University of Agricultural Sciences, Bangalore

# Reference Material
# on
# Natural Resources Management, Production System and Micro-enterprises and Livelihood Improvement for PIA of REWARD, Odisha

**September, 2024**

Special Officer

WATERSHED MANAGEMENT
UAS BANGALORE

*Promote science based approach in watershed management*

## Contents

**Session Plan:**

| # | Topic | Time | Methods | Resource Person |
|---|---|---|---|---|
| **Day-1** | | | | |
| 1 | Registration and pre-test | 09.00-10.00 | Exercise | CoE-WM Staff |
| 2 | REWARD program- importance and approaches in watershed development | 10.00-11.00 | PPT<br>Discussion | Prakash N B<br>Nagaraja N |
| ***Natural resources management*** | | | | |
| 3 | LRI based approaches in selection of soil and water conservation measures for watershed development | 11.00-12.30 | PPT<br>Discussion | Premanand B D<br>Lakshminarayana S V |
| 4 | Soil and water conservation structures for arable lands-types, importance, criteria for selection, and specifications | 12.30-14.00 | PPT<br>Discussion | Shirahatti M S<br>Lakshminarayana S V |
| 5 | Water harvesting structures-types, importance, criteria for selection, and specifications | 15.00-16.30 | PPT<br>Discussion | Satishkumar U<br>Lakshminarayana S V |
| 6 | Soil and water conservation structures for non-arable lands-types, importance, criteria for selection, and specifications | 16.30-18.00 | PPT<br>Discussion | Shirahatti M S<br>Lakshminarayana S V |
| **Day-2** | | | | |
| 7 | Action plan for execution of soil and water conservation structures in REWARD, Odisha | 09.00-10.30 | Exercise | Premanand B D<br>Lakshminarayana S V |
| ***Crop production and management*** | | | | |
| 8 | Crop production-crops selection as per land suitability (LRI based crop selection) | 10.30-12.30 | PPT<br>Discussion | Thimmegowda M N<br>Pruthviraj N |
| 9 | Integrated approaches in crop production-water and pest management | 12.30-14.00 | PPT<br>Discussion | Mudalagiriyappa<br>Murali Mohan<br>Prasanna Kumar |
| 10 | LRI based fertilizer application-major nutrients and their role in crop production | 15.00-16.30 | PPT<br>Discussion | Prakash S S<br>Sagar R |
| 11 | Soil fertility status classification based on LRI data and adjustment of fertilizers as per soil fertility status and crop nutrients requirement | 16.30-18.00 | PPT<br>Discussion | Sathish A<br>Divyashree K S |

| # | Topic | Time | Methods | Resource Person |
|---|---|---|---|---|
| **Day-3** | | | | |
| ***Livelihood support system*** | | | | |
| 12 | Concept and importance of livelihood support systems/ microenterprises in watershed management and budget | 09.00-10.30 | PPT Discussion | Lakshmikantha B P<br>Nagaraja N |
| 13 | Microenterprise- Planning and developing community micro-enterprise | 10.30-12.00 | PPT Discussion | Vivekananda N Salimath<br>Kempegowda |
| 14 | Factors of sustainable livelihood systems | 12.00-13.30 | PPT Discussion | Shrisail S Dolli<br>Nagaraja N |
| 15 | SWOT analysis for enterprise identification | 14.30-16.00 | PPT Discussion | Chandregowda M J<br>Nagaraja N |
| 16 | Intervention Plan Development | 16.00-17.30 | PPT Discussion | Vivekananda N Salimath<br>Kempegowda |
| 17 | Action plan for implementation of livelihood support systems/ microenterprises | 17.30-18.30 | Exercise | Nagaraja N<br>Lakshminarayana S V |
| 18 | Training feedback and evaluation | 18.30-19.00 | Exercise | CoE-WM Staff |

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# Background

**Watershed development and its importance:** 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.

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 perthe estimate, the area critically affected by soil erosion alonehas doubled in 30 years from 1977 to 2007 in the country. The solution is integrated watershed management/ development

A watershed, is as an area in which all water flowing into itgoes 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.

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 greateragricultural yields and other benefits.

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 wateras possible at the place it falls to avoid gully formation and putting checks at suitable intervals tocontrol 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 landuse 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.

In 1970's Soil and water conservation was taken upwith 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 croppedland. 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.

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 andnurturing of community groups. The DoLR Guidelinesissued during 2021, under WDC-PMKSY 2.0, also emphasizes the use of GIS and RS technologies for scientific planning and monitoring the performance of watershed development projects.

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.

**Emergence of REWARD program**

Appreciating the impact of Sujala-3 project in Karnataka funded by the World Bank, the REWARD-Rejuvenating Watersheds for Agricultural Resilience through Innovative Development program isbeing implemented in Karnataka covering about 34 lakh hectares and Odisha about 5 lakh hectares from 2022. 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. To achieve agricultural resilience, the science-based approachesare 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 ofgrowing period.

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.

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-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.

In this background, management of natural resources, selection of appropriate crops and cropping system, nutrient management, and improving the livelihood of the watershed communities through promotion of microenterprises and livelihood support systems assumes greater importance. In the following paragraphs, the description on these areas is presented.

# Chapter-1
# Management of Natural Resources

Soil, water and vegetation are three basic natural resources. The survival of creation depends upon them and nature has provided them as assets to human beings. In a wider view, land, water, biodiversity and genetic resources, biomass resources, forests, livestock, fisheries, wild flora and fauna are considered as natural resources. Natural Resources Management (NRM) refers to the sustainable utilization of major natural resources, such as land, water, air, minerals, forests, fisheries, and wild flora and fauna. Together, these resources provide the ecosystem services that underpin human life. In this chapter, management of two important natural resources namely soil and water are described.

## Soil and Water Conservation Structures

### Arable Land 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 of 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.

