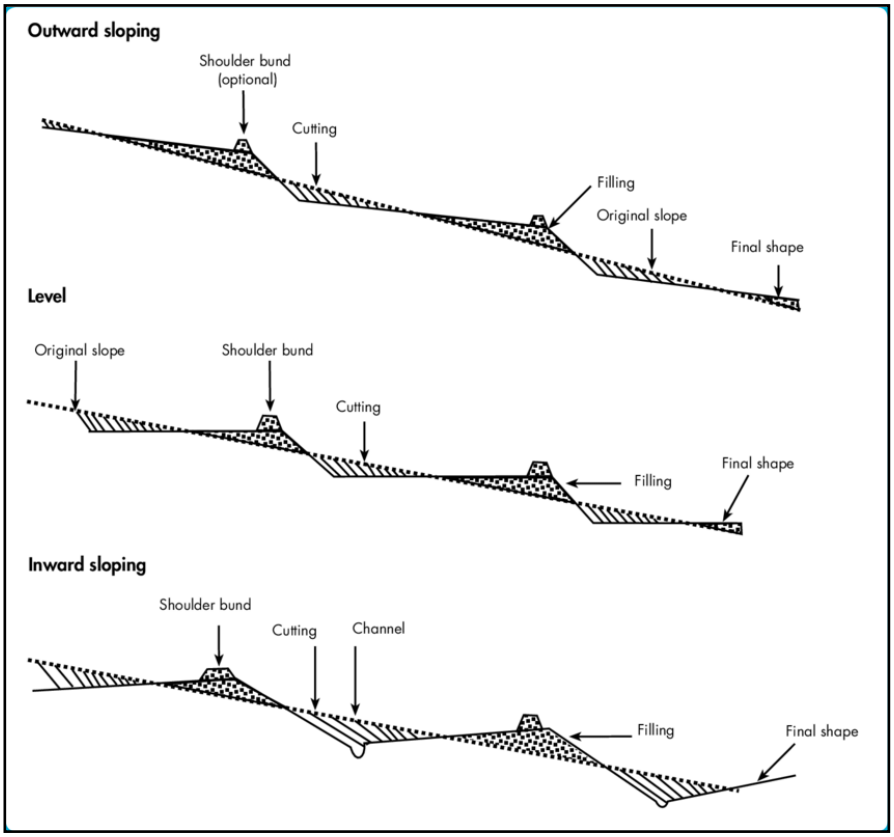
On steep sloping and undulating lands, intensive farming can only be adopted after constructing bench terraces which are one of the most popular soil conservation structural measures adopted by the farmers of hilly regions all over the world since ages. It comprises of construction of step like fields along contours usually by half cutting and half filling procedure. Original steep slope is converted into level fields and thus the hazards of erosion are minimized. By adopting bench terracing, both degree and length of slope are reduced which help in soil moisture conservation for enhanced crop production. Bench terraces are recommended for slopes up to 33 % but due to socio economic compulsion, this practice is being adopted up to 50-60 % land slopes.



Types of bench terraces and their adaptability

Level bench terraces (Table top): These are used for paddy cultivation for providing uniform impounding and can be adopted even on mild slopes receiving medium rainfall and having highly permeable deep soils

Inwardly sloping bench terraces: Some crops are quite susceptible to water stagnation. Hence in order to minimize losses, the terrace is provided with a water disposal channel towards the riser of next higher terrace rather than on the fill portion. The inner water disposal channel has a longitudinal grade to safely dispose of excess water into the natural waterway. It is usually adopted in high rainfall regions in deep soils with good permeability for crops which cannot withstand water logging such as potato, maize etc. These terraces help in quick and safe disposal of runoff through the drain provided on the inner side.



Types of bench terraces

Outwardly sloping bench terraces

In the process of constructing bench terraces, sometimes soil depth is a limiting factor and the farmers make the benches gradually over a long period of time under low rainfall conditions with shallow permeable soils. Water disposal channel or shoulder bunds should be constructed to prevent the excess runoff from damaging the riser at the earliest opportunity and allow it to pass safely from one terrace to another. Where soil depth or rainfall is not limiting, it is considered ad the intermediate step for construction of either the level bench or inwardly sloping terraces. A survey had revealed that in the middle Himalayan region. 70% of the bench terrace were constructed between land slope of 50-70 % with average outward and longitudinal slopes of 10 % and 8 %, respectively.

Puertorican or California type bench terraces

In this type o terraces, soil is gradually excavated during every ploughing and the terraces are developed by pushing the soil down the hill against a vegetative or structural barrier laid along the contour. The terrace gets developed gradually by constructing either a structural barrier or vegetative barrier in a period of 3-5 years.

Strip terraces on contour

This practice is adopted in fairly deep soils in steep hilly areas for making fruit belts in unexploited sites e.g. in Kashmir, H.P. North Eastern hilly regions and Uttaranchal hills. The width of these terraces is quite narrow (1 to 1.5 m) for the purpose of plantation of orchards and some cash generating inter crops such as potato, ginger etc.

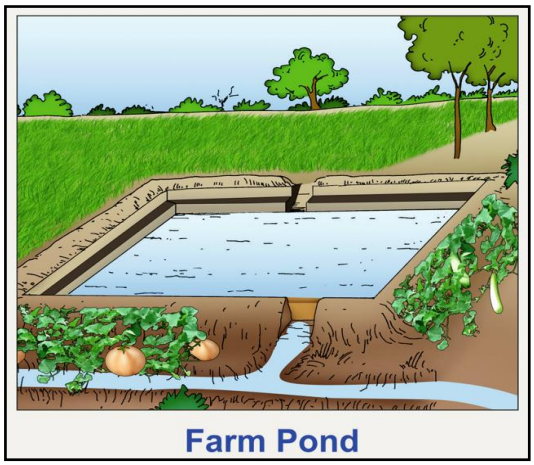
5. Farm ponds

There is very little qualitative difference between a pond/ tank, which usually serves the population of a village, and farm pond, which serves an individual agricultural field. Farms ponds greatly vary in size depending upon the rainfall. In high rainfall areas of Orissa, for example, these have only a few meters of length and width and are built across the flow path of natural drainage channels. Surplus water from one pond spills over to a lower pond. In some cases, a series of farm ponds are built on one single stream. Each pond caters to the irrigation needs of one farm and also augments ground water recharge.

In any watershed management programme farm ponds are an important component. Farm ponds are useful in storing water for irrigation. They also retard sediment and flood flows to the downstream river system. In relatively flatter terrain with good soil cover, a farm pond has an earth section with usually 3: 1 side slope on waterside and 2: 1 side slope on the downstream face (A uniform side slope of 2.5 :1 on both sides can be adopted at some sites). The sides are sodded. A natural depression nearby may be used as an earthen spillway with minimum channel section construction. A pipe drops inlet spillway and an irrigation outlet are also provided. A key trench is dug to give a good bondage between the original ground and the filled earth. Storm riprap against wave action may be required in some cases. The pond crest usually serves as a farm road (provide 4.25 m roadway for motorable roads).

A good pond site should possess the following traits:

- The site for the earthen bund should be narrow gorge with a fan shaped valley above so that a small amount of earthwork gives a large capacity.
- The drainage area above the pond should be large enough to fill the pond in 2 or 3 spells of good rainfall.
- The pond should be located where it could serve a major purpose: e.g. for irrigation, it should be above the irrigated fields and for sediment control it should intercept the flow from the most erodible parts of the catchment.
- Junction of two drainage channels or large natural depressions should be preferred.
- The land surface should not have excessive seepage losses unless it is meant to serve as a percolation tank for ground water recharge.



Farm Pond

6. Zingg terracing

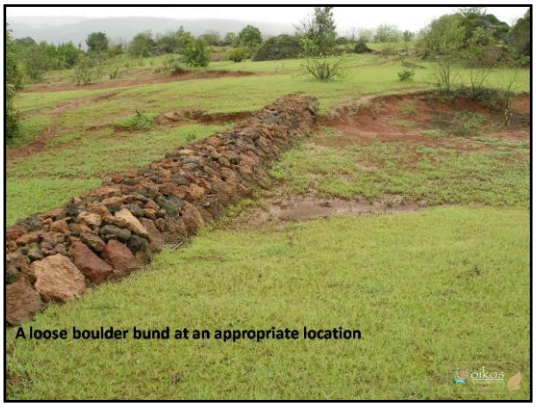
Surface runoff can be harvested from external catchments for use in cultivated fields on a slope steeper than is recommended for most runoff farming systems. This is made possible by constructing a back-slope graded terrace variously known as reverse-sloping bench or Zingg terrace. In this design, the upper part of the terrace bed also serves as a catchment to provide runoff onto inner part of the same terrace on which crops are grown. The system is recommended for gentle slope (< 6%) with deep soils, where the catchment to cropped area ratios range about 1:1 to 2:1. Zingg terraces are especially useful when combined with runoff harvesting from small roads and footpaths to grow cereals and legumes, such as maize, beans, cow peas.

Zingg Terracing with external catchment system

7. Boulder bunds

Boulder bunds are an effective and environmentally friendly agricultural technique used to combat soil erosion and conserve water in dryland regions. These structures are constructed by arranging stones or boulders in lines or ridges across slopes and fields, creating barriers that reduce the speed of surface runoff. By doing so, boulder bunds enable more water to infiltrate the soil, increasing moisture retention and benefiting crop growth. This makes them particularly valuable in arid and semi-arid areas where water scarcity is a significant challenge. The benefits of boulder bunds extend beyond water conservation. By preventing soil erosion, they help retain the nutrient-rich topsoil, thereby enhancing soil fertility over time. This, in turn, can lead to improved agricultural yields and more sustainable farming practices. Additionally, the presence of boulder bunds can create a more favorable microclimate for plant growth by moderating temperature fluctuations and maintaining consistent moisture levels. They also contribute to biodiversity, providing habitats for various plant and animal species.

Constructing boulder bunds involves using locally available stones or rocks, which are placed in lines perpendicular to the slope of the land. The design of these bunds, including their size and spacing, depends on factors such as the slope gradient, soil type, and local rainfall patterns. Generally, steeper slopes require closer bund spacing to effectively control runoff and erosion. While boulder bunds are beneficial, their construction and maintenance are labor-intensive and may require a significant initial investment in materials and labor. However, the long-term benefits, such as enhanced soil quality and increased agricultural productivity, often outweigh these initial costs. Boulder bunds are widely used in agricultural lands to protect crops and improve yields, especially in regions with hilly terrain. They are also effective in preventing landslides and maintaining soil stability on hillsides and slopes. In addition to their role in soil and water conservation, boulder bunds can be integrated with other water-harvesting techniques to maximize water use efficiency. Despite their many advantages, the successful implementation of boulder bunds requires careful planning and community involvement to ensure their sustainability and effectiveness. Overall, boulder bunds represent a simple yet powerful solution for enhancing agricultural resilience and promoting sustainable land management in vulnerable environments.



Boulder bunds

8. Strengthening of bund

Strengthening boulder bunds is essential for ensuring their long-term effectiveness in controlling soil erosion and conserving water in agricultural landscapes. One effective method of strengthening these structures is through the use of vegetative cover. Planting grasses, shrubs, or other vegetation along the bunds can stabilize the soil and stones with their root systems, providing additional protection against water flow and erosion. This practice not only enhances the structural integrity of the bunds but also contributes to biodiversity and improves the microclimate around the bunds. In some cases, agroforestry techniques, which integrate trees and shrubs with crops along the bunds, can offer additional benefits such as enhanced soil fertility and increased crop yields. Another strategy for strengthening boulder bunds is to improve the stone arrangement and structure. Interlocking stones in a tightly packed pattern can increase stability and prevent displacement during heavy rains. Using multiple layers of stones with smaller rocks or gravel in between can also reinforce the bunds, making them more resilient to intense water flow. Additionally, compacting the soil between and around the stones reduces gaps and improves water retention, minimizing the chances of water undermining the structure. In some cases, adding a layer of clay on the bund's upstream side can further enhance water retention and reduce seepage.

Structural design modifications can also play a critical role in strengthening bunds. Building bunds with a slight curve or in a stepped formation can better distribute the pressure of water flow, reducing the risk of breaching. These design enhancements help manage water flow more effectively and protect the bunds from being overwhelmed during heavy rainfall events. For particularly steep slopes, the use of geotextiles, either synthetic or natural, can provide additional reinforcement by holding soil and stones in place, thus improving the bunds' stability. Regular maintenance is vital for ensuring the longevity and effectiveness of boulder bunds. Routine inspections can help identify signs of wear or damage, such as displaced stones or erosion channels, allowing for timely repairs. Removing debris and sediment that accumulate against bunds is crucial to prevent overflow and maintain their functionality. Engaging local communities in the construction and upkeep of boulder bunds can enhance sustainability. By involving community members and providing training on best practices, there is a greater likelihood of the bunds being properly maintained and adapted to changing environmental conditions.

9. Trench cum bund

Trench cum bund

The trench cum bund technique is a widely used soil and water conservation practice that combines the benefits of both trenches and bunds to effectively capture rainwater, reduce soil erosion, and enhance soil fertility. This system involves digging shallow trenches along the contour lines of sloped land, which helps intercept and slow down surface runoff during rainfall. The soil excavated from these trenches is used to construct bunds or raised embankments on the downslope side.

These bunds act as barriers that retain water, allowing it to slowly infiltrate into the soil, thereby increasing soil moisture and reducing the erosive force of water. This method is particularly beneficial in arid and semi-arid regions where water scarcity and soil degradation are major challenges. By retaining water and preventing the loss of fertile topsoil, the trench cum bund system improves soil fertility and promotes healthier plant growth, leading to higher agricultural productivity. Additionally, the presence of bunds can support vegetation, further stabilizing the soil and enhancing the local biodiversity. Despite the initial labor and cost required for construction, the long-term benefits of increased crop yields, improved soil quality, and enhanced resilience to climate variability make the trench cum bund technique a valuable tool for sustainable land management.

Suitability of various engineering measures for erosion control in arable lands

#	*Erosion control measure*	*Suitability*			
		Land slope (%)	*Soil depth*	*Rainfall (mm)*	*Crops or land use*
1	**Bunding**				
	a) Contour bunding	< 6	Shallow to deep, permeable	< 800	Small millets, pulses, oil seeds, coarse grain, root crops
	b) Graded bunding	< 6	Shallow to deep, permeable	800-1500	Small millets, pulses, oil seeds, coarse grain, root crops
		< 6	Impermeable soils	< 800	Small millets, pulses, oil seeds, coarse grain, root crops
	c) Contour terrace wall	16 to 33	Good and very high infiltration rate	> 1000	Root crops, vegetables etc.
2	**Bench terracing**				
	a) Level	< 33	Medium to deep	< 2500-3000	Paddy, small millets, pulses, oil seed, coarse grain, vegetables in low rainfall
	b) Inward sloping	< 33	Medium to deep	< 2500-3000	Potato, other vegetables maize, oats etc.
	c) Outward sloping	< 33	Shallow	< 1200	Small millets, oats, barley etc.
3	**Puertorican Terraces**		Medium to deep	< 1500	Root crops, vegetables, oats, small millets etc.
	a) With vegetative barrier	< 12			
	b) With mechanical barriers				
4	**Trenching**				
	a) **Contour Trenches**				
	i) Continuous	< 8	Medium to Deep	< 1500	Tapioca, ginger, turmeric and similar annual crops
	ii) Staggered	< 8	Shallow to medium	< 800	Papaya, banana
		< 33	Medium to deep but well drained	< 2000	Tea, Coffee, arecanut, coconut, black pepper, cinnamon, papaya etc.
	b) Graded trenches	< 33	Medium to deep but well drained	2000-3000	Tea, Coffee, arecanut, coconut, black pepper, cinnamon, papaya etc.
5	**Conversation bench terracing**	< 10	Medium to deep but well drained	< 1200-2000	Paddy on lower portion and maize crop on sloping portion
6	**Zingg terracing**	< 10	Shallow to medium	< 1200-2000	Paddy on lower portion and maize crop on sloping portion
7	**Stone wall**				
	a) Contour	< 33	Shallow to medium	< 1500	Annual crops like tea, coffee, spices etc
	b) Graded	< 33	Shallow to medium	1500-2500	Annual crops like tea, coffee, spices etc.

Non-Arable Lands treatments

Non arable or non-agricultural lands are generally those lands which are not suitable for growing agricultural crops due to one or more of natural limitations like slope steepness, erosion hazards, stoniness, rockiness, shallow soils, wetness, flooding, extreme of climate or mandate activities such as road construction and mining. Such lands cover an area of about 107 M ha out of the total geographical area of 328 M ha of India and primarily fall under land capability classes V, VI, VII and VIII. Besides being put to tittle economic use, these lands contribute considerable amount of runoff, soil erosion and consequently undergo continuous degradation. Formation of gullies, landslides/slips, stream bank erosion etc. are some of the forms of erosion observed in such lands. Man made activities like road construction and mining on steep slopes have rendered large areas as denuded and unfit for cultivation.

These degraded lands are in fact wasted lands although they have potential for growing fodder, fuel, fiber, fruit and minor forest products. Proving good vegetative cover to a degraded site is the final answer for its rehabilitation. However, at a highly degraded site, establishment of vegetation is a difficult task due to excessive runoff/debris movement, deficient moisture and absence of fertile soils. Engineering measures are, therefore, often needed as a pre requisite to revegetation programme in order to stabilize the slopes and create conditions conducive to plant growth by trapping fine soil and improve moisture status. They are also called as the first line of defence.

The engineering measures must be supported by vegetative measures so that both of them act in unison as bio engineering measures, supplementing each other. Engineering measures in soil conservation works are basically used for i) providing mechanical stability to eroded/erodible slopes. ii) retaining debris/soil, iii) establishing the vegetation/seeds planted in place, and vi) conserving fine soil and moisture for plant growth. They, therefore, just act like a foundation on which the superstructure of vegetation can be created. The engineering measures, according to their functions, may be mainly grouped as:

- Slope stabilization measures and
- Drainage line treatment measures

A. Diversion channel/Drains

Diversion drains are made across the slope to divert excess runoff water away from an unstable area and discharge it safely into a natural waterway or grassed water course. Diversion channel is formed to avoid the rain water that flows from pasture lands, hilly areas, and forest areas entering into the cultivable area. A drain across the slope is opened for safe disposal of runoff water. The following points should be kept in mind while designing a diversion drain:

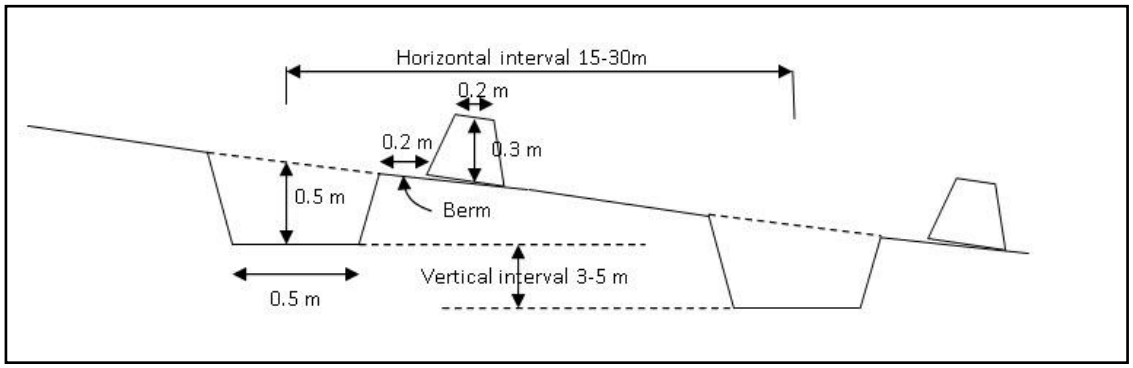
- The bed slope of the drain should be such that it is non erosive as well as non-silting one.
- The gradient of diversion drain should preferably be kept within 0.5 per cent.