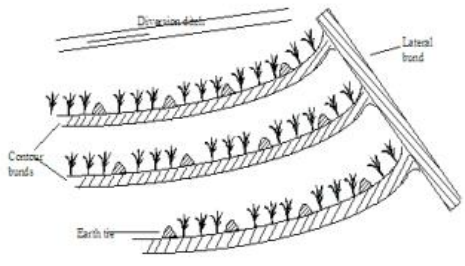



Figure 3.2 (a) Contour earth bunds for runoff farming with field Crops

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

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)

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

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)

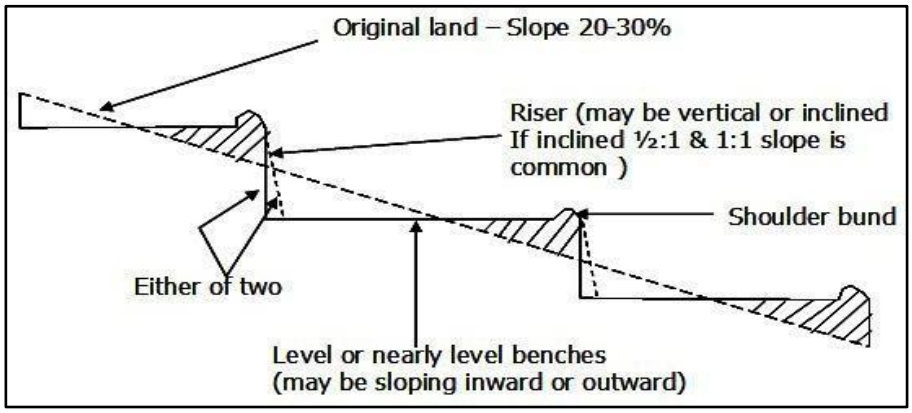
| Soil type | Bund Side slope | Seepage line slope |
|---|---|---|
| | Side slope (horizontal: vertical) | |
| Clayey | 1:1 | 3:1 |
| Loamy | 1.5:1 | 5:1 |
| Sandy | 2:1 | 6:1 |

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.

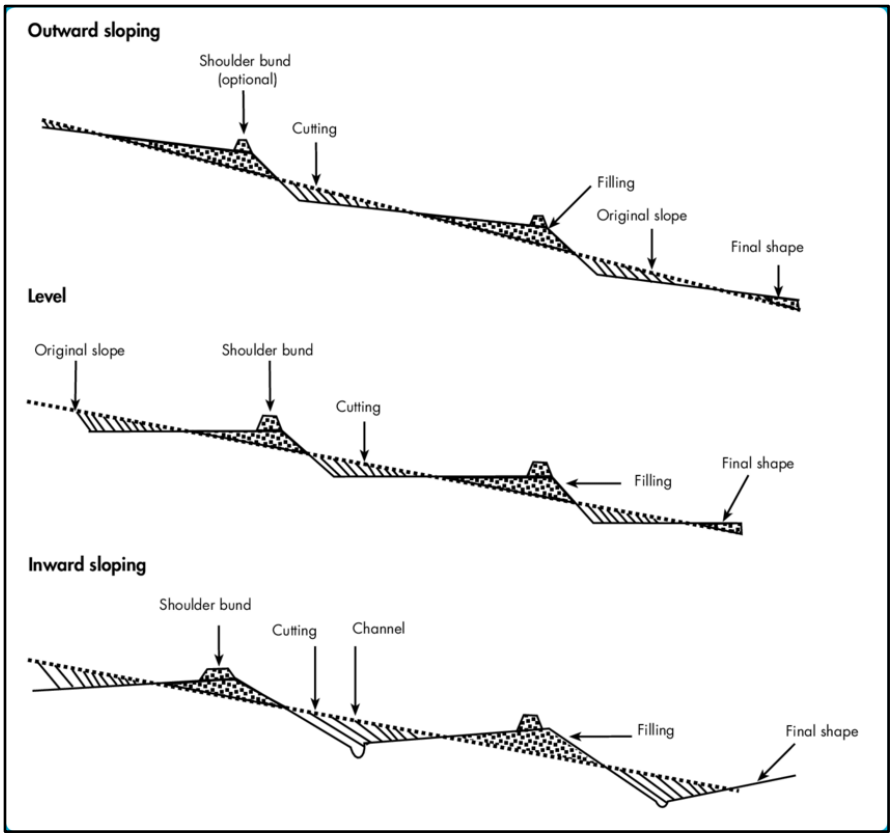



**Types of bench terraces and their adaptability**

**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**

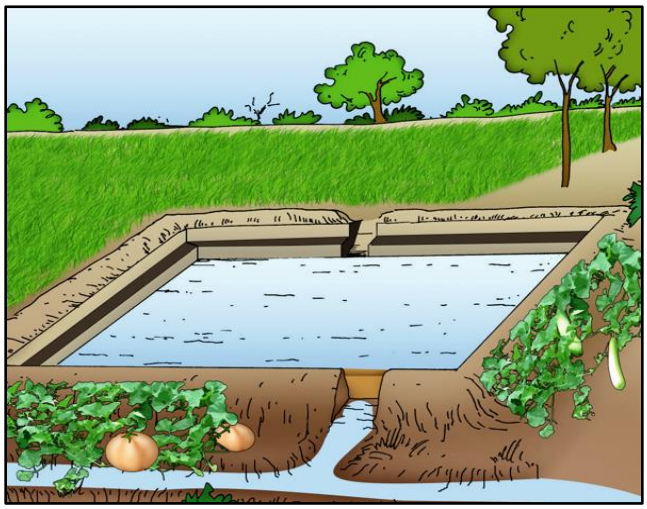
There is very little qualitative difference between a pond/ tank, which usually serves the population of a village, and farm pond, which serves an individual agricultural field. Farms ponds greatly vary in size depending upon the rainfall. In high rainfall areas of Orissa, for example, these have only 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.



## 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

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.