- A narrow and deep drain does not get silted up as rapidly as a broad and shallow drain of the same cross-sectional area and is, therefore, self-maintaining.

Diversion channel

B. Contour trenching

Contour trenching implies excavating a trench along the contour or along a uniform level. The excavated soil is heaped on downstream side of the trench in the form of a bund. Contour trenches are used both on hill slopes and barren lands for soil and moisture conservation as well as for revegetation purpose. These trenches break the slopes length, reduce the runoff and consequently retard its scouring action and carrying capacity. The water retained I n trenches helps in conserving the moisture and therefore provides advantageous site for sowing, planting and augmentation of ground water recharge. To prevent the trench from silting up, it is advisable to provide stone barrier of about 30 cm height or a grass barrier if the former is not available at site, just above the trench. Typical cross section of a contour trench system is shown in below diagram.



Contour trenches

Contour trenches can be successfully used under following situations:

- In semi-arid or arid lands where rainfall intensities are high.
- In soils which have relatively higher permeability.
- For denuded slopes where revegetation is planned.
- For Development of orchards on slopping lands.

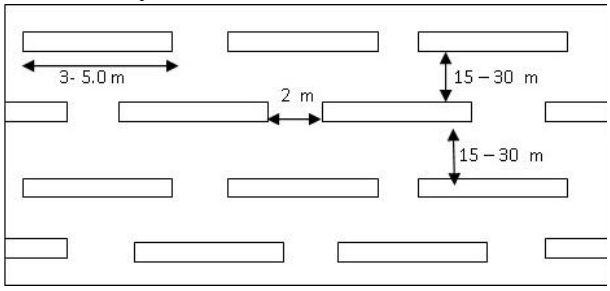
Objectives: Contour trenching is carried out with the following main objectives:

- Promote absorption and storage of water in soil profile for promoting vegetation growth.
- Moderate flash floods and improve ground water recharge.
- Control erosion on slopes where plant cover has deteriorated and vegetation is required.

Types of trenches: Contour trenches are broadly classified into i) continuous ii) staggered and iii) In-line, as discussed below:

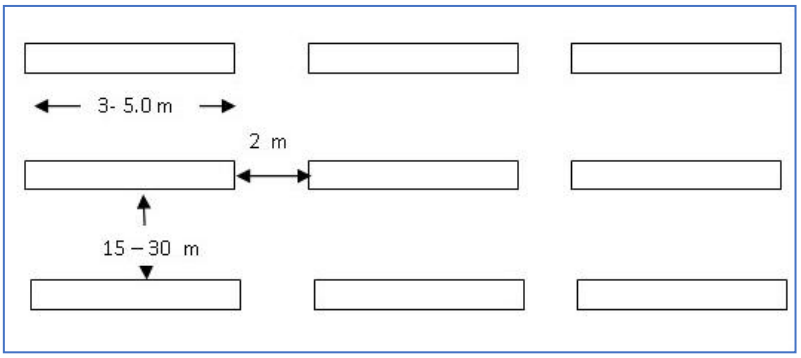
1. **Continuous contour trenches:** Continuous contour trenches (CCTs) are the ones when there is no break in their length and they can be 10 to 20 m long across the slope depending on the width of the filed. The cross section of the trench generally varies from 30 cm × 30 cm to 45 cm × 45 cm. They are constructed for moisture conservation in low rainfall areas receiving storms of mild intensities. These trenches demand high skill for construction and layout on contour. It has been observed that CCTs are prone to breaching if they should be planned and constructed with care. Equalizers of 20- 25 cm width and suitable height are placed at regular intervals to avoid concentration of flow and to prevent breaching of the trenches.

2. **Staggered contour trenches:** The staggered trenching involves the excavation of trenches of shorter length in a row along the contour with interspace between them. These trenches are arranged in straight line (staggered form). Suitable vertical intervals between the rows are restricted to impound the runoff without overflow. In the alternate row, the trenches are located directly below one another. The trenches in successive rows are thus staggered, with the trenches in the upper row and the interspace in the lower row being directly below each other. The length of the trench and the interspace between the trenches in the same row should be suitably designed such that no long unprotected or uninterrupted slope to cause unexpected runoff or erosion. As the trenches are not continuous, no vertical disposal drain is excavated. The cross-sectional area of these trenches should be designed to collect the runoff expected from intense storms at recurrence intervals of 5-10 years.



Staggered contour trenches

3. **In-line Trench:** This type of trench addresses the problem of inconsistent deposition of soil. These trenches are maximum 5 meter long and cross section is similar to continuous trenches. The gap between two in-line trenches should not be more than 2 meters as shown below. This type of trenches has the limitation that it fails to collect runoff flowing between the gaps of two trenches.



In-line trenches

C. Cresent bunds

Crescent bunds are innovative land management structures designed to improve water retention and reduce soil erosion in regions prone to uneven rainfall distribution, such as arid and semi-arid areas. These semi-circular embankments are constructed across slopes, using readily available materials like soil, rocks, and vegetation, to maximize water conservation. The design and layout of crescent bunds are crucial, as they are strategically positioned perpendicular to the natural slope of the land. This orientation allows them to effectively intercept and capture surface runoff during rain events, slowing down water flow, and promoting infiltration into the soil. By increasing the soil's water retention capacity, crescent bunds help maintain soil moisture levels, which is essential for enhancing agricultural productivity and supporting crop growth even during dry spells. Over time, this practice can lead to improved soil fertility, reduced land degradation, and higher agricultural yields, providing significant benefits to local communities reliant on farming.

Additionally, the presence of crescent bunds creates microhabitats that support biodiversity by offering shelter and resources for various plant and animal species, contributing to a more resilient ecosystem. Overall, crescent bunds represent a sustainable approach to water management that helps mitigate the impacts of climate variability and promotes the long-term health of the land.

D. Parallel contour trench

Parallel contour trenches are a soil and water conservation technique used primarily in hilly or sloped agricultural areas to prevent soil erosion and enhance water retention. These trenches are dug parallel to the natural contours of the land, following the elevation lines across a slope. By doing so, they effectively slow down the flow of water, allowing it to percolate into the soil rather than running off quickly and causing erosion. This practice is particularly beneficial in areas with steep slopes and heavy rainfall, where the risk of soil erosion is high. The trenches act as barriers that break the momentum of water as it moves downhill, capturing both water and sediments, which enrich the soil and promote fertility. By increasing the infiltration of water, contour trenches help maintain soil moisture, making it available for crops and vegetation during dry periods. This method also helps in recharging groundwater levels and improving the overall resilience of the agricultural landscape. The construction of parallel contour trenches involves careful planning and measurement to ensure they align correctly with the land's contours, often requiring the use of tools like A-frames or laser levels to guide their placement. The effectiveness of these trenches can be further enhanced by planting grasses, shrubs, or trees along the trench lines, which helps stabilize the soil and provide additional ecological benefits, such as habitat creation and carbon sequestration. Parallel contour trenches are a sustainable land management practice that not only mitigates the adverse effects of erosion but also contributes to increased agricultural productivity and environmental sustainability.

E. Vegetative strips

Vegetative strips are an effective strategy for managing and rehabilitating non-arable lands, transforming them into functional and ecologically beneficial areas. These strips, composed of grasses, shrubs, and trees, are strategically planted across slopes or degraded lands to control soil erosion, improve soil fertility, and increase biodiversity. In non-arable areas, where traditional farming is not feasible due to poor soil quality, steep slopes, or other limiting factors, vegetative strips offer a sustainable alternative for land management. The primary function of vegetative strips is to slow down water runoff, allowing it to infiltrate the soil, thereby reducing erosion and sediment loss. The roots of the plants in these strips help bind the soil, enhancing its structure and stability. Over time, as organic matter from decaying plant material accumulates, the soil's fertility improves, creating a more hospitable environment for plant and animal life. This process not only aids in soil conservation but also contributes to the restoration of degraded ecosystems.

Additionally, vegetative strips serve as corridors for wildlife, promoting biodiversity by providing habitat and food sources for various species. They can also act as windbreaks, reducing wind erosion and creating microclimates that support more diverse plant and animal communities. In areas prone to flooding, vegetative strips can mitigate the impact by absorbing excess water, thereby reducing the risk of downstream flooding. The implementation of vegetative strips requires careful planning, considering factors such as the selection of appropriate plant species, spacing, and maintenance. Native plants are often preferred for their adaptability to local conditions and their role in supporting native wildlife.

Once established, these strips require minimal maintenance and can provide long-term ecological and economic benefits, making them a valuable tool for land rehabilitation and sustainable management of non-arable lands.

F. Graded contour

Graded contours are an essential technique for treating non-arable lands, particularly in hilly or sloped areas where soil erosion and water runoff are significant concerns. This method involves constructing earthworks that follow the natural contours of the land but are slightly graded to direct water to specific areas for infiltration or storage. The primary goal of graded contours is to control water flow, minimize soil erosion, and improve land productivity, even in areas that are not suitable for conventional agriculture.

Implementation of Graded Contours: The process of creating graded contours begins with a detailed assessment of the land's topography to determine the most effective contour lines. Using tools like A-frames, laser levels, or GPS, technicians mark these lines across the slope. The contours are then constructed by creating shallow ditches or embankments along these lines, with a slight gradient to encourage water to flow toward designated collection points, such as ponds or infiltration basins. This strategic water management helps to prevent excessive runoff, which can cause erosion and nutrient loss, while promoting water infiltration into the soil.

Benefits and Environmental Impact: Graded contours offer several benefits for non-arable lands. By slowing down water movement, they reduce soil erosion and sediment loss, which are critical for maintaining soil health and preventing land degradation. The collected water can be used to recharge groundwater supplies or provide moisture to support vegetation growth, improving the overall resilience of the landscape. Over time, these benefits can transform non-arable land into a more productive and ecologically balanced environment. Additionally, graded contours can support reforestation or agroforestry efforts by creating favorable conditions for tree and shrub growth. Vegetation established along these contours helps stabilize the soil with its root systems and adds organic matter to the soil as plants decompose. This contributes to improved soil structure and fertility, enabling the land to support a broader range of plant and animal life.

Sustainable Land Management: Incorporating graded contours into land management practices can significantly enhance the sustainability of non-arable lands. By integrating water conservation, soil preservation, and ecological restoration, graded contours provide a comprehensive approach to land rehabilitation. This method is particularly valuable in areas facing challenges such as deforestation, overgrazing, and climate change, as it promotes environmental resilience and long-term productivity. With careful planning and implementation, graded contours can play a pivotal role in transforming non-arable lands into thriving ecosystems.

Recharge pond

Recharge ponds are an effective treatment for managing and rehabilitating non-arable lands, particularly in areas that suffer from water scarcity and poor soil conditions. These ponds are

designed to capture and store rainwater or runoff, allowing it to slowly percolate into the groundwater table, thereby replenishing aquifers and improving the availability of water for surrounding ecosystems.

Implementation of Recharge Ponds

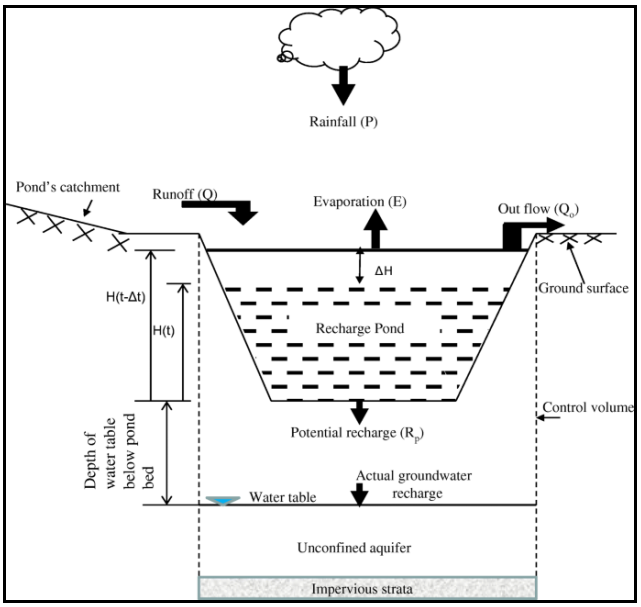
The construction of a recharge pond begins with selecting a suitable site, typically in a natural depression or at a low point in the landscape where water naturally accumulates. The size and depth of the pond are determined based on the expected volume of water it will receive and the permeability of the underlying soil. Excavation is then carried out to create the pond, and the sides may be reinforced with rocks or vegetation to prevent erosion and siltation. Once constructed, the pond collects rainwater and surface runoff, reducing the velocity of water flow and allowing sediments to settle. This process not only helps in recharging groundwater but also improves water quality by filtering out pollutants and sediments. In some cases, ponds can be lined with permeable materials to enhance infiltration rates, or designed with multiple layers to facilitate gradual water movement into the soil.

Benefits and Environmental Impact: Recharge ponds offer numerous benefits for non-arable lands:

- **Water Conservation:** By capturing rainwater and runoff, recharge ponds help to conserve water that would otherwise be lost to evaporation or runoff, ensuring a steady supply of water during dry periods.
- **Groundwater Recharge:** The primary function of recharge ponds is to replenish groundwater supplies. This is particularly important in areas with depleted aquifers or regions that rely on groundwater for irrigation and domestic use.
- **Ecosystem Support:** The presence of a recharge pond can create a microhabitat for a variety of plant and animal species, promoting biodiversity and enhancing the ecological value of the area.
- **Soil Improvement:** Over time, the increased availability of water can improve soil moisture levels, making the land more amenable to vegetation growth and reducing the risk of soil erosion.
- **Flood Mitigation:** Recharge ponds can help manage excess runoff during heavy rainfall, reducing the risk of downstream flooding and protecting nearby communities and infrastructure.

Sustainable Land Management

Integrating recharge ponds into the management of non-arable lands can significantly enhance their ecological and economic value. By providing a reliable water source and improving soil conditions, these ponds contribute to the sustainable rehabilitation of degraded landscapes. Additionally, recharge ponds can be combined with other land management practices, such as contour farming or agroforestry, to create a holistic approach to land restoration and conservation. With careful planning and community involvement, recharge ponds can transform non-arable lands into productive and resilient ecosystems that support both human and natural systems.



Recharge pond

Drainage line treatments

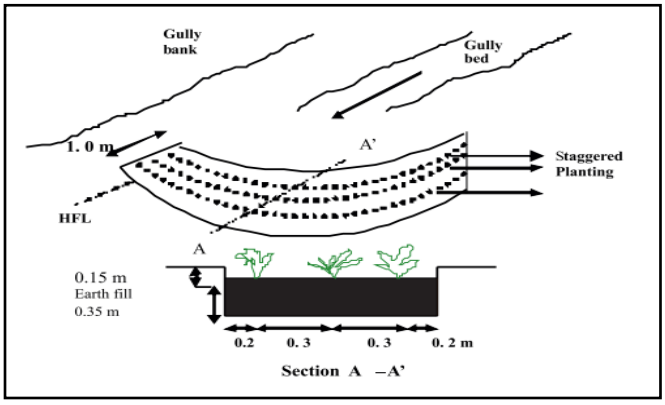
Drainage channels/gullies are the carriers of runoff and sediment in a watershed. Steep bed gradient of a channel causes high runoff velocities with associated heavy sediment flow. Hence channel gradient needs to be reduced in order to bring the runoff velocities within permissible limits. Drainage line treatment structures are classified as upper, middle and lower ridge treatments.

A. Upper ridge treatment

- **Sod strips:** Sod-forming grasses like *Cynodon dactylon, Digitaria* and *Dicanthium* are planted. In some cases, trees and shrubs such as I*pomoea cornea, Vitex nigundo, agave, Saccharum munja* and *bamboo* are also recommended for sod strip. Sod strips are utilized in gullies up to 1 meter deep, typically within catchment areas of approximately 3 hectares. These gullies have a bed slope of about 4%, making soil erosion a concern. To combat this, a planting arrangement is employed that consists of three staggered rows of crops, such as agave, which are known for their drought resistance and soil stabilization properties. Each row has a width of 1 meter, and the height of the planting is maintained at 0.5 meters. The soil in these rows is refilled to a height of 0.35 meters, ensuring the plants have sufficient support and access to nutrients. Additionally, there are 1-meter intervals between the rows, allowing for optimal spacing that facilitates water management and minimizes erosion. This strategic planting helps to conserve soil and water, promoting sustainable agriculture in areas with sloped terrain.

Spacing between two sod strips will be decided based on the slope of the gully

#	Gully slope (%)	Horizontal interval (m)
1	1-2	50
2	2-3	30
3	3-4	20

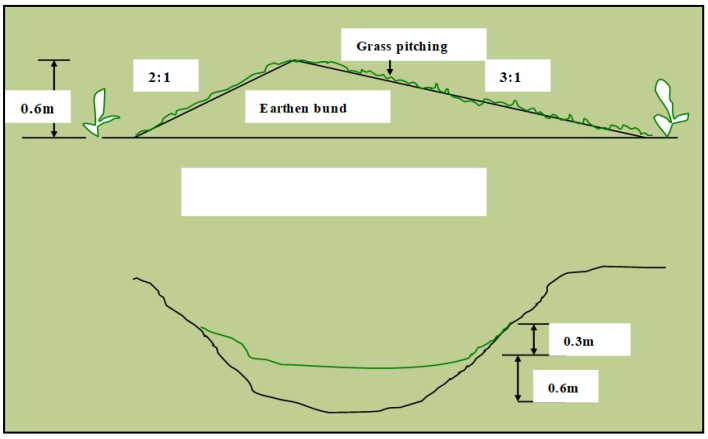


Sod strips

- **Sodded earthen check**

Sodded earthen checks are utilized in areas with gentle slopes ranging from 1 to 4 %. They are typically employed in catchment areas or watersheds up to 3 hectares in size. These structures are designed to control water flow and reduce soil erosion in gullies with depths between 1 and 1.15 meters and widths up to 5 meters. The checks are installed with a vertical interval of 0.9 to 1.0 meters to ensure effective water management.

In terms of design, the sodded earthen check is constructed with a height of 0.60 meters and a length of 0.60 meters. The slope on the upper side of the check is maintained at a 2:1 ratio, while the lower side has a slope of 3:1. This ensures stability and gradual water flow. The bottom width of the structure is 3 meters, providing a solid base. The cross-sectional area of the check is calculated as half of the product of the bottom width and height, which helps determine the volume of soil needed for construction. These specifications enable the sodded earthen check to effectively reduce soil erosion and improve water retention in sloped agricultural landscapes.