Trench cum bund

## 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** | | | | |
| | Contour bunding | < 6 | Shallow to deep, permeable | < 800 | Small millets, pulses, oil seeds, coarse grain, root crops |
| | 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 |
| | Contour terrace wall | 16 to 33 | Good and very high infiltration rate | > 1000 | Root crops, vegetables etc. |
| **2** | **Bench terracing** | | | | |
| | Level | < 33 | Medium to deep | < 2500-3000 | Paddy, small millets, pulses, oil seed, coarse grain, vegetables in low rainfall |
| | Inward sloping | < 33 | Medium to deep | < 2500-3000 | Potato, other vegetables maize, oats etc. |
| | Outward sloping | < 33 | Shallow | < 1200 | Small millets, oats, barley etc. |
| **3** | **Puertorican Terraces** | | Medium to deep | < 1500 | Root crops, vegetables, oats, small millets etc. |
| | With vegetative barrier | < 12 | | | |
| | With mechanical barriers | | | | |
| **4** | **Trenching** | | | | |
| | Contour Trenches | | | | |
| | Continuous | < 8 | Medium to Deep | < 1500 | Tapioca, ginger, turmeric and similar annual crops |
| | 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. |
| | 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** | | | | |
| | Contour | < 33 | Shallow to medium | < 1500 | Annual crops like tea, coffee, spices etc |
| | Graded | < 33 | Shallow to medium | 1500-2500 | Annual crops like tea, coffee, spices etc. |

## Non-Arable Land 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:

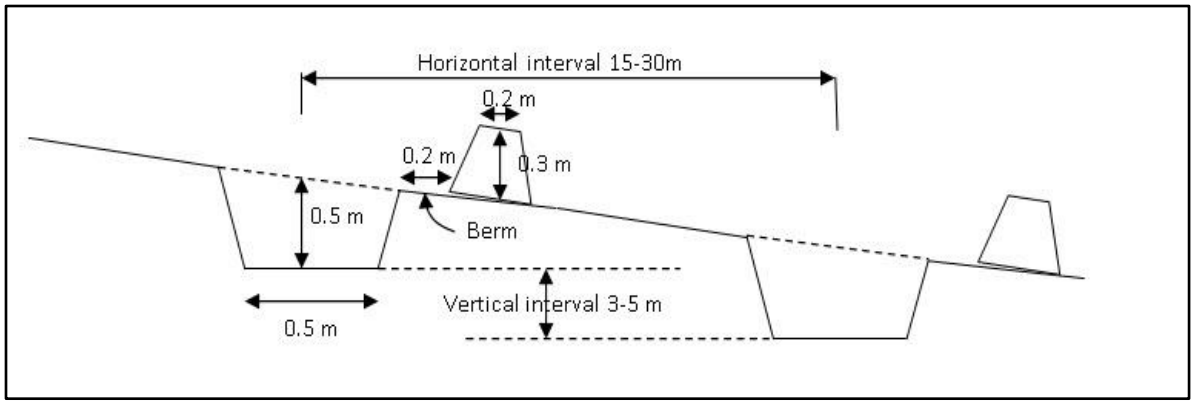
- The bed slope of the drain should be such that it is non erosive as well as non-silting one.

- 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:

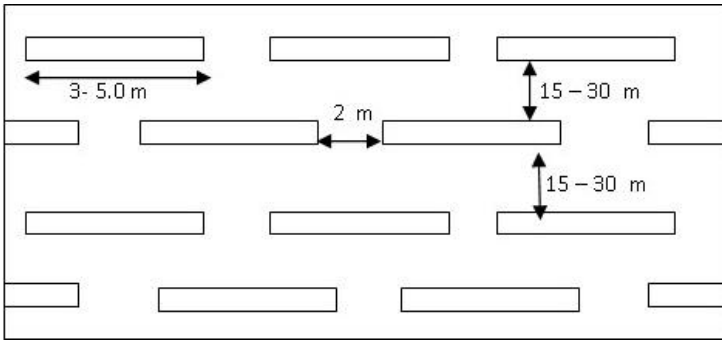
- Promote absorption and storage of water in soil profile for promoting vegetation growth.
- Moderate flash floods and improve ground water recharge.
- Control erosion on slopes where plant cover has deteriorated and vegetation is required.

**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.

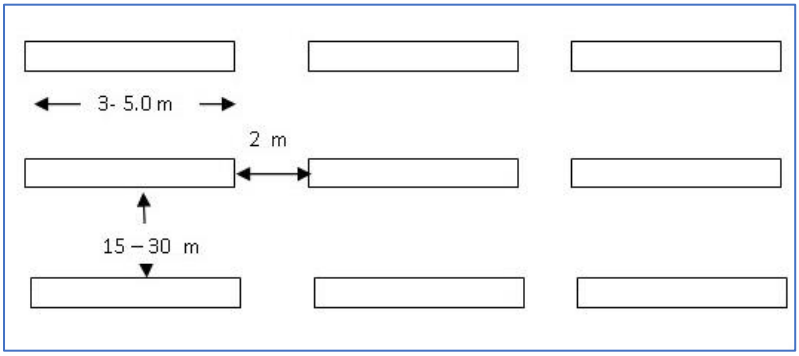
2. **Staggered contour trenches:** The staggered trenching involves the excavation of trenches of shorter length in a row along the contour with interspace between them. These trenches are arranged in straight line (staggered form). Suitable vertical intervals between the rows are restricted to impound 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.