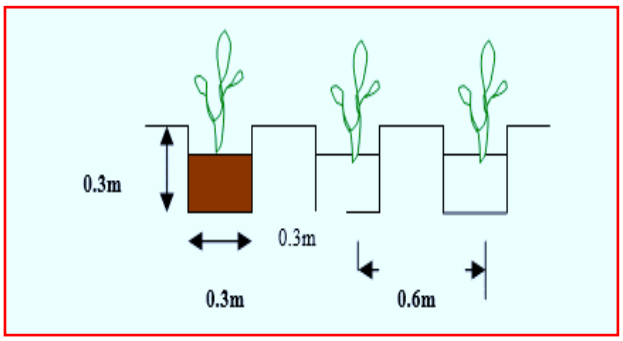


Sodded earthen check

- **Shrub check**

Shrub checks are implemented in areas with slopes ranging from 1 to 4 %, specifically within watershed or catchment areas of 3 to 5 hectares. They are used to control erosion and manage water flow in gullies that are up to 1 meter deep and 5 meters wide. The vertical interval between shrub checks is typically maintained between 0.9 and 1.0 meters to optimize their effectiveness in slowing down water runoff.

In terms of design, the length of a shrub check is determined by the distance between the highest flood levels (HFL) on either side of the gully. The width of the shrub check is set at 1.50 meters to provide a substantial barrier against water flow. The cross-sectional area of the shrub check is calculated as 0.27 square meters, based on a typical configuration of 0.3 meters in height and width, with a multiplication factor of 3 to account for the density of the shrubs. This design helps stabilize the soil, reduce erosion, and retain moisture, making shrub checks an effective and natural solution for managing water and soil resources in sloped terrains.



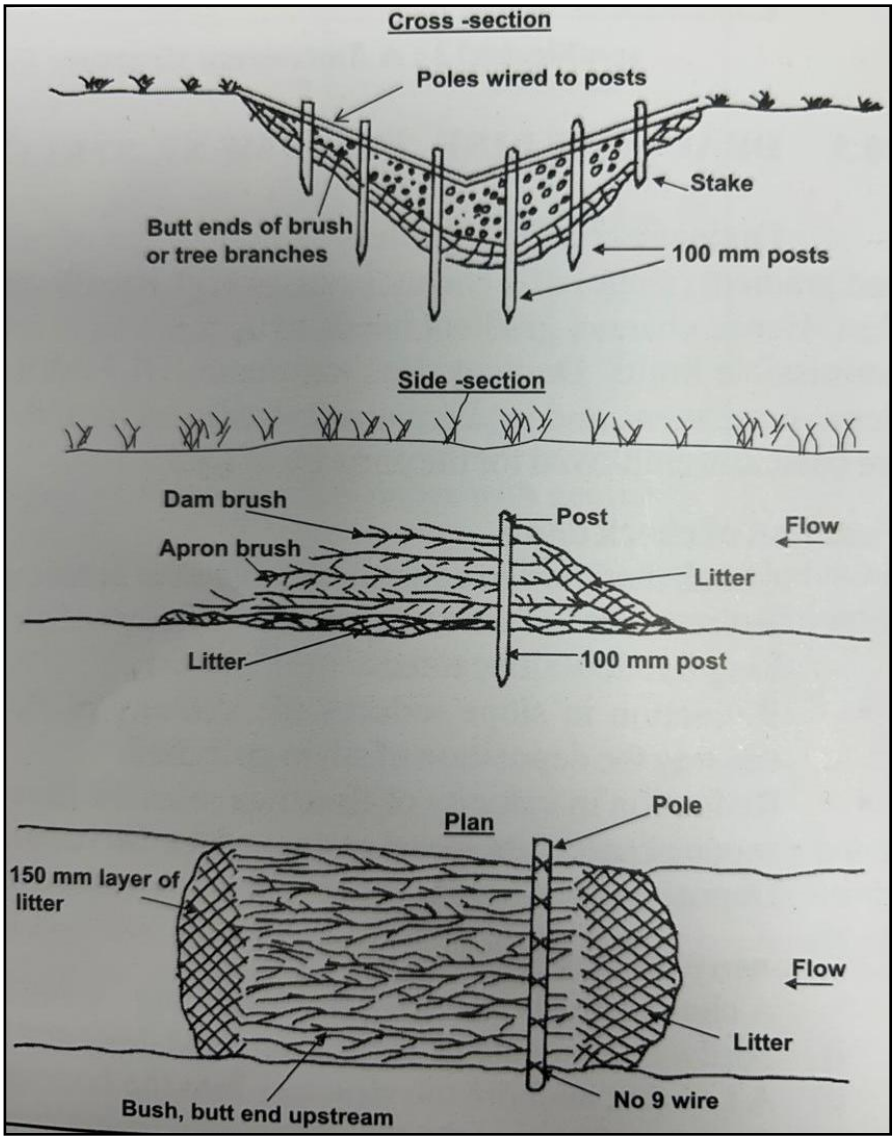
Shrub check

- **Brush wood checks**

Brushwood check dams are constructed in small gullies (1.2 to 2.1 m deep) where wooden posts are abundantly available. Such check dams maybe i) Single row post check dam and ii) Double row post brush dam depending on the need as described below.

i) Single row post brush dam

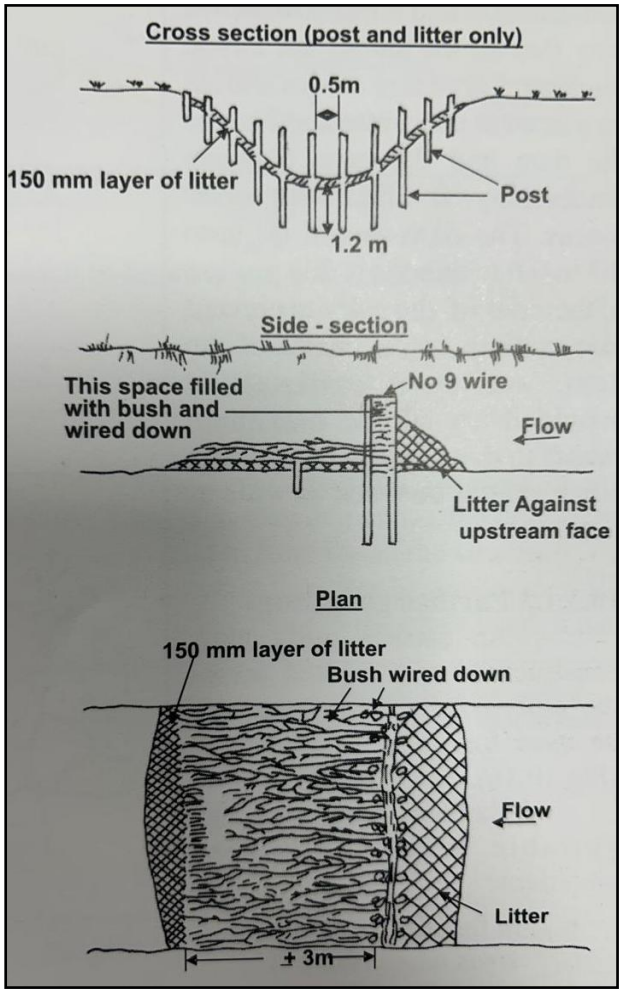
The construction of the single row post dams begins by easing the side slope of gully to 1:1. Then the wooden posts of about 10 – 15 cm diameter are driven into the bed and banks of the gully to a depth of about 0.75 – 0.9 m below the surface and about 0.6-0.9 m apart. Posts of self-sprouting species such as willow are preferred for this purpose. Tops of the posts are kept at such a height so that they form a distinct notch should be sufficient to discharge the waterflow safely without undermining the dam at the ends. A 15 cm thick layer of litter is placed on the floor of the gully between the posts extending upstream to the proposed base of the dam and downstream end of the apron. Green branches of the tree are placed on the top of the litter lengthwise along the gully with butt ends facing attained. Cross poles are fixed on upstream side of the structure and brush is tied to the structure with galvanized wire.



Single row post brush dam

ii) Double row post brush dam

For the construction of the double roe post dams the gully sides are sloped back and two rows of wooden posts are erected across the gully. The distance between the rows is not kept more than 0.9 m. the posts are driven at a distance of 0.5 m apart in a row to go at least 0.9 to 1.2 m into the hard bed of the gully. A 15 cm layer of litter is laid on the floor of the gully again extending to the proposed base of the dam and downstream to the end of apron. A 0.3 m layer of brush is laid on the apron and tied to the lower row post. A row of stake is driven through the middle of the apron into the floor of gully and brush is tied to it to form a dense mat. The space between two rows of posts is filled with brush laid across the gully. This is compressed tightly and held in position with the wire. Litter is placed on the upstream side of the dam.



Double row post brush dam

- **Mini percolation tank:**

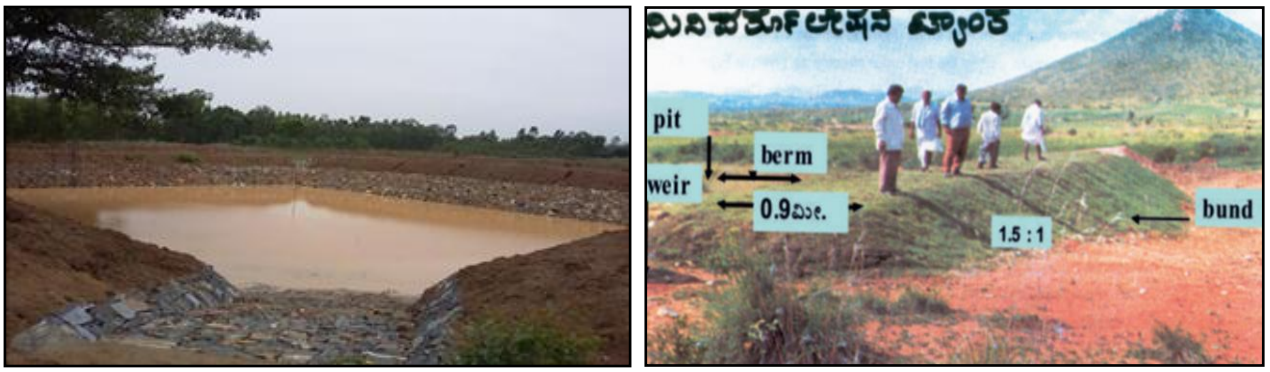
The rain water flowing in gully or undulating lands will be collected in Mini Percolation Tank so that the moisture percentage in the surrounding area is increased besides using for pitture irrigation of Forest/ Horticulture plants. The excavated soil is put as bund and grasses will come up with the soil spread over the exposed surfaces so that water storage is increased. Surplussing is through an outlet.

A mini percolation tank is an effective water conservation structure used to manage water resources in both arable and non-arable lands. It is particularly useful in drainage lines and U-shaped gullies within watershed or catchment areas ranging from a minimum of 5 hectares to a maximum of 20 hectares. The primary purpose of a mini percolation tank is to enhance groundwater recharge by allowing water to percolate into the soil, thereby increasing water availability for agriculture and reducing runoff.

The design of a mini percolation tank features an upper width of 1 meter and side slopes with a ratio of 1.5:1 to ensure stability and accommodate varying water levels. The storage water height within the tank ranges from a minimum of 1 meter to a maximum of 1.60 meters, allowing flexibility in managing water levels during different seasons. The combined height

for flowing water and safety is set at 1 meter to ensure the structure can handle unexpected surges in water flow without compromising its integrity.

The total bund height of the tank is designed to be 2.60 meters, with a basement depth of 0.10 meters to provide a solid foundation. This configuration helps capture and store water effectively, promoting infiltration and increasing soil moisture content. By strategically implementing mini percolation tanks, communities can improve water security, support agricultural activities, and enhance the resilience of their landscapes to climate variability.



Mini percolation tank

- **Boulder check**

A boulder check is an erosion control structure designed to stabilize gullies by slowing down water flow and encouraging sediment deposition. This method is particularly effective in areas where the gully erosion is moderate and the available watershed or catchment area is about 8 hectares.

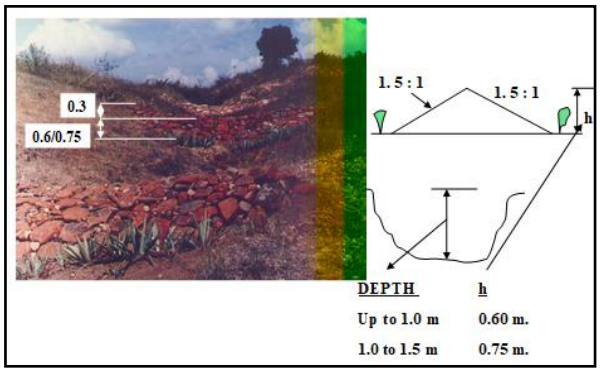
Site Selection: For constructing a boulder check, site selection is crucial. The site should be in a gully with a depth ranging from 1 to 2 meters and a width of approximately 5 meters. The vertical interval, which is the distance between successive boulder checks along the gully, is typically set at 1 meter. These dimensions ensure that the structure effectively reduces the flow velocity of water and traps sediment, preventing further deepening and widening of the gully.

Design Specifications: The design of the boulder check is tailored to the specific characteristics of the gully. The length of the boulder check is determined by the length of the gully at the crest point, ensuring that the structure spans the full width of the gully where the water flow is concentrated. The bottom width of the boulder check is calculated based on the side slope of the bund, using the formula Z + 1, where Z represents the horizontal distance of the slope relative to the vertical rise. The side slopes of the boulder check on both the upper and lower sides are typically constructed at a ratio of 1.5:1, providing stability to the structure while allowing it to withstand the force of flowing water.

Construction Details: The basement of the boulder check, which serves as its foundation, is designed to be 0.30 meters deep. This ensures that the structure is anchored securely in the ground, reducing the risk of it being undermined or dislodged during heavy water flow. The boulders used in the construction should be of sufficient size and weight to resist being

washed away, and they should be carefully arranged to create a porous barrier that slows water flow without completely blocking it. This porosity is essential for allowing water to pass through while still reducing its speed and allowing sediment to settle.

Application and Benefits: Boulder checks are particularly effective in medium-sized gullies within agricultural or forested areas where erosion needs to be managed without the use of more complex engineering structures. The construction of boulder checks not only helps in reducing the velocity of water flow but also aids in trapping sediments, thereby gradually filling up the gully and stabilizing the surrounding land. Over time, the reduced erosion can lead to the restoration of vegetation, further strengthening the stability of the area.



Boulder check

- **Rubble check**

A rubble check is an erosion control structure commonly used to stabilize and rehabilitate gullies, particularly in areas where erosion is severe and needs immediate intervention. Rubble checks are constructed using loose stones or rubble and are designed to slow down the flow of water in gullies, allowing sediment to accumulate and reducing further erosion.

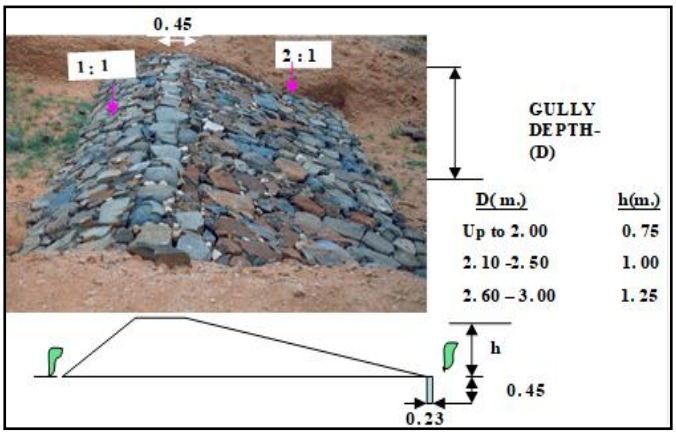
Site Selection: Rubble checks are most effective in watersheds or catchment areas ranging from 8 to 15 hectares. These structures are ideally suited for gullies that have a depth of 1 to 3 meters and a bottom width of around 8 meters. The size and design of the rubble check must be appropriate for the gully's dimensions to ensure that the structure effectively controls water flow and minimizes erosion.

Design Specifications: The rubble check is designed with specific parameters to match the gully's characteristics. The distance between two successive rubble checks is typically set at 2 to 2.5 meters. This spacing ensures that the water flowing down the gully is repeatedly slowed, preventing it from gaining enough momentum to cause significant erosion. The side slopes of the rubble check are constructed with different gradients for stability. On the upper side, the slope is set at a 1:1 ratio, meaning the horizontal distance is equal to the vertical rise. On the downside, the slope is gentler, with a 2:1 ratio, providing added stability against the downward force of water.

Construction Details: The foundation of the rubble check, or its basement, is designed to be 0.30 meters deep. This depth helps to anchor the structure firmly in the ground, reducing the risk of it being washed away during heavy rains or high-water flow. The rubble used in the construction should consist of large, stable stones that can withstand the pressure of flowing

water. These stones are arranged in a way that creates a semi-permeable barrier across the gully. This allows water to pass through slowly, while also trapping sediments behind the structure.

Application and Benefits: Rubble checks are particularly useful in larger gullies where more substantial intervention is required to control erosion. By constructing a series of rubble checks along the length of the gully, the overall water velocity is reduced, leading to increased sediment deposition and a gradual reduction in gully depth over time. This process not only stabilizes the gully but also helps in the restoration of vegetation, which further enhances soil stability. Additionally, rubble checks are relatively easy to construct using locally available materials, making them a cost-effective solution for erosion control in rural and semi-arid areas.



Rubble check

- **Sunken pond**

A sunken pond is a water conservation structure specifically designed to collect and store runoff water in areas prone to erosion or where water availability is limited. These ponds are particularly beneficial in agricultural landscapes, where they help in managing water resources efficiently and in preventing soil degradation. The design and construction of a sunken pond are tailored to the specific characteristics of the soil and the gully in which it is located.

Site Selection: The ideal location for a sunken pond is within a watershed or catchment area of up to 15 hectares. This size limitation ensures that the pond can effectively capture and store the runoff from the surrounding area without being overwhelmed by excessive water flow. The width of the gully at the bottom plays a crucial role in determining the suitability of the site. For areas with black soil, the gully should have a minimum bottom width of 5 meters, while for areas with red soil, a minimum bottom width of 3.1 meters is sufficient. These dimensions account for the different soil types' stability and water retention capacities.