**Crescent bunding**

**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.

### G. 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

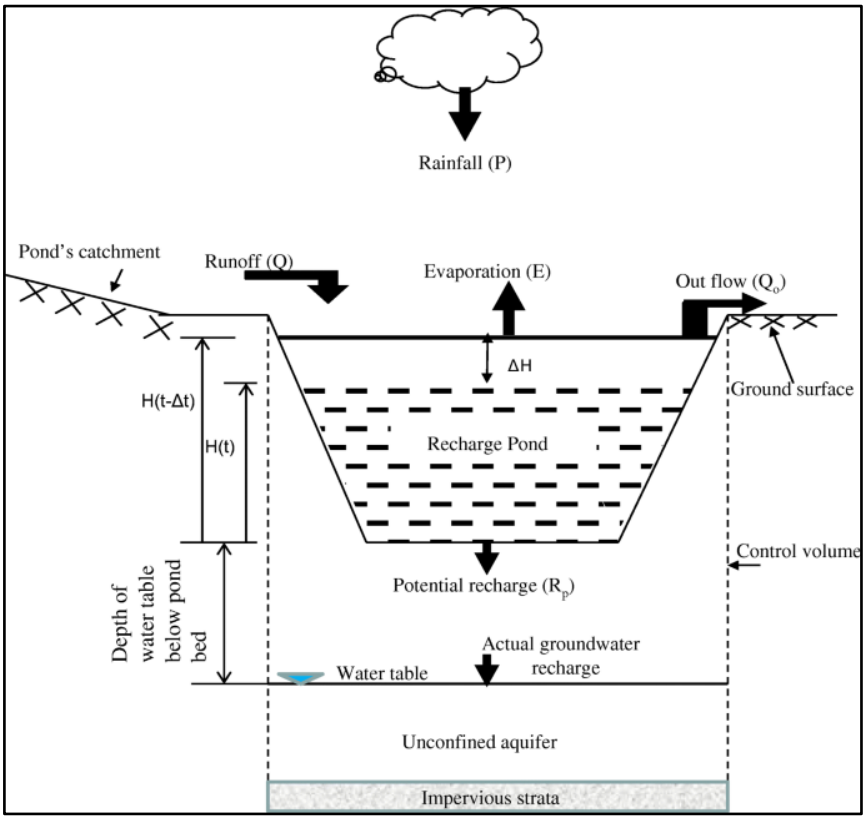
depth of the pond are determined based on the expected volume of water it will receive and the permeability of the underlying soil. Excavation is then carried out to create the pond, and the sides may be reinforced with rocks or vegetation to prevent erosion and siltation. Once constructed, the pond 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

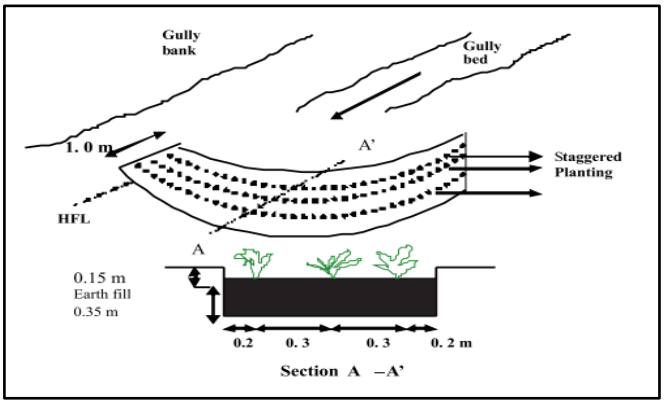
Drainage channels/gullies are the carriers of runoff and sediment in a watershed. Steep bed gradient of a channel causes high runoff velocities with associated heavy sediment flow. Hence channel gradient needs to be reduced in order to bring the runoff velocities within permissible limits. Drainage line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