Design Specifications: The design of a sunken pond is carefully planned to optimize water storage while maintaining the structural integrity of the surrounding landscape. The top width of the pond is set at a minimum of 5 meters, and the top length is a minimum of 8.4 meters, ensuring that the pond can store a significant volume of water. The total depth of the pond varies depending on the site's requirements, with a minimum depth of 0.9 meters and a

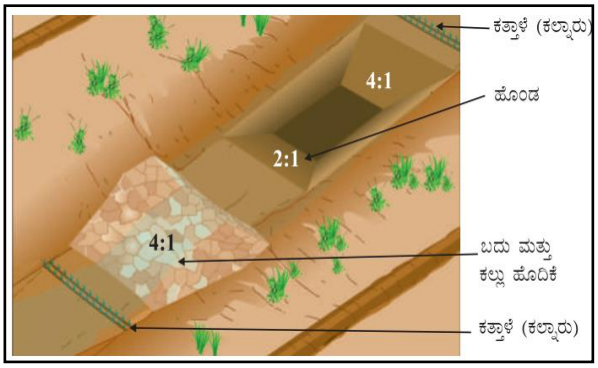
maximum depth of 1.8 meters. These depth ranges allow for effective water storage while preventing the pond from becoming too deep, which could lead to instability or safety concerns.

The side slopes of the pond are critical to its stability and are designed according to the soil type. For black soil, the side slopes are constructed at a ratio of 1.5:1, which provides a gentle enough gradient to prevent erosion while still being steep enough to maximize water storage. For red soil, the side slopes are steeper, with a 1:1 ratio, reflecting the soil's ability to hold shape and prevent slumping. The upper side of the pond has a gentler slope of 4:1, allowing for easy access and reducing the risk of erosion, while the lower side has a steeper 2:1 slope to support the pond's structural integrity.

Application and Benefits:

Sunken ponds are highly effective in areas where water conservation is essential, such as in arid or semi-arid regions. By capturing and storing runoff water, these ponds help to recharge groundwater levels, provide water for irrigation during dry periods, and reduce the risk of soil erosion by controlling water flow within the gully. The pond's design ensures that it is both functional and stable, with side slopes tailored to the specific soil conditions to prevent erosion and maintain the pond's structure over time.

In addition to their practical benefits, sunken ponds also contribute to the local ecosystem by creating a habitat for aquatic life and supporting the growth of vegetation around the pond. This vegetation, in turn, helps to stabilize the soil and further reduce erosion, creating a sustainable and resilient landscape. Sunken ponds are a valuable tool in integrated watershed management, providing both immediate and long-term benefits to the environment and the local community.



Sunken pond

- **Gabion**

A gabion is an erosion control structure constructed using wire baskets filled with rocks or other durable materials. These structures are typically used to stabilize gullies, control water flow, and prevent further erosion. Gabions are particularly useful in areas where other erosion control methods, like rubble checks, have failed or where the soil conditions require a more robust solution.

Site Selection: The ideal site for constructing a gabion is within a gully where the contributing water area is up to 15 hectares. This size ensures that the gabion can effectively manage the water flow without being overwhelmed by excessive runoff. Gabions are especially suited for gullies with loose soil, where the risk of erosion is high, and other control methods, such as rubble checks, have been compromised due to the intensity of water flow. Selecting a site with these characteristics ensures that the gabion will provide the necessary stability and erosion control.

Design Specifications: The design of a gabion is tailored to the specific conditions of the gully and the volume of water it needs to manage. The basic dimensions of the gabion structure include a width of 1 meter and a length that equals the width of the nala (or watercourse) plus an additional 2 meters. This extra length allows the gabion to anchor securely into the banks on either side of the gully, providing additional stability and preventing the structure from being dislodged during heavy water flow.
The depth of the gabion typically ranges between 60 and 90 centimeters. This depth ensures that the gabion is well-anchored in the gully bed, reducing the risk of it being undermined by water flow. The baskets used to construct the gabion generally have dimensions of 1 to 2 meters in length, 1 meter in width, and 1 meter in height. These baskets are filled with rocks or other durable materials, which are packed tightly to form a sturdy barrier that can withstand the force of flowing water.

The overall height of the gabion structure depends on the cross-section of the gully and the level of surplussing required. Surplussing refers to the controlled overflow of water that the gabion allows to pass while still trapping sediment and slowing the water's velocity. The height is carefully calculated to ensure that the gabion effectively manages the water flow without causing backwater flooding or other issues upstream.

Application and Benefits: Gabions are highly effective in controlling erosion in gullies where other methods have failed or where soil conditions are particularly challenging. By slowing down the flow of water and trapping sediment, gabions help to stabilize the gully, reduce further erosion, and encourage the deposition of sediment, which can gradually fill in the gully and restore the landscape. The use of wire baskets filled with rocks makes gabions particularly durable, allowing them to withstand the pressures of high-water flow over an extended period.

Additionally, gabions are relatively easy to construct and can be assembled using locally available materials. This makes them a cost-effective solution for erosion control in rural or remote areas. The porous nature of the gabion allows water to pass through while still reducing its velocity, which is crucial for preventing the rapid erosion that can occur in loose soil gullies. Over time, the gabion can also promote vegetation growth in the gully, further stabilizing the area and enhancing the local ecosystem. Overall, gabions provide a robust and long-lasting solution for gully erosion, helping to protect the landscape, conserve soil, and manage water resources effectively.


Gabion

B. Middle ridge treatment

1. Dugout pond

Dugout ponds are man-made ponds created by excavating soil at the site. The excavated soil is then used to form embankments around the pond, providing structural stability. These ponds can be filled either by surface runoff from rain or by tapping into groundwater sources if aquifers are available. For irrigation purposes, water stored in dugout ponds typically needs to be pumped out, as the ponds are generally at a lower elevation than the surrounding land where irrigation is required.

Construction Methods for Dugout Ponds:

The construction of a dugout pond begins with careful planning and site preparation. Start by surveying the proposed site to assess the topography, soil type, and water source availability. It is crucial to calculate the volume of water required for the intended use, such as irrigation or livestock watering, to determine the appropriate size and shape of the pond. Once the pond's boundaries are marked with stakes and string, excavation can commence. Begin by removing the topsoil layer, setting it aside for use in landscaping or embankment construction later. Excavation can be carried out using heavy equipment like backhoes, excavators, or bulldozers, although manual digging may suffice for smaller ponds. The pond's sides should be shaped with a gentle slope, typically at a 1:2 or 1:3 gradient, to prevent erosion and ensure stability.

After excavation, the next step is to construct embankments using the soil excavated from the pond. These embankments should be compacted thoroughly to reduce seepage and enhance stability, and additional impermeable materials like clay can be added if necessary. In areas with highly permeable soils, lining the pond with materials such as clay, plastic liners, or geotextiles may be required to prevent water loss. The installation of proper inlet and outlet structures is also crucial; these structures help channel surface runoff or other water sources into the pond while managing overflow during heavy rains. Finally, the embankments should be stabilized by planting grasses or other ground cover to minimize erosion, and the pond should be filled with water to check for any signs of leaks or seepage.

Maintenance Tips for Dugout Ponds:

Regular maintenance is essential to keep a dugout pond in optimal condition. Begin with frequent inspections to identify any signs of damage, such as erosion, cracks, leaks, or sediment buildup. Pay special attention to the embankments, inlets, outlets, and liners for signs of wear and tear. Sediment management is another key aspect of pond maintenance; remove accumulated sediment periodically to maintain the pond's storage capacity. This can be achieved through dredging equipment or manual tools, taking care not to damage the pond's liner or embankments in the process.

Erosion control is also critical; planting grasses or shrubs along the embankments can help stabilize the soil, and any eroded areas should be promptly repaired by adding and compacting soil. To prevent algae growth, establish buffer strips of vegetation around the pond to reduce nutrient runoff, or introduce fish species that feed on algae. Monitoring water quality is important, particularly if the pond is used for aquaculture or irrigation; parameters such as pH, turbidity, and dissolved oxygen levels should be regularly checked. Actions like aeration, adding beneficial bacteria, or using filtration systems can help maintain water quality. Additionally, control of pests and invasive species should be a routine part of maintenance. Regularly check for and manage aquatic weeds or other invasive species using manual removal, biological controls, or environmentally safe herbicides. Finally, ensure that all equipment, such as pumps and pipes used for water management, is well-maintained, cleaned, or replaced as needed to prevent breakdowns and ensure efficient operation.

Dugout pond

2. Sand bags

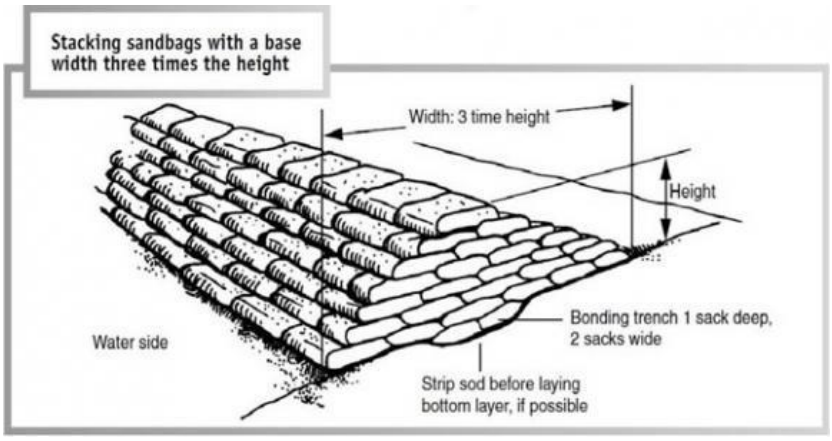
Sandbags are versatile and cost-effective tools commonly used in flood control, erosion prevention, military fortification, and construction. Filled with sand or soil, they act as barriers to water, wind, and debris, making them essential in emergency response situations, such as during heavy rains, hurricanes, or river overflows. Sandbags are typically made of strong materials like burlap, polypropylene, or other heavy-duty fabrics, which ensure durability and resistance to tearing or puncturing. Their simplicity, portability, and ease of deployment make them an ideal choice for creating temporary dikes, levees, or retaining walls, especially in areas prone to flooding or erosion.

Site Selection and Design Criteria: When using sandbags for flood control or other protective measures, selecting an appropriate site is crucial to their effectiveness. The site should be strategically located to intercept or divert water flow, preferably on firm and stable ground to prevent shifting or sinking. In flood control scenarios, the sandbag barrier should be placed away from the water source with enough distance to allow for adequate stacking and reinforcement. It is important to consider the elevation and slope of the ground, as sandbags are more effective on flat or gently sloping terrain where water flow can be more easily controlled. Additionally, sites near existing infrastructure, such as storm drains or channels, should be avoided unless necessary precautions are taken to prevent water from bypassing the sandbag barrier.

Design criteria for sandbag barriers include the height, width, and length of the barrier, which should be determined based on the expected water level and flow rate. The typical sandbag wall is constructed in a staggered pattern with a wider base that tapers upward for stability. Each sandbag should be filled to about two-thirds capacity to ensure proper molding and stacking. For greater effectiveness, especially in areas with strong currents or high-water levels, multiple layers or tiers of sandbags may be required, with the top layer compacted and reinforced to minimize seepage.

Advantages:

Sandbags offer several advantages in flood management, construction, and other applications. They are highly cost-effective due to the low cost of materials and ease of assembly. Sandbags are lightweight when empty, making them easy to transport and deploy quickly in emergency situations. Their flexibility allows them to conform to various surfaces and shapes, which makes them ideal for creating custom barriers in irregular terrain. Additionally, sandbags are environmentally friendly; they can often be reused, and materials like burlap are biodegradable, reducing long-term environmental impact. In military contexts, sandbags provide excellent protection against shrapnel and small arms fire due to their density and energy-absorbing properties. Overall, sandbags are a practical, adaptable solution for a wide range of protective and containment needs.



Sand bags

3. Loose rock ravine reclamation structure

A loose rock ravine reclamation structure, also known as a loose rock check dam or rock-fill structure, is a small, porous dam constructed across a ravine, gully, or stream channel using loose rocks, boulders, or cobblestones. These structures are primarily designed to control erosion, reduce the speed of water flow, trap sediment, and promote groundwater recharge in areas where water runoff or soil erosion poses a significant threat. Loose rock reclamation structures are widely used in watershed management, land restoration projects, and agricultural areas to stabilize soil and prevent further degradation of the landscape.

Design Criteria for Loose Rock Ravine Reclamation Structures: The design of a loose rock reclamation structure depends on several factors, including the size and shape of the ravine, the slope and terrain of the land, the volume of water flow, and the type of soil present. A well-designed structure should be placed at strategic intervals along the length of a ravine or gully to effectively manage water flow and sediment accumulation. Key criteria for designing these structures include:

Site Selection: The structure should be located where the ravine or gully is relatively narrow and shallow, as this reduces the amount of material required and maximizes the effectiveness of the structure in trapping sediments. Sites with minimal undercutting or sidewall erosion are ideal for installation. The selected site should also be upstream of critical areas needing protection, such as agricultural fields, roads, or residential areas.

Structure Dimensions: The height of the loose rock structure should typically not exceed 1.5 meters (5 feet) to avoid excessive pressure buildup and ensure safety. The width should be at least three times the height to provide stability, and the length should span the entire width of the ravine or gully. To maintain stability, the structure should have a trapezoidal cross-section, with a wide base tapering upwards. The slope of the upstream face should be gentler (around 3:1) compared to the downstream face (2:1).

Materials: Rocks used for the structure should be hard, durable, and resistant to weathering. They should range in size, from large boulders forming the base to smaller rocks and stones used to fill gaps. The use of locally available materials reduces costs and environmental impact. The placement of larger rocks at the bottom and smaller ones at the top helps create a stable, permeable structure that allows water to flow through while trapping sediment.

Foundation and Keying: The base of the structure should be dug into the streambed or ravine to a depth of about 30–50 cm (1–1.5 feet) to prevent undercutting. The sides of the structure should also be keyed into the banks to ensure stability and prevent water from flowing around the structure, which can cause further erosion.

Advantages: Loose rock ravine reclamation structures offer several benefits, particularly in erosion control and watershed management:

Erosion Control: These structures reduce the velocity of water flow, minimizing the erosive force of moving water on the soil. This helps prevent further deepening or widening of ravines or gullies.

Sediment Trapping: As water flows through the porous structure, it loses energy and drops sediment. Over time, this sediment accumulation can help restore the ravine or gully to a more stable state, allowing for vegetation growth and further stabilization.

Groundwater Recharge: By slowing down water flow, these structures promote the infiltration of water into the ground, which can enhance groundwater recharge and improve water availability in the surrounding areas.

Cost-Effective and Sustainable: Loose rock structures are relatively inexpensive to construct and maintain, especially when local materials are used. They do not require specialized equipment or technical expertise, making them suitable for community-led initiatives. Additionally, they blend naturally into the landscape and do not significantly alter the ecosystem.

4. Ravine reclamation structures

Ravine reclamation structures are critical interventions in landscapes characterized by steep, incised channels formed due to water-induced soil erosion. Ravines typically develop when intense rainfall or improper land use practices result in excessive runoff, carving deep gullies into the soil. Over time, these gullies expand, degrading the land and reducing its agricultural potential. Reclamation structures are designed to address this by stabilizing the soil, controlling erosion, and improving water management. Key structures used in ravine reclamation include check dams, gabion structures, and contour bunds. Check dams, made from materials like stone, concrete, or wood, are placed across the ravine to reduce water speed, trap sediment, and create flat areas where vegetation can grow. Gabion structures, which are wire mesh boxes filled with stones, serve a similar purpose but are more flexible, adjusting to the movement of water while still controlling erosion. Contour bunds, placed along the contours of the land, slow down water flow across the surface, allowing for increased infiltration and preventing the formation of new gullies.

The benefits of these structures extend beyond erosion control. Ravine reclamation improves the hydrology of the area by increasing groundwater recharge and maintaining more consistent moisture levels in the soil. This is particularly beneficial in arid and semi-arid regions, where water availability is a limiting factor for agriculture. Reclaimed ravines can be rehabilitated for productive uses like farming, forestry, or grazing, significantly improving the livelihoods of local communities. The vegetation that re-establishes in these areas helps to stabilize the soil further, reduces the risk of future erosion, and creates microhabitats for various plant and animal species, enhancing local biodiversity. Additionally, ravine reclamation projects often have broader environmental impacts, contributing to carbon sequestration, improving the local microclimate, and mitigating the effects of climate change.

These efforts not only restore the ecological balance but also promote sustainable land use practices that can prevent further degradation in the future.

Ravine Reclamation Structure

5. Gokatte

Protection of land and water has been an issue of prime importance to rural communities. Over time, various conservation practices have been developed through the use of indigenous knowledge, a bold sense of experimentation and a keen eye for measurement and calculation. It is, therefore, not surprising that tanks, ponds, wells and cattle pools developed by these local skills provide the blue-print for present day check dams, gully plugs and trench cum bunds.

Gokatte or cattle pool is a simple and traditional water conservation practice. These pools can be found all over – in and around villages, outside towns, at one corner of the field, at the base of the hill and in some instances, even in the middle of a tank. While some have been built very systematically using stones, others have been created in pits. This is built without the help of any special tools or gadgets.

There are many different types of gokattes in Karnataka, such as community cattle pool, town pond, small pond, madaka, excavated well, water pit etc. Though the water conservation methods varied, gokattes were in practice in some form or the other, as a community effort even as recently as two decades ago. However, community-based activity was directed not only at the building of gokattes but for desilting and strengthening of tanks, repairing the wall, whitewashing and removing mud from the ponds, which were all a part of the community effort. People participated in good numbers for the construction of the Gokatte and the tank.

Gokatte

Eye-technology: A gokattes is a simple but amazing construction which captures and collects all the rain in an area. Using the unique eye-technology of the elders, this system uses the skill of the trained eye to work out the entire process of the flow of water to the gokattes by just observing the gradient of the land. So scientific was the point of placing the gokattes that not a drop of water is wasted, thereby filling the gokattes to the brim. The overflow water reaches the village tank and this in turn would fill up all the wells in the area.

Normally all the *gokattes* in an area were connected to each other. This facilitated a system where a full pool would flow into the next one, which in turn would fill up another nearby pond. When all the ponds were full, the water would reach the main tank in the town. The cattle would generally graze in the hills located at the outskirts of the town. On their return, the cattled rank water from the *gokattes* which were situated at the base of the hills or on the borders of the villages. As these pools were built on a slope, some portion of the water soaked into the earth and the rest was retained in pools for cattle.

C. Lower ridge treatment

1. Nala bund

Nala bunding, a water conservation technique, plays a critical role in arid and semi-arid regions where water scarcity is a challenge. It is designed to store rainwater, thereby creating a sustainable water source for cattle, wildlife, and humans, while simultaneously increasing the moisture content in the surrounding soil and recharging the underground water table. By acting as a temporary reservoir during the rainy season, Nala bunds ensure that water is retained long enough for it to percolate into the ground, which is vital for enhancing groundwater resources in areas prone to water shortages.

Design Specifications:

Dimensions: A Nala bund typically has a width ranging from 5 to 15 meters and a depth of 1 to 3 meters, depending on the size of the nala and the expected runoff volume. These dimensions are crucial for holding sufficient water to allow for infiltration while preventing structural instability.

Slope: The slope of the nala bund is maintained at 1% to 3% to slow down the water flow and prevent erosion. A gentle slope ensures a controlled release of water through a surplus arrangement, avoiding bund damage during heavy rainfall.