### A. Upper ridge treatment

1. **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 |

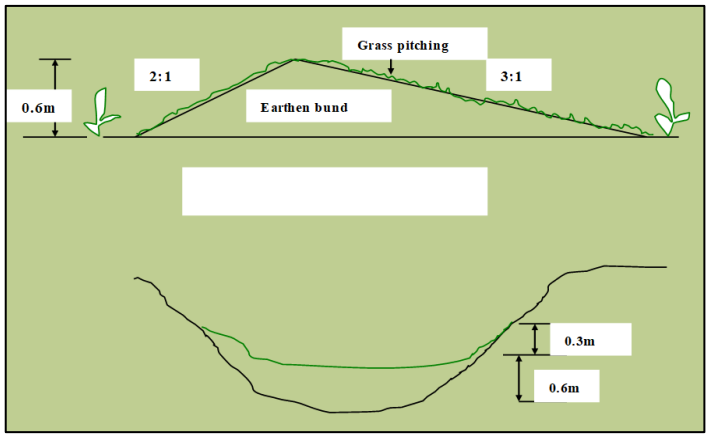



**Sod strips**

**2. 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.



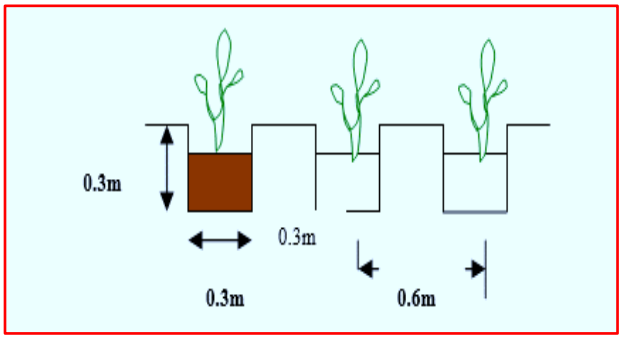

**Sodded earthen check**

**3. 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.



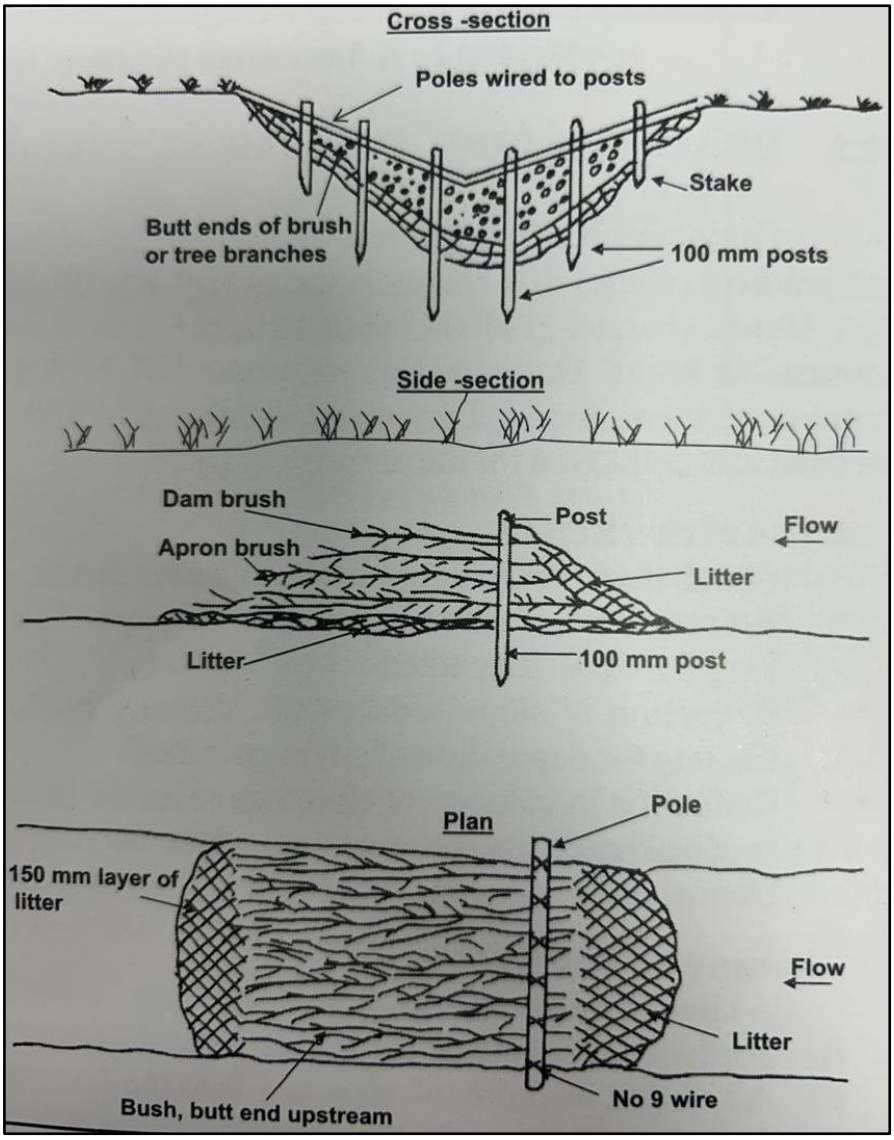

**Shrub check**

**4. 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**

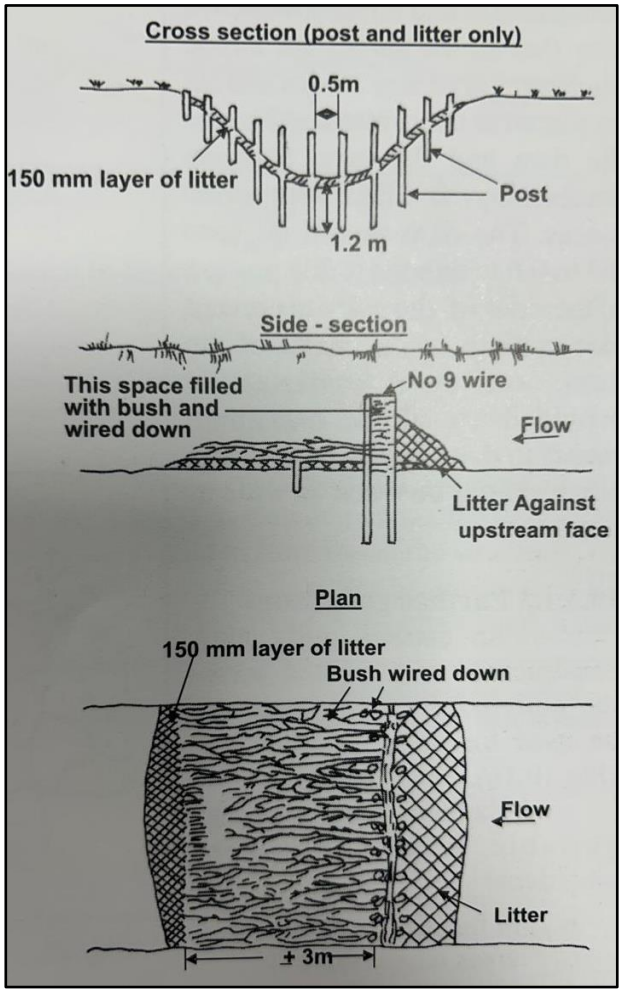
The construction of the single row post dams begins by easing the side slope of gully to 1:1. Then the wooden posts of about 10 – 15 cm diameter are driven into the bed and banks of the gully to a depth of about 0.75 – 0.9 m below the surface and about 0.6-0.9 m apart. Posts of self-sprouting species 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**

**5. Mini percolation tank:**

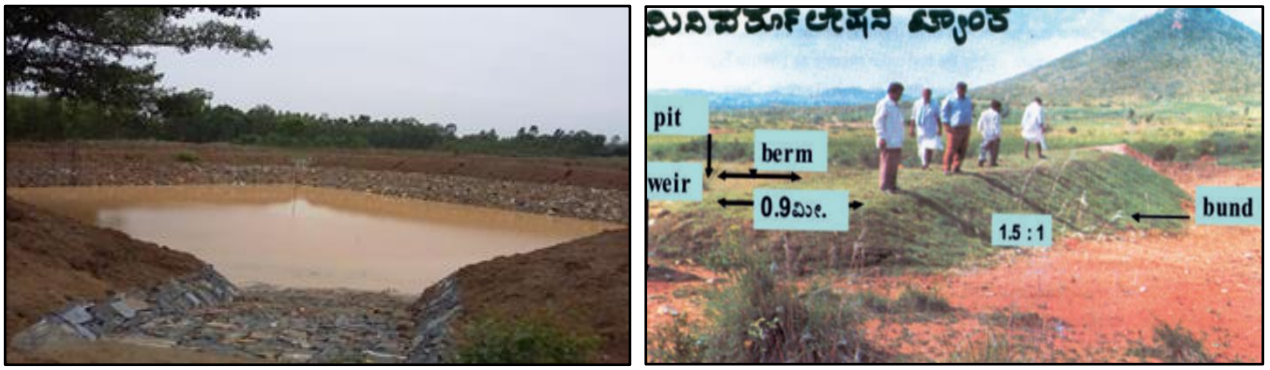
The rain water flowing in gully or undulating lands will be collected in Mini Percolation Tank so that the moisture percentage in the surrounding area is increased besides using for pitture irrigation of Forest/ Horticulture plants. The excavated soil is put as bund and grasses will come up with the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

**6. Boulder check**

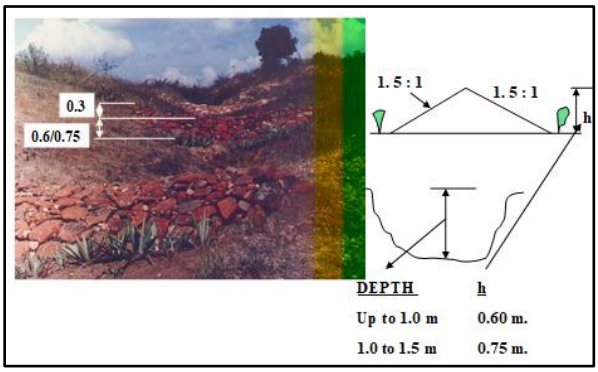
A boulder check is an erosion control structure designed to stabilize gullies by slowing down water flow and encouraging sediment deposition. This method is particularly effective in areas where the gully erosion is moderate and the available watershed or catchment area is about 8 hectares.

**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**

**7. 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.

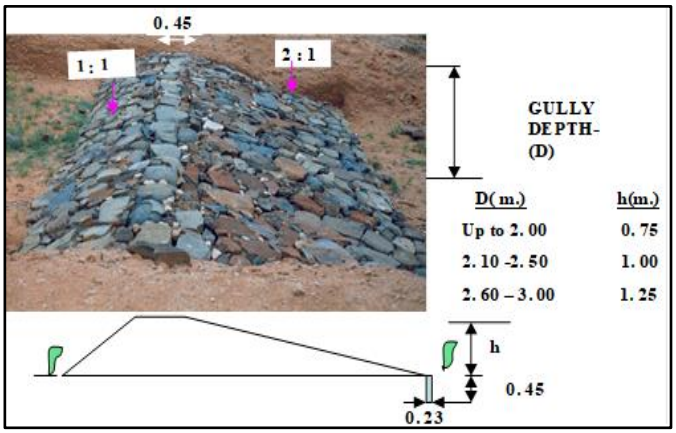
**Site Selection:** Rubble checks are most effective in watersheds or catchment areas ranging from 8 to 15 hectares. These structures are ideally suited for gullies that have a depth of 1 to 3 meters and a bottom width of around 8 meters. The size and design of the rubble check must be appropriate for 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**

## 8. 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.

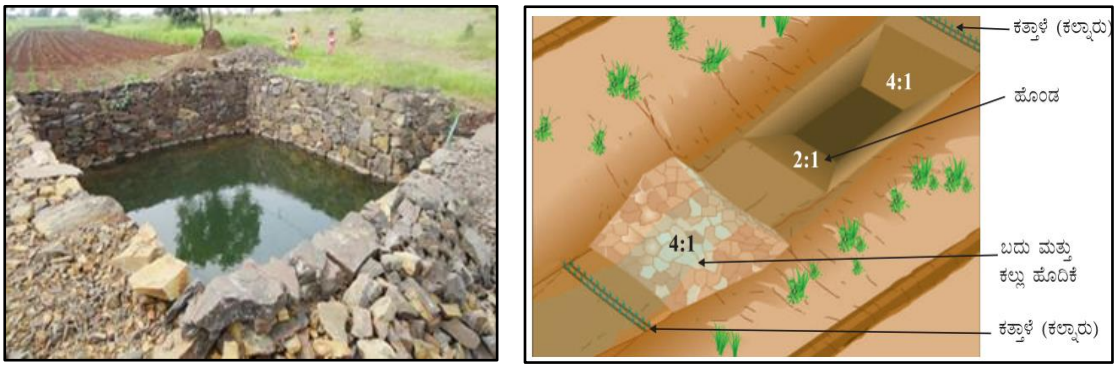
**Design Specifications:** The design of a sunken pond is carefully planned to optimize water storage while maintaining the structural integrity of the surrounding landscape. The top width of the pond is set at a minimum of 5 meters, and the top length is a minimum of 8.4 meters, ensuring that the pond 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**

**9. 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.

**2. Sand bags**

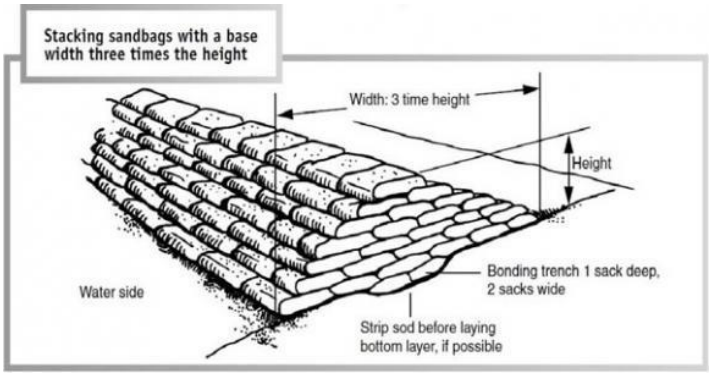
Sandbags are versatile and cost-effective tools commonly used in flood control, erosion prevention, military fortification, and construction. Filled with sand or soil, they act as barriers to water, wind, and debris, making them essential in emergency response situations, such as during heavy rains, 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.