Catchment Area: The design of the bund must also consider the size of the catchment area, which depends on the region's rainfall patterns. In regions with annual rainfall below 750 mm, the catchment area typically ranges from 80 to 500 hectares. In areas with more than 750 mm of rainfall, the catchment area can be smaller, ranging from 40 to 250 hectares. These values ensure that the Nala bund can capture and store an optimal amount of water without causing flooding or overtopping.

Site Selection

Gully Characteristics: The ideal location for a Nala bund is in gully sites that are relatively narrow and deep but have a longer length. This kind of site minimizes the earthwork required, making construction more efficient and cost-effective.

Surplus Arrangement: In designing the bund, the site must also include a provision for a surplus arrangement that is located 2 to 3 meters away from the main structure. This is necessary to channel excess water safely away from the bund during periods of heavy rainfall.

Bank Strength: The gully banks need to be strong and stable enough to withstand the pressure exerted by the impounded water. Weak or eroded banks can lead to the failure of the structure, which would defeat the purpose of the bund. Therefore, it is essential to assess the soil's stability and, if necessary, reinforce the banks with vegetation or masonry to prevent collapse.

Ecological and Agricultural Benefits

Nala bunds not only improve the availability of water for cattle and wildlife but also help maintain the soil moisture regime for extended periods. This moisture is crucial for vegetation growth, which further stabilizes the soil and prevents erosion. The bund’s impact on groundwater recharge is also significant, as it helps maintain water tables, supporting wells and boreholes in the surrounding areas. This is particularly important in regions that rely on rain-fed agriculture, as it extends the growing season and improves crop yields by ensuring that water is available during dry spells. Overall, Nala bunding is a sustainable, low-cost method for managing water resources, improving soil health, and supporting both wildlife and agricultural needs in water-stressed areas. Proper design and site selection are critical to its success, ensuring that the bund can perform its functions effectively over the long term.

Nala bund

2. Percolation tank

A percolation tank is a critical water conservation structure designed to improve groundwater recharge by capturing surface runoff and allowing it to percolate into the subsurface. It is particularly beneficial in areas with fractured and weathered rock formations, which enhance the infiltration rate and facilitate quicker groundwater recharge. These tanks are commonly located across small streams or in gently sloping terrains, often in regions that experience seasonal rainfall. The stored water in the tank percolates through the soil, recharging nearby wells and boreholes, and also supports agriculture during dry periods.

Key Design and Site Selection Considerations

1. Location and Terrain:

The ideal location for a percolation tank is across small streams or drainage channels in areas where the terrain allows for water retention without excessive earthwork. The terrain should have low elevation and a slope gradient between 3% to 5%, ensuring sufficient runoff collection while preventing erosion. The tank should be constructed downstream of runoff zones or in the upper part of the transition zone where water naturally accumulates.

Fractured and Weathered Rock: Percolation tanks are most effective in terrains with fractured and weathered rocks, as these geological formations allow for rapid water infiltration into the underground aquifers. The more fractured the rock, the faster the water percolates, ensuring a quicker recharge of groundwater resources.

2. Catchment Area and Soil Conditions:

Rainfall Evaluation: Before constructing a percolation tank, it is essential to evaluate the long-term rainfall pattern of the region. The tank should be designed in such a way that it fills up fully during the monsoon season, preferably more than once. This ensures that maximum water is captured and stored for percolation throughout the year.

Soil Type: The soils in the catchment area should be light and sandy. Sandy soils prevent the silting of the tank bed, which is a common problem in tanks located in areas with heavier, clay-rich soils. Siltation reduces the infiltration rate and eventually decreases the efficiency of the percolation tank in recharging groundwater.

3. Submergence Area:

The area that will be submerged by the percolation tank should preferably be uncultivated land to avoid disrupting agricultural activities. If cultivated land is submerged, it could lead to loss of crops or reduced agricultural productivity. Therefore, selecting sites with minimal impact on agricultural land is a key consideration in the site selection process.

4. Weir and Embankment Design:

A masonry weir is typically provided in the narrow gorge or nala portion to control the overflow of water and prevent structural damage during heavy rains. The weir allows excess water to flow out in a controlled manner while ensuring that the tank retains enough water for percolation. This weir also helps in maintaining the structural integrity of the percolation tank, preventing overtopping and erosion.

The embankments are constructed across natural depressions, valleys, or gorges to store surface runoff for percolation. The embankments should be designed to withstand water pressure, and they can be constructed using local materials such as stone, concrete, or earth.

5. Groundwater Recharge and Community Benefits:

Groundwater Recharge: The primary function of a percolation tank is to recharge groundwater by holding runoff water long enough for it to infiltrate into the soil and reach the aquifer. This helps in raising the water table and maintaining water availability in wells and boreholes, particularly during dry seasons.

Agricultural and Social Benefits: In addition to groundwater recharge, percolation tanks provide a reliable source of water for agricultural activities, helping farmers irrigate crops during dry spells. This makes the area more resilient to drought. These tanks also supply drinking water for livestock and can support small-scale community water needs.

6. Survey and Design Specifications:

The site selection, survey, and design of percolation tanks are very similar to those used in the construction of nala bunds and check dams. This includes evaluating the slope of the land, catchment area characteristics, soil type, and rainfall patterns, as well as ensuring that the design can manage the expected runoff volumes without structural failure.

Storage Capacity: The capacity of the tank depends on the expected runoff from the catchment area and the rainfall. The storage volume must be calculated to ensure that it can capture sufficient water to provide year-round benefits while also allowing excess water to escape safely through the weir during heavy rains.

Additional Design Considerations:

Desilting: Over time, the tank may collect silt from the surrounding catchment area, which reduces its capacity and effectiveness. Regular desilting is necessary to maintain the percolation tank's functionality. Catchment area treatment with contour bunding or vegetative barriers can reduce siltation.

Catchment Treatment: To further increase the effectiveness of the percolation tank, upstream catchment area treatment is essential. This involves constructing smaller structures such as contour trenches or check dams that reduce soil erosion and control the flow of water before it reaches the percolation tank.

Vegetative Cover: Encouraging the growth of vegetation around the embankment and within the catchment area helps to stabilize the soil and reduce erosion. Vegetation also improves the filtration of water entering the tank, reducing silt loads.

Environmental and Long-term Sustainability

Ecological Restoration: By increasing soil moisture and recharging groundwater, percolation tanks contribute to ecological restoration in degraded areas. This can result in improved biodiversity, re-establishment of vegetation, and enhanced soil fertility.

Sustainable Agriculture: The moisture retained by percolation tanks during the rainy season can be crucial for supporting agriculture, particularly in rain-fed areas. By ensuring that groundwater levels remain stable, these tanks help in promoting sustainable agricultural practices.

Community Development: In rural areas, percolation tanks also serve as community resources, providing water for domestic use, livestock, and irrigation. They help in reducing the dependency on external water supplies and create more self-sufficient communities.

Percolation tank

3.Check dam

A check dam, sometimes referred to as a ditch check, is a small dam constructed across water channels such as ditches, swales, or small waterways to reduce water flow speed and control erosion. Check dams are typically low-cost, simple structures that play a crucial role in soil conservation, especially in areas where water runoff can cause significant erosion and

sediment transport. While some check dams are temporary, others may be semi-permanent depending on the materials used and the purpose they serve.

How Check Dams Work:

Reducing Flow Velocity: By constructing a barrier across a waterway, a check dam slows down the flow of water. This reduction in flow velocity helps prevent the water from eroding the surrounding soil, which is particularly important in areas with steep slopes or loose soils. The slower flow allows sediment to settle out of the water, creating natural sediment traps that help to stabilize the waterway over time.

Allowing Controlled Water Seepage: Check dams are often built with porous materials such as rocks or vegetative logs, which allow water to slowly percolate through the structure rather than flowing over it quickly. This porosity helps in maintaining a steady flow of water while reducing the chances of erosion downstream.

Sediment Trapping: As water slows down behind the check dam, sediments carried by the flow are deposited. This helps to reduce sediment load downstream and prevents silt from clogging waterways or reservoirs.

Materials Used in Construction:

Rocks: Rocks are the most common material used in check dams because they are readily available, durable, and provide natural porosity. The gaps between the rocks allow water to pass through while trapping sediment. In vegetated areas, the combination of rocks and plants provides additional erosion control.

Sandbags: Sandbags can be used to create temporary check dams. These structures are often deployed in emergency situations to slow water flow and control erosion. Sandbags are effective but not as durable as rock or permanent materials, so they are typically used for short-term purposes.

Fibre Logs: Fibre logs are biodegradable materials made from straw, coconut fiber, or other organic materials. These logs are placed across the waterway to slow water flow and trap sediment. Over time, they break down and contribute organic matter to the soil, making them an environmentally friendly option for temporary erosion control.

Cement Concrete and Other Materials:

In areas where more permanent solutions are required, check dams can be constructed using cement concrete. These structures are more durable and can last for many years, providing long-term erosion control and water management. Concrete check dams are typically used in larger or more heavily engineered projects where a permanent structure is needed to protect against erosion.

Additional Considerations for Check Dam Construction:

Spacing: Multiple check dams are often constructed along a watercourse, spaced at intervals based on the slope of the land. If the land is steeper, the check dams are placed closer

together to slow the water more effectively and prevent it from gaining too much speed between dams.

Maintenance: Check dams require periodic maintenance, particularly in areas where they trap a lot of sediment. Over time, the buildup of sediment can reduce the effectiveness of the check dam, so it is important to remove excess sediment periodically to maintain proper water flow.

Environmental Benefits: In addition to preventing erosion, check dams help improve water quality by filtering out sediment and pollutants. They can also promote the growth of vegetation along the banks of the waterway, which further stabilizes the soil and prevents future erosion.

Check dam

10.Operation and Maintenance of Watershed Development Works

Operation and Maintenance (O&M) of watershed development works are critical phases that ensure the long-term sustainability and effectiveness of interventions implemented during watershed projects. While the construction of physical and biological measures such as check dams, contour bunds, percolation tanks, vegetative barriers, and plantations mark the completion of developmental activities, their continued functionality depends on regular care, community participation, and institutional arrangements for upkeep.

Purpose and Importance: Watershed development aims to restore ecological balance by conserving soil, enhancing groundwater recharge, and improving vegetative cover. However, without proper O&M, the benefits of these investments decline rapidly due to siltation, structural damage, or neglect of vegetative components. Therefore effective O&M will (a) prolong the lifespan of structures and plantations, (b) prevent degradation and silting of water bodies, (c) ensure continued groundwater recharge and soil moisture retention, (d) enhance productivity and livelihood benefits, and (e) strengthen community ownership and responsibility

Components of O&M

1. Structural Maintenance
    - Periodic desilting of check dams, farm ponds, and percolation tanks
    - Repair of cracks, seepage zones, or damaged masonry in check dams and nala bunds
    - Strengthening of spillways, toe walls, and embankments before monsoon
    - Clearing of vegetative growth blocking outlets or spillways
2. Vegetative Maintenance
    - Replanting of dead saplings and gap filling in plantations
    - Weeding, mulching, and pruning to promote healthy plant growth
    - Controlled grazing and fire protection around treated areas
    - Periodic enrichment of grass cover on bunds and slopes
3. Hydrological and Soil Conservation Measures
    - Maintenance of contour and graded bunds through reshaping and raising
    - Cleaning and stabilization of drainage lines and waterways
    - Upkeep of field channels and outlet drains for safe water disposal
4. Community and Institutional Maintenance
    - Watershed Committees and User Groups play a vital role in O&M through participatory management
    - Establishment of Watershed Development Fund (WDF) for repair and maintenance
    - Capacity building of local stakeholders for technical supervision and monitoring

Institutional Framework: The Government of Karnataka has developed the institutional framework with a defined roles and responsibilities of different stakeholders and utilization of watershed development fund. The same is given below:

ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿ ನಂತರ ಕಾರ್ಯಾಚರಣೆ ಮತ್ತು ನಿರ್ವಹಣೆ

1. ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯ ರಚನೆ:

i.ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯನ್ನು ಕೆಳಗಿನಂತೆ ರಚಿಸತಕ್ಕದ್ದು.

1. ಜಲಾನಯನ ಪ್ರದೇಶದಲ್ಲಿ ಬರುವ ಗ್ರಾಮ ಪಂಚಾಯಿತಿ ಅಧ್ಯಕ್ಷರು ಸಮಿತಿಯ ಅಧ್ಯಕ್ಷರಾಗಿರುತ್ತಾರೆ.
2. ಗ್ರಾಮ ಪಂಚಾಯಿತಿಯ ಇತರೆ ಇಬ್ಬರು ಸದಸ್ಯರು (1 ರಿಂದ 2 ಮಂದಿ) ಸದಸ್ಯರಾಗಿರುತ್ತಾರೆ.
3. ಜಲಾನಯನ ಪ್ರದೇಶದ ಬಳಕೆದಾರರ ಗುಂಪಿನ ಸದಸ್ಯರು / ಸ್ಥಳೀಯರು (UG 5 ರಿಂದ 7 ಮಂದಿ), ಸ್ವಸಹಾಯ ಗುಂಪು (4 ರಿಂದ 6 ಮಂದಿ)
4. ಸಂಬಂಧಪಟ್ಟ ರೈತ ಸಂಪರ್ಕ ಕೇಂದ್ರದ ಸಹಾಯಕ ಕೃಷಿ ಅಧಿಕಾರಿ / ಕೃಷಿ ಅಧಿಕಾರಿ – ಒಬ್ಬರು
5. ಜಲಾನಯನ ಪ್ರದೇಶದ ನೀರು ಕುಯಿಲು ರಚನೆಯಿಚಿದ ಉಪಯೋಗ ಪಡೆಯುತ್ತಿರುವ ರೈತರು / ಪ್ರಗತಿಪರ ರೈತರು – 2 ಮಂದಿ
6. ಗ್ರಾಮ ಪಂಚಾಯಿತಿಯ ಪಂಚಾಯಿತಿ ಅಭಿವೃದ್ಧಿ ಅಧಿಕಾರಿಗಳು ಸಮಿತಿಯ ಕಾರ್ಯದರ್ಶಿಯಾಗಿರುತ್ತಾರೆ.

ii.ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯಲ್ಲಿ ಅಧ್ಯಕ್ಷ ಮತ್ತು ಕಾರ್ಯದರ್ಶಿ ಸೇರಿ ಕನಿಷ್ಠ 15 ಮತ್ತು ಗರಿಷ್ಠ 20 ಜನ ಸದಸ್ಯರು ಇರುವುದು.

iii.ಸಮಿತಿಯ ಸಭೆಗಳಲ್ಲಿ ತೀರ್ಮಾನಿಸುವ ಎಲ್ಲಾ ಕಾರ್ಯಕ್ರಮಗಳು, ತೀರ್ಮಾನಗಳನ್ನು ಅನುಷ್ಠಾನಗೊಳಿಸುವ ಜವಾಬ್ದಾರಿ ಕಾರ್ಯದರ್ಶಿಯವರದಾಗಿರುತ್ತದೆ.

2. ಸಮಿತಿಯ ಪದಾಧಿಕಾರಿಗಳು:

1. ಅಧ್ಯಾಯ–2 ರ (i) (1) ರಲ್ಲಿ ಸೂಚಿಸಿರುವ ಸದಸ್ಯರು ಈ ಸಮಿತಿಯ ಅಧ್ಯಕ್ಷರಾಗಿರುತ್ತಾರೆ.
2. ಸಂಬಂಧಿಸಿದ ಗ್ರಾಮಪಂಚಾಯಿತಿ ಅಭಿವೃದ್ಧಿ ಅಧಿಕಾರಿಯವರು ಸಮಿತಿಯ ಪದನಿಮಿತ್ತ ಕಾರ್ಯದರ್ಶಿಯಾಗಿರುತ್ತಾರೆ.

3. ಅಧ್ಯಕ್ಷರ ಕರ್ತವ್ಯಗಳು:

i. ಅಧ್ಯಕ್ಷರು ಈ ಮುಂದಿನ ಕರ್ತವ್ಯಗಳನ್ನು ನಿರ್ವಹಿಸತಕ್ಕದ್ದು.

1. ಸಮಿತಿಯ ಎಲ್ಲಾ ಸಭೆಗಳ ಅಧ್ಯಕ್ಷತೆ ವಹಿಸುವುದು.
2. ಅಧ್ಯಕ್ಷರು ಸಮಿತಿಯ ಮಾರ್ಗದರ್ಶನ ನೀಡುವಂತಹ ಇತರ ಕಾರ್ಯಗಳನ್ನು ನಿರ್ವಹಿಸತಕ್ಕದ್ದು.

4. ಸದಸ್ಯ ಕಾರ್ಯದರ್ಶಿಯ ಕರ್ತವ್ಯಗಳು:

i. ಕಾರ್ಯದರ್ಶಿಯು ಈ ಮುಂದಿನ ಕರ್ತವ್ಯಗಳನ್ನು ನಿರ್ವಹಿಸತಕ್ಕದ್ದು:

- ಸಮಿತಿಯ ಅನುಮೋದನೆ ಪಡೆದು ಕಾಲ–ಕಾಲಕ್ಕೆ ಸ್ಥಳ ಪರಿಶೀಲನೆ ಕೈಗೊಳ್ಳುವುದು ಹಾಗೂ ದುರಸ್ಥಿಗೆ ಬಂದಿರುವ ಕಾಮಗಾರಿಗಳನ್ನು ಗುರುತಿಸುವುದು.
- ಗುರುತಿಸಲಾದ ಕಾಮಗಾರಿಗಳನ್ನು ಗ್ರಾಮ ಪಂಚಾಯಿತಿ ಮಟ್ಟದಲ್ಲಿ ದುರಸ್ಥಿ ಕೈಗೊಳ್ಳಲು ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿ ಸಭೆಯಲ್ಲಿ ಅನುಮೋದನೆ ಪಡೆದುಕೊಳ್ಳುವುದು.

- ಅಧ್ಯಾಯ–4 ರಲ್ಲಿ ವಿವರಿಸಿರುವಂತೆ ಸಮಿತಿಯ ಸಭೆ ಕರೆಯುವುದು ಮತ್ತು ಅದಕ್ಕೆ ಅನುಕೂಲ ಕಲ್ಪಿಸಿಕೊಡುವುದು ಮತ್ತು ಎಲ್ಲ ಸಭೆಗಳ ನಡವಳಿಗಳನ್ನು ದಾಖಲಿಸುವುದು.
- ಸಮಿತಿಯ ಲಕ್ಕಪತ್ರಗಳು ಮತ್ತು ದಾಖಲೆಗಳನ್ನು ಇಟ್ಟುಕೊಳ್ಳುವುದು.
- ಹಣಕಾಸು, ಲೆಕ್ಕ ಪರಿಶೋಧನೆಚು ಮಾಹಿತಿಗಳನ್ನು ಲೆಕ್ಕ ಪರಿಶೋಧನೆಗಾಗಿ ಜಲಾಜಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯ ಚಟುವಟಿಕೆಗಳ ವರದಿ ಮತ್ತು ಲೆಕ್ಕಪತ್ರಗಳ ವಿವರಪಟ್ಟಿಯನ್ನು ತಯಾರಿಸುವುದು ಹಾಗೂ ಹಾಜರುಪಡಿಸುವುದು.

ii. ಸಮಿತಿಯ ಮಾರ್ಗದರ್ಶನ ನೀಡುವಚಿಥ ಇತರ ಎಲ್ಲಾ ಕಾರ್ಯಗಳನ್ನು ಸಹ ನಿರ್ವಹಿಸತಕ್ಕದ್ದು.

5. ಸಮಿತಿಯ ಅಧಿಕಾರಿಗಳು ಮತ್ತು ಜವಾಬ್ದಾರಿಗಳು

ಅಧಿಕಾರಿಗಳು:

i. ಈ ಸಮಿತಿಯ ಕರ್ನಾಟಕ ಗ್ರಾಮ ಸ್ವರಾಜ್ ಮತ್ತು ಪಂಚಾಯತ್ ರಾಜ್ ಅಧಿನಿಯಮ 1993 ರ ಪ್ರಕರಣ 61–ಎ ರಡಿ ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿ ಹಾಗೂ ಕೃಷಿ ಆಧಾರಿತ ಚಟುವಟಿಕೆಗಳನ್ನು ನಿರ್ವಹಿಸಲು ಅಧಿಕಾರ ಹೊಂದಿರುತ್ತದೆ.

ii. ಜಲಾನಯನ ವ್ಯಾಪ್ತಿಯಲ್ಲಿನ ಸಮುದಯಾಧಾರಿತ ಮತ್ತು ನಾಲಾ ಪ್ರದೇಶದಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾದ ಜಲಾನಯ ಚಟುವಟಿಕೆಗಳನ್ನು ಹಾಲಾಗದಂತೆ ಕ್ರಮಗಳನ್ನು ಕೈಗೊಳ್ಳುವ ಜವಾಬಾಽರಿ, ಅಧಿಕಾರ ಸಮಿತಿಗಿದ್ದು, ಕ್ಷಣಕರ್ತ ವ್ಯಕ್ತಿ/ಸಂಘಸಂಸ್ಥೆ/ ಕಾರ್ಖಾನೆಗಳ ಮೇಲೆ ಕ್ರಮ ಜರುಗಿಸಲು ಶಿಫಾರಸ್ಸು ಮಾಡುವ ಅಧಿಕಾರ ಸಮಿತಿಗಿರುತ್ತದೆ.

iii. ವಾರ್ಷಿಕ ದುರಸ್ತಿ ಹಾಗೂ ನಿರ್ವಹಣಾ ಕಾರ್ಯಗಳನ್ನು ಉತ್ತಮವಾಗಿ ನಿರ್ವಹಿಸಲು, ಸರ್ಕಾರ ಕಾಲಕಾಲಕ್ಕೆ ನಿಗದಿಪಡಿಸಿದ ಅನುಪಾತದಂತೆ ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿ ನಿಧಿ ಅನುದಾನವನ್ನು ಬಳಸಿಕೊಂಡು ಜಲಾನಯನ ಪ್ರದೇಶದಲ್ಲಿರುವ ಸಮುದಾಯಾಸ್ತಿಗಳನ್ನು ದುರಸ್ತಿಗೊಳಿಸಿ ನಿರ್ವಹಿಸುವ ನಿರ್ವಹಣೆಯ ಅಧಿಕಾರ ಸಮಿತಿಗಿರುತ್ತದೆ.

ಜವಾಬ್ದಾರಿಗಳು:

iv. ಜಲಾನಯನ ಪ್ರದೇಶದ ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯ ಈ ಕೆಳಕಂಡ ಕ್ರಮಗಳನ್ನು ಜಾರಿಗೊಳಿಸುವುದು.

ಆಸ್ತಿಗಳ ಭೌತಿಕ ನಿರ್ವಹಣೆ:

v. ಸಮಿತಿ ವಾರ್ಷಿಕ ದುರಸ್ತಿ, ಉಸ್ತುವಾರಿ ಹಾಗೂ ಕಾರ್ಯಾಚರಣೆಗಳ ಕ್ರಿಯಾಯೋಜನೆಯನ್ನು ರೂಪಿಸುವುದು ಮತ್ತು ಸಮಿತಿ ಸಭೆಯಲ್ಲಿ ಅನುಮೋದನೆ ಪಡೆದು ಜಾರಿಗೊಳಿಸತಕ್ಕದ್ದು.

vi. ಜಲಾನಯನ ಪ್ರದೇಶದಲ್ಲಿ ಎಲ್ಲಾ ರಚನೆಗಳನ್ನು ವಾರ್ಷಿಕವಾಗಿ ಅಥವಾ ಅಗತ್ಯವಿದ್ದು ತಕ್ಷಣ ದುರಸ್ತಿ ಮಾಡಿ ಉತ್ತಮ ಸ್ಥಿತಿಯಲ್ಲಿ ನಿರ್ವಹಿಸುವುದು ಸಮಿತಿಯ ಜವಾಬ್ದಾರಿಯಾಗಿರುತ್ತದೆ. ಈ ದುರಸ್ತಿ ಕಾರ್ಯಗಳನ್ನು ಸಮಿತಿಯು ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿ ನಿಧಿ ಅನುದಾಯದಿಂದ ಕೈಗೊಳ್ಳುವುದು.

ಜಲಾನಯನ ಪ್ರದೇಶಗಳ ಆಸ್ತಿಗಳ ರಕ್ಷಣೆ ಹಾಗೂ ಒತ್ತುವರಿ ತಡೆಯುವುದು:

- ಜಲಾನಯನ ಪ್ರದೇಶದಲ್ಲಿನ ಪೋಷಕ ಕಾಲುವೆ, ನಾಲಾ/ಹಳ್ಳಗಳ, ಖಾಸಗಿ ಹಿಡುವಳಿಗಳಲ್ಲಿನ ಕಾಲುವೆಗಳನ್ನು ವ್ಯವಸ್ಥಿತವಾಗಿ ನೋಡಿಕೊಳ್ಳುವುದು, ಅತಿಕ್ರಮಣ,

ಒತ್ತುವರಿ, ಬೇರೆಡೆ ತಿರುಗಿಸುವುದು ಮತ್ತು ಅಲ್ಲಿ ನಿರ್ಮಿಸಿರುವ ಯಾವ್ಯದೇ ರಚನೆಯನ್ನು ಹಾನಿಮಾಡದಂತೆ ನೋಡಿಕೊಳ್ಳುವುದು.

- ಜಲಾನಯನ ಪ್ರದೇಶಗಳ ಆಸ್ತಿಗಳ ಒತ್ತುವರಿ ತಡೆಯುವುದು, ಜಲಾನಯನ ಪ್ರದೇಶದಲ್ಲಿ ಸವಕಳಿ ಆಗುವಚಿತಹ ಯಾವ್ಯದೇ ಚಟುವಟಿಕೆ ನಿರ್ಬಂಧಿಸುವುದು.
- ಜಲಾನಯನ ಪ್ರದೇಶದಲ್ಲಿನ ರಾಜಕಾಲುವೆ, ಬಸಿಗಾಲುವೆ, ಕೋಡಿಕಾಲುವೆಗಳನ್ನು ಹಾನಿಮಾಡುವುದು, ಒತ್ತುವರಿ ಮಾಡುವುದು, ಅನಧಿಕೃತವಾಗಿ ತೆರೆಯುವುದು, ನೀರಿನ ಹರಿವಿಗೆ ಅಡ್ಡಿಪಡಿಸುವುದನ್ನು ತಡೆಯುವುದು, ಅವಧಿವಾರು ಸ್ವಚ್ಛಗೊಳಿಸುವುದು ಇತ್ಯಾದಿ.

ಪರಿಸರ ನಿರ್ವಹಣೆ:

- ಜಲಾನಯನ ಪ್ರದೇಶದ ಸಾಮೂಹಿಕ ಹಾಗೂ ಖಾಸಗಿ ಹಿಡುವಳಿಗಳಲ್ಲಿ ಮೃಣ್ಣು ಸವಕಳಿ ತಡೆಯಲು ಕ್ರಮಗಳು.
- ಜಲಾನಯನ ಪ್ರದೇಶದಲ್ಲಿನ ತೋಪುಗಳ ಹುಲ್ಲುಗಾವಲು, ಮರಗಿಡಗಳನ್ನು ನಿರ್ವಹಣೆ ಮಾಡುವುದು, ಅತಿಕ್ರಮ್ಣ ತಡೆಯುವುದು, ಇತ್ಯಾದಿ.

ಸರ್ಕಾರದ ನಿಯಮಗಳ ಪಾಲನೆ:

- ಜಲಾನಯನ ಪ್ರದೇಶದಲ್ಲಿನ ಮೀನುಗಾರಿಕೆ, ಮ್ಮರಳು, ಹೂಳು, ಇತ್ಯಾದಿಗಳ ಬಳಕೆಗೆ ಸರ್ಕಾರದ ನಿಯಮಗಳನ್ನು ಪಾಲಿಸುವುದು ಹಾಗೂ ಜಾರಿಗೊಳಿಸುವುದು.

ಹಣಕಾಸು ನಿರ್ವಹಣೆ:

vii. ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿ ನಿಧಿ ಖಾತೆಯಲ್ಲಿರುವ ಅನುದಾನದ ಠೇವಣಿಯಿಂದ ಬರುವಂತಹ ಬಡ್ಡಿ ಹಾಗೂ ಪ್ರಧಾನ ಠೇವಣಿಯ ಬಾಗಶಃ ಮೊತ್ತವನ್ನು ಜಲಾನಯನ ಸಮುದಾಯ ಭೂಮಿಯಲ್ಲಿ ಅನುಷ್ಠಾನಗೊಳಿಸಲಾಗಿರುವ ಆಸ್ತಿಗಳ ನಿರ್ವಹಣೆ ಅಥವಾ ದುರಸ್ತಿಗೆ ಈ ಕೆಳಕಂಡಂತೆ ಉಪಯೋಗಿಸಿಕೊಳ್ಳತಕ್ಕದ್ದು.

ಕ್ರ.ಸಂ.	ವರ್ಷ	ಠೇವಣಿಯ ಶೇಕಡಾವಾರು	ಸಂಗ್ರಹಣೆಯಾದ ಬಡ್ಡಿಯ ಶೇಕಡವಾರು
1	1 ನೇ ವರ್ಷ	10%	30%
2	2 ನೇ ವರ್ಷ	15%	25%
3	3 ನೇ ವರ್ಷ	20%	20%
4	4 ನೇ ವರ್ಷ	25%	15%
5	5 ನೇ ವರ್ಷ	30%	ಉಳಿಕೆ ಬಡ್ಡಿ ಮೊತ್ತ

viii. ಐದು ವರ್ಷದ ಅವಧಿಯಲ್ಲಿ ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿ ನಿಧಿ ಖಾತೆಯಲ್ಲಿ ಲಭ್ಯವಿರುವ ಸಂಪೂರ್ಣ ಹಣವನ್ನು ಅಗತ್ಯತೆಗನುಸಾರ ಬಳಕೆ ಮಾಡಬಹುದಾಗಿದೆ. ಆದರೆ ಪ್ರತಿ ದುರಸ್ತಿಯ ವೆಚ್ಚ ಆಯಾ ಕಾಮಗಾರಿಯ ವೆಚ್ಚದ ಶೇ. 25ರಷ್ಟು ವ್ರೆತ್ತವನ್ನು ಮೀರಬಾರದು. ಐದು ವರ್ಷಗಳ ನಂತರ ಅಥವಾ ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿ ನಿದಿ ಸಂಪೂರ್ಣವಾಗಿ ವೆಚ್ಚವಾದ ನಂತರ ಸಮುದಾಯ ಆಸ್ತಿಗಳ ನಿರ್ವಹಣೆಗೆ ಪ್ರತ್ಯೇಕ ಅನುದಾನದ ವ್ಯವಸ್ಥೆಯನ್ನು ಗ್ರಾಮ ಪಂಚಾಯಿತಿಯಿಂದ ಮಾಡುವುದು

ix. ಸಮುದಾಯ ಭೂಮಿಯಲ್ಲಿ ನಿರ್ಮಿಸಲಾದ ರಚನೆಗಳು ದುರಸ್ತಿಗೆ ಬಂದಿದ್ದಲ್ಲಿ ಅಂತಹ ಕಾಮಗಾರಿಗಳ ದುರಸ್ತಿಯ ಅಂದಾಜು ಪತ್ರಿಕೆಗಳನ್ನು ಸಂಬಂಧಪಟ್ಟ ಕೃಷಿ ಅಧಿಕಾರಿ / ಸಹಾಯಕ ಕೃಷಿ ಅಧಿಕಾರಿಗಳು ತಯಾರಿಸಬೇಕು. ಹಾಗೂ ಕಾಮಗಾರಿಗಳ ದುರಸ್ತಿಯ ಅಂದಾಜು ಪತ್ರಿಕೆಯ ಮೊತ್ತಕ್ಕೆ ಅನುಗುಣವಾಗಿ ಸಂಬಂಧಪಟ್ಟ ಮೇಲಾಧಿಕಾರಿಗಳಿಗೆ ನೀಡಿರುವ ಆರ್ಥಿಕ ಅಧಿಕಾರದನ್ವಯ ಮಂಜೂರಾತಿ ಪಡೆಯಬೇಕು.

x. ಸಮಿತಿಯು ಕಾನೂನು ರೀತ್ಯಾ ಮಾಡಬೇಕಿರುವ ವಾರ್ಷಿಕ ಲೆಕ್ಕ ಪರಿಶೋಧನೆ, ವಾರ್ಷಿಕ ವರದಿಗಳನ್ನು ನಿಗದಿತ ಅವಧಿಯೊಳಗೆ ಗ್ರಾಮಪಂಚಾಯಿತಿಗೆ ಸಲ್ಲಿಸುವುದು.

xi. ಸಮಿತಿ ತನ್ನ ಲೆಕ್ಕ ಪತ್ರಗಳನ್ನು, ದಾಖಲೆಗಳನ್ನು ತನ್ನ ಕಛೇರಿಯಲ್ಲಿ ಕಟ್ಟುನಿಟ್ಟಾಗಿ ನಿರ್ವಹಿಸುವುದು. ಸಮಿತಿಯ ಲೆಕ್ಕ ವ್ಯವಹಾರಗಳನ್ನು ಪಾರದರ್ಶಕವಾಗಿ ನಡೆಸಿ ತ್ರೈಮಾಸಿಕವಾಗಿ ಸಾರ್ವಜನಿಕ ಸ್ಥಳದಲ್ಲಿ, ಗ್ರಾಮ ಪಂಚಾಯಿತಿಯ ಸೂಚನಾ ಫಲಕಗಳಲ್ಲಿ ಪ್ರಚಾರ ಪಡಿಸುವುದು.

xii. ಸಮಿತಿಯ ಹಣಕಾಸು ವ್ಯವಹಾರಗಳಲ್ಲಿ ಯಾವ್ಯದೇ ರೀತಿಯ ದುರುಪಯೋಗವಾದಲ್ಲಿ ಹಣದುರುಪಯೋಗ, ನಷ್ಟ ಮತ್ತು ತನಿಖೆಗೆ ಸಂಬಂಧಿಸಿದಂತೆ ಕರ್ನಾಟಕ ಪಂಚಾಯತ್ ರಾಜ್ (ಗ್ರಾಮ ಪಂಚಾಯಿತಿಗಳ ಆಯವ್ಯಯ ಮತ್ತು ಲೆಕ್ಕಪತ್ರಗಳು) ನಿಯಮಗಳು, 2006 ರ ನಿಯಮ 111 ರಡಿಯ ನಿರೂಪಣೆಯಂತೆ ಕ್ರಮವಹಿಸುವುದು.

ನಿಯಮಾವಳಿಗಳಿಗೆ ತಿದ್ದುಪಡಿ:

xiii. ಸಮಿತಿಯ ಮೂಲ ಉದ್ದೇಶಗಳಿಗೆ ವ್ಯತಿರಿಕ್ತವಾಗಿ ಸಮಿತಿಯ ಉಪವಿಧಿಗಳಲ್ಲಿ ಯಾವ್ಯದೇ ತಿದ್ದುಪಡಿಗಳನ್ನು ಮಾಡುವ ಹಾಗಿಲ್ಲ. ಆದರೆ ತನ್ನ ಉಪವಿದಿಗಳ ಪರಿಮಿತಿಯಲ್ಲಿ ನಿಯಮಗಳನ್ನು, ನೀತಿ ನಿಬಂಧನೆಗಳನ್ನು ರೂಪಿಸಿ ಅಳವಡಿಸಿಕೊಳ್ಳುವ ಅಧಿಕಾರ ಸಮಿತಿಗಿರುತ್ತದೆ. ಕಾಲಕಾಲಕ್ಕೆ ಅಗತ್ಯಬೀಳುವ ತಿದ್ದುಪಡಿಗಳನ್ನು ಮಾಡುವುದು, ಹೊಸ ನಿಯಮಾವಳಿಗಳನ್ನು ರೂಪಿಸುವುದು ಇತ್ಯಾದಿಗಳನ್ನು ಗ್ರಾಮ ಸ್ವರಾಜ್ ಮ್ತು ಪಂಚಾಯತ್ ರಾಜ್ ಅಧಿನಿಯಮ 1993 ರ ಪ್ರಕರಣ 61–ಎ ರಡಿ ಅಥವಾ ಸರ್ಕಾರ ಕಾಲಕಾಲಕ್ಕೆ ಹೊರಡಿಸುವ ಆದೇಶಗಳ ಚೌಕಟ್ಟಿನಲ್ಲಿರಬೇಕು.

ವ್ಯಾಜ್ಯಗಳ ನಿರ್ವಹಣೆ:

xiv. ಸಮಿತಿಯ ಕಾರ್ಯನಿರ್ವಹಣೆಯಲ್ಲಿ ಉದ್ಭವಿಸುವ ಎಲ್ಲಾ ವ್ಯಾಜ್ಯಗಳನ್ನು ಪರಿಹರಿಸುವ ಜವಾಬ್ದಾರಿ ಸಮಿತಿಯದ್ದಾಗಿರುತ್ತದೆ. ಯಾವ್ಯದೇ ಸದಸ್ಯ ಸಮಿತಿಯ ನಿರ್ಣಯದಿಂದ ಬಾಧಿತನಾದಲ್ಲಿ ಗ್ರಾಮ ಪಂಚಾಯಿತಿ ಮೂಲಕ ಪರಿಹಾರ ಪಡೆಯಲು ಮೇಲ್ಮನವಿ ಸಲ್ಲಿಸುವ ಅಧಿಕಾರ ಹೊಂದಿರುತ್ತಾನೆ ಅಥವಾ ಸಮಿತಿಯೇ ಅಗತ್ಯಬಿದ್ದಲ್ಲಿ ಮೇಲ್ಮನವಿ ಸಲ್ಲಿಸಬಹುದು.