**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 theother, 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.

**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**

# Chapter-2
# Production Systems

## Crops selection based on land suitability

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) s. 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 beenat 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 andhuman health. These problems demand a systematic appraisal of our soil and climatic resources torecast 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. Theseuses can be productive such as i) arable farming, ii) livestock production, iii) forestry or other usessuch 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 therequirements of alternative land use.

## Land evaluation procedures

The land evaluation activities undertaken and the order in which the work is done depend on thetype 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 andassumptions 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. Interimfindings 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 unitsis 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 factpractical 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 topsoil; 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 approachesin 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 occurringin 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

evaluationand 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 thecultivation is considered marginally economical. The final soil-site evaluation/suitability is based on the number and degree of limitation (s). Modern approaches involve simulation modelpredicting 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 eachsoil 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 orderto 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 andland use conditions (ii) development of soil site criteria or crop requirements (iii) matching of croprequirements with existing soil and climatic conditions and (iv) choosing of the best fit among thecrops 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 requirementsforms 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 andthe 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 kindof 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 maybe overcome in time but cannot be corrected with existing knowledge at current acceptable cost

Class N2 : (Permanently not suitable) Land having limitations that will be very difficult to correct and use

There are no sub-classes within the suitability class S1. Classes S2, S3 and N1 are dividedinto 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 suitabilityunits 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 tofind 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 varietiesfrom 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
- Finalization 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 ofMinimum 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.

## Agronomic measures

1. **Contour Cropping:** Contour Cropping is a conservation farming method that is used on slopes to control soil losses due to water erosion. Contour cropping involves planting crops across the slope instead of up and down the slope. Use of contour cropping protects the valuable top soil by reducing the velocity of runoff water and inducing more infiltration. On long and smooth slope, contour cropping is more effective as the velocity of flow is high under such situation and contour cropping shortens the slope length to reduce the flow velocity. Contour cropping is most effective on slopes between 2 and 10 percent.

Fig. Contour cropping

2. **Strip Cropping:** Strip cropping is the practice of growing strip of crops having poor potential for erosion control, such as root crop (intertilled crops), cereals, etc., alternated with strips of crops having good potentials for erosion control, such as fodder crops, grasses, etc., which are close growing crops. Strip cropping is a more intensive farming practice than contour farming. The farming practices that are included in this type of farming are contour strip farming, cover cropping, farming with conservation tillage and suitable crop rotation. A crop rotation with a combination of intertilled and close growing crops, farmed on contours, provides food, fodder and conserves soil moisture. Close growing crops act as barriers to flow and reduce the runoff velocity generated from the strips of intertilled crops, and eventually reduce soil erosion. Strip cropping is laid out by using the following three methods:

Fig. Strip cropping

a. **Contour strip cropping:** In contour strip cropping, alternate strips of crop are sown more or less following the contours, similar to contouring. Suitable rotation of crops and tillage operations are followed during the farming operations
b. **Field strip cropping:** In a field layout of strip cropping, strip of uniform width is laid out across the prevailing slope, while protecting the soil from erosion by water. To protect the soil from erosion by wind, strips are laid out across the prevailing direction of wind. Such practices are generally followed in areas where the topography is very irregular, and the contour lines are too curvy for strict contour farming
c. **Buffer strip cropping:** Buffer strip cropping is practiced where uniform strip of crops are required to be laid out for smooth operations of the farm machinery, while farming on a contour strip cropping layout. Buffer strip of legumes, grasses and similar other crops are laid out between the contour strips as correction strips. Buffer strips provide very good protection and effective control of soil erosion

3. **Mulching:** Mulches are used to minimize rain splash, reduce evaporation, control weeds, reduce temperature of soil in hot climates, and moderate the temperature to a level conducive to microbial activity. Mulches help in breaking the energy of raindrops, prevent splash and dissipation of soil structure, obstruct the flow of runoff to reduce their velocity and prevent sheet and rill erosion. They also help in improving the infiltration capacity by maintaining a conductive soil structure at the top surface of land.

Fig. Mulching of cropped field

**Types of mulching material:** To protect the land from erosion different types of materials are used as listed below.

1. Cut grasses or foliage
2. Straw materials
3. Wood chips
4. Saw dusts
5. Papers
6. Stones
7. Glass wools
8. Metal foils
9. Cellophanes
10. Plastics

The mulches may be broadly classified into the following five types:

1. **Synthetic mulch:** It includes organic and inorganic liquids that are sprayed on the soil surface to form a thin film for controlling the various atmospheric agents acting on the soil surface. The different synthetic mulching materials are: resins, asphalt emulsions, latex and cut back asphalt, canvas etc.

2. **Petroleum mulch:** The petroleum mulches are easier to apply and also less expensive. These mulches are available in the form of emulsions of asphalt in water, which can be sprayed on the soil surface at ambient temperature to form a thin film in continuous form that clings to soil, but does not penetrate deep inside the soil. The mulch film promotes uniform and rapid seed germination and also plays a significant role for vigorous growth of seedling. An ideal surface film is also stable against erosion, sufficiently porous to allow water into the soil, yet insoluble in water and resistant enough to the forces of weather, causing it to last as long as necessary for vegetation to become established.

3. **Conventional mulch:** The mulches such as hay or straw are more effective than the petroleum mulches. These mulches not only conserve the moisture and reduce the fluctuation of soil temperature, but also protect the soil from rain drop impacts and hold the excess surface water in contact with the soil, so as to increase the infiltration rate and thereby reduce the runoff and soil erosion. In addition, during day hours these mulches also absorb as much insolation as bare soil does, but little energy is conducted downward. This causes the surface of the mulch to become hot and the underlying soil to remain cool. On the other hand, during night hours, the mulch cools down permitting the soil to remain warm. The paper mulches also counted under conventional mulch are reported to produce remarkable results. Paper mulches are observed to increase the soil temperature, especially of the surface soil layers. There are several evidences to show that paper mulching gives better performance in improvement of soil condition, besides promoting the earthworm activity. But at the same time, caution has to be taken against the toxic elements of chemicals leached out of the paper. The bituminized treated papers have toxic effects on the plants.