6. ಗ್ರಾಮ ಪಂಚಾಯಿತಿ ಜವಾಬ್ದಾರಿಗಳು:

i. ಸಮಿತಿಯ ಕಾರ್ಯಚಟುವಟಿಕೆಗಳು ಸಮಿತಿಯ ನಿಯಮಾವಳಿಯ ಪ್ರಕಾರ ನಡೆಯಲು ಮಾರ್ಗದರ್ಶನ ಮತ್ತು ಸಹಕಾರ ನೀಡುವುದು.

ii. ಸಮಿತಿಯಲ್ಲಿ ಪರಿಹಾರವಾಗದ ಯಾವ್ಯದೇ ಕುಂದುಕೊರತೆಗಳನ್ನು ಬಗೆಹರಿಸುವುದು.

iii. ಸಮಿತಿಯ ಕಾರ್ಯಕ್ರಮಗಳಿಗೆ ಸರ್ಕಾರದ ಇತರೇ ಇಲಾಖೆಗಳ, ಅಭಿವೃದ್ಧಿ ಯೋಜನೆಯಡಿ ಬೆಂಬಲ ಬೇಕಾದಲ್ಲಿ ಒದಗಿಸುವುದು, ತಾಂತ್ರಿಕ ಸಲಹೆ,

ಮಾರ್ಗದರ್ಶನ, ತರಬೇತಿಗಳು ಇತ್ಯಾದಿ ಪೂರಕ ಕಾರ್ಯಕ್ರಮಗಳನ್ನು ಹಮ್ಮಿಕೊಳ್ಳುವುದು.

iv. ನಿಯಮಿತಕಾಲಿಕವಾಗಿ ಸಮಿತಿಯ ಕಾರ್ಯಪ್ರಗತಿಯನ್ನು ಮೌಲ್ಯಮಾಪನ ಮಾಡುವುದು ಅಗತ್ಯವಾಗುವ ಎಲ್ಲಾ ತಾಂತ್ರಿಕ ಹಾಗೂ ಆಡಳಿತಾತ್ಮಕ ಸಹಕಾರ ನೀಡುವುದು.

v. ಸಮಿತಿಯಿಂದ ಯಾವ್ಯದೇ ರೀತಿಯಲ್ಲಿ ಹಣದ ದುರ್ಬಳಕೆಯಾದಂತಹ ಸಂದರ್ಭಗಳಲ್ಲಿ ಅಧ್ಯಾಯ 5 ರ ಖಂಡ 17ರ ಉಪವಿಧಿಗಳಂತೆ ಅದರ ಬ್ಯಾಂಕ್ ಖಾತೆಯನ್ನು ಸ್ಥಗಿತಗೊಳಿಸುವ ಅಥವಾ ತನಿಖೆ ನಡಿಸಿ ಸಂಬಂಧಿತ ಕಾನೂನು ಕ್ರಮಗಳನ್ನು ಕೈಗೊಳ್ಳುವ ಅಧಿಕಾರ ಗ್ರಾಮ ಪಂಚಾಯಿತಿಗೆ ಇರುತ್ತದೆ.

ಅಧ್ಯಾಯ–4

ಸಮಿತಿಯ ಸಭೆಯಲ್ಲಿ ಅನುಸರಿಸಬೇಕಾದ ಕಾರ್ಯವಿಧಿಗಳು

7. ಸಮಿತಿಯ ಸಭೆಗಳನ್ನು ಕರೆಯುವುದು

- ಸಮಿತಿಯು, ಆಯಾ ಗ್ರಾಮ ಪಂಚಾಯಿತಿ ಕಛೇರಿ ಆವರಣದೊಳಗೆ ಅಥವಾ ಅನುಕೂಲಕರವಾಗಬಹುದಾದಂತಹ ಇತರ ಸ್ಥಳದಲ್ಲಿ ಕನಿಷ್ಠಪಕ್ಷ ಎರಡು ತಿಂಗಳಿಗೊಮ್ಮೆ ಸಭೆ ಸೇರತಕ್ಕದ್ದು.
- ಸಮಿತಿಯ ಸಭೆಯನ್ನು, ಅದರ ಅಧ್ಯಕ್ಷರೊಂದಿಗೆ ಸಮಾಲೋಚಿಸಿ, ಕಾರ್ಯದರ್ಶಿಯ ನಿಗದಿಪಡಿಸಬಹುದಾದಂತಹ ದಿನಗಳಂದು ಮತ್ತು ಸಮಯದಲ್ಲಿ ನಡೆಸತಕ್ಕದ್ದು.
- ಕಾರ್ಯದರ್ಶಿಯು, ಸಮಿತಿಯ ಪ್ರತಿಯೊಂದು ಸಭೆಯ ಬಗ್ಗೆ ಸದಸದ್ಯರಿಗೆ ಕನಿಷ್ಠಪಕ್ಷ ಒಂದು ವಾರದ ಮೊದಲು ನೋಟೀಸನ್ನು ನೀಡತಕ್ಕದ್ದು ಮತ್ತು ಉದ್ದೇಶಿತ ಕಾರ್ಯಸೂಚಿಯ ಒಂದು ಪ್ರತಿಯನ್ನು ನೋಟಿಸಿನೊಂದಿಗೆ ತಲುಪುವಂತೆ ವ್ಯವಸ್ಥೆ ಕೈಗೊಳ್ಳುವುದು.
- ಆದರೆ, ಸಭಾಧ್ಯಕ್ಷರು, ಕಾರ್ಯಸೂಚಿಯಲ್ಲಿ ಸೇರಿಸಿರದ ಯಾವುದೇ ತುರ್ತು ವ್ಯವಹಾರದ ವಿಷಯವನ್ನು ಸಭೆಯ ಮುಂದೆ ಮಂಡಿಸಬಹುದು.
- ಅಲ್ಲದೆ, ಕಾರ್ಯದರ್ಶಿಯು ಕನಿಷ್ಠಪಕ್ಷ ಒಂದು ದಿನ ಮೊದಲು ನೋಟೀಸನ್ನು ನೀಡುವ ಮೂಲಕ ತುರ್ತು ಸಭೆಯನ್ನು ಕರೆಯಬಹುದು.
- ಸಮಿತಿಯ ಸದಸ್ಯರು ಯಾವುದೇ ವಿಷಯಗಳನ್ನು ಸಭೆಯ ಮುಂದೆ ಮಂಡಿಸಲು ಇಚ್ಛಿಸಿದಲ್ಲಿ ವಿಷಯವನ್ನು ಸಮಿತಿಗೆ ಲಿಖಿತ ಮೂಲಕ ಸಭೆಯ ದಿನಾಂಕದಿಂದ ಮೂರು ದಿನಗಳ ಮುಂಚೆ ಒಪ್ಪಿಸುವುದು.

8. ಕೋರಂ

ಸಮಿತಿಯ ಸಭೆಯನ್ನು ನಡೆಸುವುದಕ್ಕೆ ಅಗತ್ಯವಾದ ಕೋರಂ ಈ ಮುಂದಿನಂತಿರತಕ್ಕದ್ದು:

- ಅಧ್ಯಕ್ಷರು ಅಥವಾ ಉಪಾಧ್ಯಕ್ಷರು, ಮತ್ತು ಕಾರ್ಯದರ್ಶಿ ಸ್ಥೆರಿದಂತೆ ಸಮಿತಿಯ ಕನಿಷ್ಠ 1/3 ಭಾಗದಷ್ಟು ಸದಸ್ಯರು ಸಭೆಗೆ ಹಾಜರಿರತಕ್ಕದ್ದು.
- ಕೋರಂ ಕೊರತೆಯಿಚಿದಾಗಿ ಸಮಿತಿಯ ಸಭೆಯನ್ನು ನಡೆಸಲಾಗದಿದ್ದರೆ. ಸದಸ್ಯ ಕಾರ್ಯದರ್ಶಿಯ ಅಧಿಸ್ರಚಿಸುವ ಮತ್ತೊಂದು ದಿನಕ್ಕೆ ಸಭೆಯನ್ನು ಮುಂದೂಡಬಹುದು.
- ಮುಂದೂಡಲ್ಪಟ್ಟ ಸಭೆಯೂ ಸಹ ಅಗತ್ಯ ಕೋರಂನ್ನು ಹೊಂದಿದ್ದಲ್ಲಿ, ಆಗ ವಾಸ್ತವವಾಗಿ ಹಾಜರಿರುವ ಸದಸ್ಯರನ್ನೆ ಕೋರಂ ಎಂದು ಪರಿಗಣಿಸಿ ಸಭೆ ನಡೆಸಬಹುದು.

9. ಅಧ್ಯಕ್ಷರು ಹಾಗೂ ಉಪಾಧ್ಯಕ್ಷರ ಗೈರು ಹಾಜರಿಯಲ್ಲಿ ಅನುಸರಿಸಬೇಕಾದ ಪದ್ಧತಿ

ಅಧ್ಯಕ್ಷರು ಅಥವಾ ಉಪಾಧ್ಯಕ್ಷರು ಗೈರುಹಾಜರಾಗಿದ್ದಲ್ಲಿ, ಸಭೆಯಲ್ಲಿ ಹಾಜರಿರುವ ಸದಸ್ಯರಲ್ಲಿ ಒಬ್ಬ ಸದಸ್ಯನನ್ನು, ಸಭಾಧ್ಯಕ್ಷನಾಗಿ ಚುನಾಯಿಸತಕ್ಕದ್ದು ಹಾಗೂ ಸದರಿ ಸದಸ್ಯ ಆ ಸಭೆಯ ಅಧ್ಯಕ್ಷತೆಯನ್ನು ವಹಿಸತಕ್ಕದ್ದು.

ವಿವರಣೆ:– ಈ ಉಪಬಂಧದ ಉದ್ದೇಶಕ್ಕಾಗಿ "ಗೈರು ಹಾಜರಿ" ಎಚಿದರೆ ಕೇವಲ ತತ್ಕಾಲಿಕ ಸ್ವರೂಪದ್ದಾಗಿರುತ್ತದೆಯೇ ಹೊರತು ಆಕಸ್ಮಿಕ ಖಾಲಿ ಹುದ್ದೆಗೆ ಉಲ್ಲೇಖಿತವಾಗುವುದಿಲ್ಲ.

10. ಪ್ರಶ್ನೆಗಳನ್ನು ನಿರ್ಣಯಿಸುವ ವಿಧಾನ

- ಸಮಿತಿಯ ಮುಂದೆ ಇರುವ ಎಲ್ಲ ವಿಷಯಗಳನ್ನು ಸಾಮಾನ್ಯವಾಗಿ ಹಾಜರಿರುವ ಸದಸ್ಯರೆಲ್ಲರೂ ಒಮ್ಮತಾಭಿಪ್ರಾಯದಿಂದ ನಿರ್ಧರಿಸತಕ್ಕದ್ದು.
- ಒಮ್ಮತಾಭಿಪ್ರಾಯ ಮೂಡದಿದ್ದಲ್ಲಿ, ಈ ಉಪವಿಧಿಯ ಖಂಡ 14 ರಡಿಯಲ್ಲಿ ಗೊತ್ತುಪಡಿಸಲಾದ ಮಾದರಿಯಲ್ಲಿ ಮತ ಹಾಕುವ ಮೂಲಕ ನಿರ್ಧರಿಸಕ್ಕದ್ದು.

11. ಮತ ಹಾಕುವ ವಿಧಾನ

- ಎಲ್ಲ ಸದಸ್ಯರು ಮತ ಹಾಕುವುದಕ್ಕೆ ಸಮಾನ ಹಕ್ಕನ್ನು ಹೊಂದಿರತಕ್ಕದ್ದು.
- ಕೈಗಳನ್ನು ಎತ್ತುವ ಮೂಲಕ ಮತ ಹಾಕಬಹುದು, ಆದರೆ ಸಮಿತಿಯು, ಯಾವುದೇ ವಿಷಯ ಅಥವಾ ವಿಷಯಗಳನ್ನು ಮತಪತ್ರದ ಮೂಲಕ ನಿರ್ಧರಿಸತಕ್ಕದೆಂದು ನಿರ್ಣಯಿಸಬಹುದು.
- ವಿಷಯವನ್ನು ಮತಕ್ಕೆ ಹಾಕಿದಲ್ಲಿ, ಸಮಿತಿಯ ಹಾಜರಿರುವ ಸದಸ್ಯರು ಸಾಧಾರಣ ಬಹುಮತದಿಂದ ಅದನ್ನು ಬೆಂಬಲಿಸದ ಹೊರತು, ಅದನ್ನು ಅಂಗೀಕರಿಸತಕ್ಕದ್ದಲ್ಲ.
- ಸಮಾನ ಸಂಖ್ಯೆಯ ಮತಗಳು ಬಿದ್ದ ಸಂದರ್ಭದಲ್ಲಿ, ಸಭಾಧ್ಯಕ್ಷರು ಎರಡನೇ ಅಥವಾ ನಿರ್ಣಾಯಕ ಮತವನ್ನು ಹೊಂದಿರತಕ್ಕದ್ದು ಮತ್ತು ಅದನ್ನು ಚಲಾಯಿಸತಕ್ಕದ್ದು.

12. ನಿರ್ಣಯಗಳನ್ನು ದಾಖಲಿಸುವುದು

- ಕಾರ್ಯದರ್ಶಿಯು, ಸಮಿತಿಯ ನಿರ್ಣಯಗಳ ದಾಖಲೆಯನ್ನು ನಿರ್ವಹಿಸತಕ್ಕದ್ದು ಮತ್ತು ನಿರ್ಣಯಗಳ ಪ್ರತಿಗಳನ್ನು ಸದಸ್ಯರಿಗೆ 10 ದಿನಗಳಲ್ಲಿ ಪರಿಚಲನೆ ಮಾಡತಕ್ಕದ್ದು.
- ಮೇಲೆ ನಮೂದಿಸಿದ ದಾಖಲೆಯನ್ನು ಸದಸ್ಯರ ಅವಗಾಹನೆಗಾಗಿ ಸಮಿತಿಯ ಕಾರ್ಯದರ್ಶಿಯ ಸುಪರ್ದಿನಲ್ಲಿ ಇಡತಕ್ಕದ್ದು.

ಶಿಸ್ತುಕ್ರಮ

13. ದೂರುಗಳ ಪರಿಹಾರ ಕಾರ್ಯತಂತ್ರ

- ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯ ಸಮಗ್ರ ಕಾರ್ಯ ನಿರ್ವಹಣೆಗೆ ಸಂಬಂಧಪಟ್ಟಂತೆ ಯಾವ್ಯದೇ ದೂರು, ಸಮುದಾಯ ಮತ್ತು ನಾಲಾ ಪ್ರದೇಶದಲ್ಲಿ ಸೃಜಿಸಲಾಗಿರುವ ಆಸ್ತಿಗಳ ನಿರ್ವಹಣಾ ಸಮಿತಿ ಯಾವೊಬ್ಬ ಸದಸ್ಯನ ವಿರುದ್ಧವಾಗಿರುವ ಸಂದರ್ಭದಲ್ಲಿ ಹಣಕಸು, ಲೆಕ್ಕಪರಿಶೋಧನೆ ಮತ್ತು ಯೋಜನಾ ಸ್ಥಾಯಿ ಸಮಿತಿಯು ಈ ಮುಂದಿನ ಕಾರ್ಯವಿಧಾನವನ್ನು ಅನುಸರಿಸಬೇಕು.
  - ದೂರು ಸ್ವೀಕರಿಸಿದ 10 ದಿನಗಳೊಳಗಾಗಿ ಇಬ್ಬರು ಸದಸ್ಯರಿಗೆ ತನಿಖಾ ತಂಡವನ್ನು ರಚಿಸಬೇಕು.

- ಸದರಿ ತಂಡವು ದೂರನ್ನು ಪರಿಶೀಲಿಸಿ ಅವ್ಯವಹಾರಗಳನ್ನು ಸರಿಪಡಿಸುವ ವಿಧಾನಗಳನ್ನು ಸೂಚಿಸಿ, ತಂಡ ರಚನೆಯಾದ ಹತ್ತು ದಿನಗಳೊಳಗಾಗಿ ಗ್ರಾಮ ಪಂಚಾಯಿತಿಗೆ ವರದಿ ನೀಡಬೇಕು.
- ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಗೆ ದೂರು ಪ್ರತಿಗಳ (ಫಿರ್ಯಾದುದಾರನ ಹೆಸರು ತಿಳಿಸಿದ್ದಲ್ಲಿ) ಮತ್ತು ತನಿಖಾ ತಂಡದ ವರದಿಯೊಂದಿಗೆ ಕಾರಣ ಕೇಳುವ ನೋಟಿಸನ್ನು ಕಳುಹಿಸಿ ಅವ್ಯವಹಾರಗಳನ್ನು ಸರಿಪಡಿಸಲು 10 ದಿನಗಳ ಕಾಲಾವಕಾಶ (ನೋಟೀಸು ಜಾರಿಗೊಳಿಸಿದ ದಿನಾಂಕದಿಂದ) ನೀಡಬೇಕು.
- ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯು 15 ದಿನದೊಳಗಾಗಿ (ಕಾರಣ ಕೇಳುವ ನೋಟೀಸು ಜಾರಿಗೊಳಿಸಿದ ದಿನಾಂಕದಿಂದ) ಗ್ರಾಮ ಪಂಚಾಯಿತಿಗೆ ಅನುಪಾಲನಾ ವರದಿಯನ್ನು ಸಲ್ಲಿಸಬೇಕು.
- ಅನುಪಾಲನಾ ವರದಿಯನ್ನು ಸ್ವೀಕರಿಸಿದ ತರುವಾಯ ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯು ಅವ್ಯವಹಾರಗಳನ್ನು ಸರಿಪಡಿಸಿದ ಬಗ್ಗೆ ಗ್ರಾಮ ಪಂಚಾಯಿತಿಯು ಖುದ್ದಾಗಿ ಪರಿಶೀಲಿಸಬೇಕು.
- ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯ ಅನುಪಾಲನಾ ವರದಿಯನ್ನು ಸಲ್ಲಿಸಿದ್ದರೂ ಅವ್ಯವಹಾರಗಳನ್ನು ಸರಿಪಡಿಸಿ ಅಥವಾ ಕಾರಣ ಕೇಳುವ ನೋಟೀಸಿಗೆ ಅನುಗುಣವಾಗಿ ಕ್ರಮ ಕೈಗೊಳ್ಳಲು ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯು ನಿರಾಕರಿಸಿದೆ ಎಂದು ಗ್ರಾಮ ಪಂಚಾಯಿತಿ ಅಭಿಪ್ರಾಯಪಟ್ಟರೆ ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯನ್ನು 15 ದಿನಗಳ ಅವಧಿಯೊಳಗಾಗಿ ರದ್ದು ಮಾಡಬಾರದೇಕೆ ಎಂಬ ಬಗ್ಗೆ ಕಾರಣ ಕೇಳುವ ಎರಡನೇ ನೋಟೀಸನ್ನು ಗ್ರಮ ಪಂಚಾಯಿತಿಯು ಜಾರಿ ಮಾಡಬೇಕು.
- ಅವ್ಯವಹಾರಗಳನ್ನು ಸರಿಪಡಿಸಲು ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯು ಎರಡನೇ 15 ದಿನಗಳ ಅವಧಿಯಲ್ಲಿ ತೆಗೆದುಕೊಂಡ ಕ್ರಮಗಳ ತೃಪ್ತಿಕರವಾಗಿಲ್ಲದಿದ್ದಲ್ಲಿ ಹಣಕಾಸು, ಲೆಕ್ಕಪರಿಶೋಧನೆ ಮತ್ತು ಗ್ರಾಮ ಪಂಚಾಯಿತಿಯು ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯನ್ನು ರದ್ದುಪಡಿಸುವ ಪ್ರಸ್ತಾವನೆಯನ್ನು ತಾಲ್ಲೂಕು ಪಂಚಾಯಿತಿಯ ಚರ್ಚಿಸಿ ಸೂಕ್ತ ನಿರ್ಧಾರ ಕೈಗೊಳ್ಳಬೇಕು.
- ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯನ್ನು ರದ್ದುಪಡಿಸಿದ ಸಂದರ್ಭದಲ್ಲಿ ಅದು ಹಾಗೆ ರದ್ದುಗೊಂಡ 1 ತಿಂಗಳೊಳಗಾಗಿ ಜಲಾಯನಯ ನಿರ್ವಹಣಾ ಸಮಿತಿಯ ಮರು ರಚನೆ ಮಾಡಿದ ಬಗ್ಗೆ ಖಚಿತಪಡಿಸಿಕೊಳ್ಳಬೇಕು.
- ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯ ರಚನೆಯಾಗುವವರೆಗೆ ಅದರ ಪ್ರಕಾರ್ಯಾಗಳನ್ನು ಗ್ರಾಮ ಪಂಚಾಯಿತಿ ನಿರ್ವಹಿಸಬೇಕು.
- ಮೇಲಿನ ವಿಧಾನವನ್ನು ಉಪಖಂಡಿಕೆ () ರಿಂದ () ನ್ನು ಅನುಸರಿಸಿ ಶಿಸ್ತು ಕ್ರಮ ಜರುಗಿಸುವ ಅಧಿಕಾರ ಕೃಷಿ ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿ ಇಲಾಖೆಯ ಜಿಲ್ಲಾಮಟ್ಟದ ಅಧಿಕಾರಿಗೆ ಇರುತ್ತದೆ. ಪರಂತು ಉಪಖಂಡಿಕೆ () ಹಾಗೂ () ರಂತೆ ಗ್ರಾಮ ಪಂಚಾಯಿತಿಗೆ ಮಾತ್ರ ಕ್ರಮ ಜರುಗಿಸುವ ಅಧಿಕಾರವಿರುತ್ತದೆ.

14. ಹಣಕಾಸು

➢ ರಿಸರ್ವ ಬ್ಯಾಂಕ್‌ನಿಂದ ಮನ್ನಣೆ ಪಡೆದ ರಾಷ್ಟ್ರೀಕೃತ ಬ್ಯಾಂಕ್ ಅಥವಾ ಅನುಸೂಚಿತ ಬ್ಯಾಂಕ್ ಅಥವಾ ಸಹಕಾರಿ ಬ್ಯಾಂಕ್‌ನ ಖಾತೆಯಲ್ಲಿ ಅಥವಾ ಅಂಚೆ ಕಚೇರಿಯಲ್ಲಿ ಸಮಿತಿಯ ವಿವಿಧ ನಿಧಿಗಳನ್ನು ಠೇವಣಿ ಇಡತಕ್ಕದ್ದು, ಅಂಥ ಖಾತೆಯನ್ನು ಸಮಿತಿಯ ಹೆಸರಿನಲ್ಲಿ ತೆರೆಯತಕ್ಕದ್ದು.

- ಮೇಲೆ ತಿಳಿಸಿರುವ ಖಾತೆಗಳನ್ನು ಅಧ್ಯಕ್ಷರು, ತಾಲ್ಲೂಕು ಸಹಾಯಕ ಕೃಷಿ ನಿರ್ದೇಶಕರು ಮತ್ತು ಸದಸ್ಯ ಕಾರ್ಯದರ್ಶಿಯವರು ಜಂಟಿಯಾಗಿ ನಿರ್ವಹಿಸತಕ್ಕದ್ದು.
- ಸಮಿತಿಯ ಎಲ್ಲಾ ಆದಾಯ ಮತ್ತು ವೆಚ್ಚಗಳನ್ನು ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿಯ ಪ್ರತಿ ಸಭೆಯಲ್ಲೂ ಚರ್ಚಿಸತಕ್ಕದ್ದು.
- ಒಂದು ಸಾವಿರ ರೂ.ಗಳನ್ನು ಮೀರಿದ ಯಾವುದೇ ಹಣ ಹಿಂತೆಗೆಯುವಿಕೆಗೆ ಜಲಾನಯನ ನಿರ್ವಹಣಾ ಸಮಿತಿ ಪೂರ್ವಾನುಮತಿ ಪಡೆಯತಕ್ಕದ್ದು.

15. ಲಾಭದ ಮೇಲೆ ನಿಷೇಧ

ಆಲಾಯನಯ ನಿರ್ವಹಣಾ ಸಮಿತಿ ಲಾಭ ಮತ್ತು ಆಸ್ತಿಯ ಯಾವುದೇ ಭಾಗವನ್ನು ವೃತ್ತಿ ವೇತನದ ರೂಪದಲ್ಲಾಗಲೀ ಅಥವಾ ಆತನ ಲಾಭದ ರೂಪದಲ್ಲಾಗಲೀ ಯಾವುದೇ ಸದಸ್ಯನಿಗೆ ಅಥವಾ ಯಾವುದೆ ಸದಸ್ಯರ ಮೂಲಕ ಪಡೆಯ ಬಯಸಿದ್ದಲ್ಲಿ ಯಾವ್ಯದೇ ವ್ಯಕ್ತಿಗೆ ಪ್ರತ್ಯಕ್ಷವಾಗಿ ಅಥವಾ ಪರೋಕ್ಷವಾಗಿ ವಿನಿಯೋಗಿಸತಕ್ಕದ್ದಲ್ಲ ಅಥವಾ ವರ್ಗಾಯಿಸತಕ್ಕದ್ದಲ್ಲ.

ಪರಂತು, ಈ ಖಂಡದಲ್ಲಿರುವ ಯಾವುದೂ, ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿ ಪರವಾಗಿ ಸದ್ಭಾವನೆಯಿಂದ ಖರ್ಚು ಮಾಡಿದ್ದಲ್ಲಿ ಯಾವುದೇ ಸದಸ್ಯನಿಗೆ ಮರುಪಾವತಿಯ ಸಂದಾಯ ಮಾಡುವುದಕ್ಕೆ ಅಡ್ಡಿಪಡಿಸತಕ್ಕದ್ದಲ್ಲ.

ಮತ್ತು ಪರಂತು, ಸದಸ್ಯರಿಗೆ ತರಬೇರಿಗಾಗಿ ಹಂಚಿಕೆಯಾದ ಯಾವುದೇ ವೃತ್ತವನ್ನು ಸದ್ಭಾವನೆಯಿಂದ ಅಂತಹ ಸದಸ್ಯರಿಗೆ ಸಂದಾಯ ಮಾಡುವುದಕ್ಕೆ ಈ ಖಂಡದಲ್ಲಿರುವ ಯಾವುದೂ ಅಡ್ಡಪಡಿಸತಕ್ಕದ್ದಲ್ಲ.

ಇತರ ವಿವರಗಳು

16. ಸದಸ್ಯತ್ವವನ್ನು ಕೊನೆಗೊಳಿಸುವುದು

ಈ ಕೆಳಕಂಡ ಯಾವ್ಯದೇ ಘಟನೆಗಳು ಸಂಭವಿಸಿದಲ್ಲಿ ಸದಸ್ಯತ್ವವು ರದ್ದಾಗತಕ್ಕದ್ದು.

- ಸದಸ್ಯರು ಸಮಿತಿಯ ನಿರಂತರ ಮೂರು ಸಭೆಗಳಿಗೆ ಗೈರು ಹಾಜರಾದಲ್ಲಿ.
- ಸಮಿತಿಯ ವ್ಯಾಪ್ತಿಯಲ್ಲಿ ಬರುವ ಯಾವ್ಯದೇ ವ್ಯವಹಾರದ ನಿರ್ವಹಣೆಯಲ್ಲಿ ಆತ/ಆಕೆಯು ಭ್ರಷ್ಟಾಚಾರದಲ್ಲಿ ತೊಡಗಿದ್ದಲ್ಲೆ;
- ಯಾವ್ಯದೇ ಕಾರಣದ ನಿಮಿತ್ತ ಸದಸ್ಯ ಗ್ರಾಮಪಂಚಾಯಿತಿ ವ್ಯಾಪ್ತಿ ತೊರೆದಲ್ಲಿ;
- ಯಾವ್ಯದೇ ನ್ಯಾಯಾಲಯದಿಂದ ಆತ/ಆಕೆಯು ಆಪಾದಿತನೆಂದು ತೀರ್ಮಾನವಾಗಿದ್ದಲ್ಲಿ;

17. ಸದಸ್ಯರನ್ನು ತೆಗೆದುಹಾಕುವುದು

- ಸಮಿತಿಯ ಉದ್ದೇಶಗಳಿಗೆ ವಿರುದ್ದವಾಗಿ ನಡೆದುಕೊಳ್ಳುವುದು ಅಥವಾ ದುರ್ನಡತೆ ಎಸಗಿದಾಗ ಸದಸ್ಯರಿಂದ ಲಿಖಿತ ರೂಪದಲ್ಲಿ ಸಮಜಾಯಿಷಿಯನ್ನು ಕೋರಿ ಆ ಮೂಲಕ ಮುನ್ನೇಚ್ಚರಿಕೆಗಳನ್ನು ನೀಡಿದಾಗ್ಯೂ ಸದಸ್ಯನ ನಡಾವಳಿಗಳಲ್ಲಿ ಬದಲಾವಣೆ ಆಗದಿದ್ದ ಪಕ್ಷದಲ್ಲಿ ಹಾಗೂ ಮಾನಸಿಕ ಅಸ್ವಸ್ಥನೆಂದು ವೈದ್ಯಕೀಯವಾಗಿ ದೃಢಪಟ್ಟಿದ್ದಲ್ಲಿ ಸಮಿತಿಯು, ಮೂರನೇ ಎರಡರಷ್ಟು ಸದಸ್ಯರ ಬಹುಮತದಲ್ಲಿ ಅಂತಹ ಸದಸ್ಯರ ಸದಸ್ಯತನವನ್ನು ರದ್ದುಗೊಳಿಸಬಹುದು. ಸದಸ್ಯತ್ವ ರದ್ದುಗೊಂಡ ಸದಸ್ಯನು ಈ ಸಂಬಂಧ ಯಾವ್ಯದೇ ಅಹವಾಲುಗಳಿದ್ದಲ್ಲಿ 30 ದಿನಗೊಳಗೆ ಗ್ರಾಮ ಪಂಚಾಯಿತಿಗೆ ಸಕಾರಣಗಳೊಂದಿಗೆ ಲಿಖಿತ ಅರ್ಜಿಯನ್ನು ಸಲ್ಲಿಸಬಹುದು.

ಗ್ರಾಮ ಪಂಚಾಯಿತಿಯು ಸಾಮಾನ್ಯ ಬಹುಮತದ ಮೂಲಕ ಅಂತಹ ಸದಸ್ಯರ ಅಹವಾಲನ್ನು ಪರಿಶೀಲಿಸಿ, ಸದಸ್ಯತನವನ್ನು ಪುನರ್ ನೇಮಕ ಮಾಡಬಹುದು ಅಥವಾ ರದ್ದುಗೊಳಿಸುವುದು.

18. ಆಕಸ್ಮಿಕ ಖಾಲಿಸ್ಥಾನಗಳನ್ನು ತುಂಬುವುದು

- ಯಾವುದೇ ಸದಸ್ಯರ ಸ್ಥಾನವು ಆಕೆಯ/ಆತನ ಪದಾವಧಿಯು ಸಾಮಾನ್ಯ ಕ್ರಮದಲ್ಲಿ ಮುಕ್ತಾಯಗೊಳ್ಳುವ ಮೊದಲೇ ಖಾಲಿಯಾದಲ್ಲಿ, ತತ್ಪರಿಣಾಮವಾಗಿ ಉಂಟಾಗುವ ಆ ಆಕಸ್ಮಿಕ ಖಾಲಿ ಸ್ಥಾನವನ್ನು ಸಮಿತಿಯು ತನ್ನ ಸಭೆಯಲ್ಲಿ ಒಬ್ಬರನ್ನು ಆ ಸ್ಥಾನಕ್ಕೆ ತುಂಬಬಹುದು.
  ಪರಂತು, ಸಮಿತಿಯು ಈ ಉಪವಿಧಿಗಳ ಖಂಡ 16 ರ ಮೇರೆಗೆ ಸಂಪೂರ್ಣವಾಗಿ ವಿಸರ್ಜನೆಯಾಗಿದ್ದಲ್ಲಿ ಖಂಡ 16 ರ ಮೇರೆಗೆ ಗೊತ್ತುಪಡಿಸಿದ ಕಾರ್ಯವಿಧಾನವನ್ನು ಅನುಸರಿಸತಕ್ಕದ್ದು.
- ಮೇಲಿನ () ಖಂಡದ ಮೇರೆಗೆ ನೇಮಕಗೊಂಡ ಸದಸ್ಯನ ಪದಾವಧಿಯು ಸಮಿತಿಯ ಉಳಿದ ಅವಧಿಗೆ ಅಥವಾ 20 ನೇ ಖಂಡದ ಪ್ರಕಾರ ಆತ/ಆಕೆ ಸದಸ್ಯನಾಗಿರುವುದು ಮುಕ್ತಾಯವಾಗುವವರೆಗೆ ಇವುಗಳಲ್ಲಿ ಯಾವುದು ಮೊದಲು ಅಲ್ಲಿಯವರೆಗೆ ಇರುವುದು.

19. ಅಧಿಕೃತ ಸಂವಹನ ಮತ್ತು ಒಪ್ಪಂದಗಳು:

- ಕಾರ್ಯದರ್ಶಿಯ ಸಮಿತಿಯ ಪೂರ್ವಾನುಮೋದನೆಯನ್ನು ಪಡೆದು ಉಪವಿಧಿಯ 9ನೇ ಖಂಡದಲ್ಲಿ ನಿರ್ದಿಷ್ಟಪಡಿಸಿದ ಯಾವುದೇ ಪ್ರಕಾರ್ಯಗಳನ್ನು ನಿರ್ವಹಿಸಲು ಸಮಿತಿಯ ಪರವಾಗಿ ಲಿಖಿತ ಒಪ್ಪಂದಗಳನ್ನು ಮಾಡಿಕೊಳ್ಳತಕ್ಕದ್ದು.
- ಸಮಿತಿಯ ಎಲ್ಲಾ ಅಧಿಕೃತ ಪತ್ರಗಳನ್ನು ಕಾರ್ಯದರ್ಶಿಯ ಸಹಿ ಮಾಡತಕ್ಕದ್ದು.

Conclusion

Operation and maintenance are not merely post-construction activities but an integral component of sustainable watershed management. Regular inspection, timely repairs, and strong community participation ensure that the physical, biological, and institutional interventions continue to deliver ecological and socio-economic benefits for decades.

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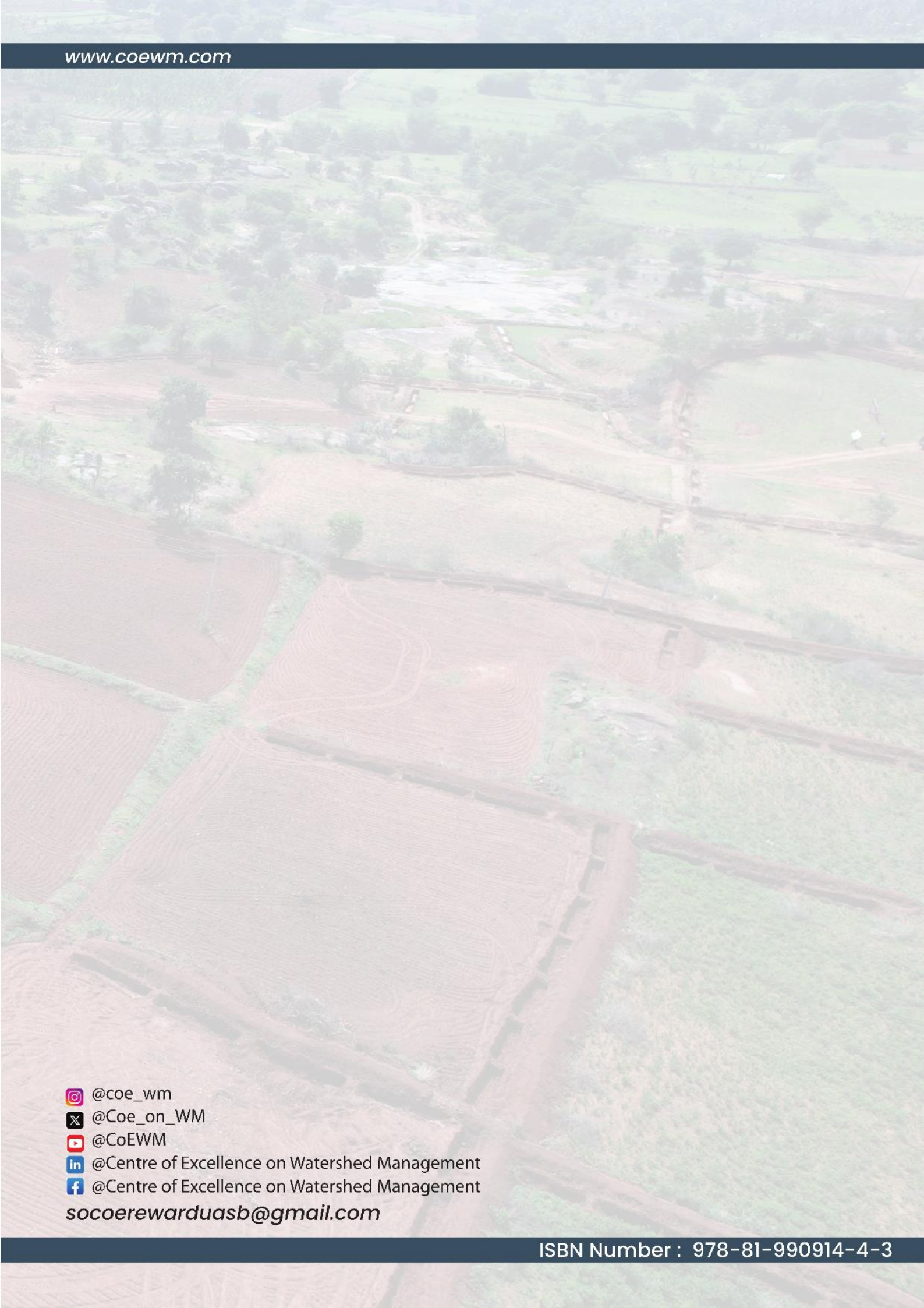

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