4. **Stone mulch:** It involves the spreading of stone pieces on the ground surface to conserve the moisture and also to reduce the wind erosion. It is a very old practice, followed in arid zones. Soil under the stones tends to be in moist condition, but the temperature of that soil becomes slightly higher. The soils lying below the stones, harbour small animals and involve high nitrification. The stone mulching is also used for trapping the dew, particularly in those locations where significant dew fall takes place. Central arid zone research h institute Jodhpur, has reported the use of rubble mulch, which is simply combination of small fragments of stones and bricks. This mulch provides better results on moisture conservation compared to the stone mulching, synthetic mulching and mulching made by straw materials.

5. **Organic mulch:** The tree branches, twigs, leaves, leaf litter, grasses, weeds etc. are used as organic mulch to cover the soil surface. The organic mulches are found superior to the artificial mulches in respect of conservation of moisture, reduction in evaporation and runoff. Use of this mulch controls the evaporation more effectively, particularly when rainfall takes place at frequent intervals, but it is not very effective when the numbers of rains are few and scattered. In other words, organic mulch does not conserve the moisture available due to infrequent rains and small showers, but these mulches may be quite effective for large rains lasting for several days which results in a wet surface with the availability of excess surface water for deep percolation. Further, the light mulches are almost ineffective for controlling the evaporation, because moisture conserving efficiency of mulch is inversely related to their capacity to absorb water or to extract it from the soil by capillary action. Resistant mulches do not decay shortly but last for a long time. As a result, they are more effective for conserving the soil moisture.

**Grassed waterways:** Grassed waterways are natural or manmade constructed channels established for the transport of concentrated flow at safe velocities from the catchment using adequate erosion resistant vegetation which cover the channels. These channels are used for the safe disposal of excess runoff from the crop lands to some safe outlet, namely rivers, reservoirs, streams etc. without causing soil erosion. Terraced and bunded crop lands, diversion channels, spillways, contour furrows, etc. from which excess runoff is to be disposed of, preferably use constructed grassed waterways for safe disposal of the runoff. The grassed waterways outlets are constructed prior to the construction of terraces, bunds etc. because grasses take time to get established on the channel bed. Generally, it is recommended that there should be a gap of one year so that the grasses can be established during the rainy season.

Grassed waterways are used as outlets to prevent rill and gully formation. The vegetative cover slows the water flow, minimizing channel surface erosion. When properly constructed, grassed waterways can safely transport large water flows to the down slope. These waterways can also be used as outlets for water released from contoured and terraced systems and from diverted channels. This best management practice can reduce sedimentation of nearby water bodies and pollutants in runoff. The vegetation improves the soil aeration and water quality (impacting the aquatic habitat) due to its nutrient removal (nitrogen, phosphorus, herbicides and pesticides) through plant uptake and sorption by soil. The waterways can also provide a wildlife habitat.

The designs of the grassed waterways are similar to the design of the irrigation channels and are designed based on their functional requirements. Generally, these waterways are designed for carrying the maximum runoff for a 10-year recurrence interval period. The rational formula is invariably used to determine the peak runoff rate. Waterways can be shorter in length or sometimes, can be even very long. For shorter lengths, the estimated flow at the waterways outlets forms the design criterion, and for longer lengths, a variable capacity waterway is designed to account for the changing drainage areas.

**Promotion of good agricultural practices:** Groundwater stock before the Kharif or Rabi season in a particular year is critical for devising a sustainable use plan for the season. The choice of crop, the crop acreage etc., require a knowhow of the groundwater stock. The groundwater budget estimates prepared come in handy in preparing an action plan for the sustainable groundwater use case prior to the season (Kharif or Rabi). "Groundwater outlook" can be prepared prior to the beginning of the crop season and through this advisory for suitable use of groundwater at farm scale can be leveraged. This may involve irrigation amounts and scheduling as well. Agriculture being the largest consumer of fresh water (>82 per cent), having a potential of minimizing water use and reducing the dependence on groundwater. Groundwater supports more than 60 per cent of the irrigation needs. Efficient water management practices in agriculture saves huge quantum of water (about 30-50 per cent in different crops) and minimize ground water exploitation. The dependence on groundwater for agriculture can be reduced by increasing the proportionate usage of harvested rainwater and treated water conjunctively.

1. **Irrigation management**: Efficient utilization of water through soil and crop management practices is crucial for optimizing water resources, reducing water wastage, and maximizing crop productivity. By implementing the following practices, farmers can enhance water-use efficiency and minimize water losses: Enhancing water productivity in agriculture depends largely on its efficient conveyance from source to the field of application, application methods and distribution. A properly designed water distribution system will make irrigation easy & efficient. Several types of structures are used to convey, divert & control irrigation water on the farm.

**Requirements of good distribution network**

- It should provide desired quantity of water economically and efficiently to each part of the sub command
- It should have enough capacity to meet crop water requirements during peak use periods
- The system should be large enough to allow delivery of water in the time allotted when water is supplied on rotation or turn basis

**Benefits of lining of water courses**

- Reduction of water losses to a negligible quantity
- Facilitates planned division and subdivision of water
- Reduction in the width of land lost under the water course section (lined channels needs reduced section)
- Prevent water logging adjoining the water course and stagnation in the field, in the event of a break in the earthen channel
- Reduction in operation and maintenance cost

Generally, water transit through main canal, branches & distributaries and field channels. Channel to deliver water to each and every field in the command area of an outlet is called water course, which is approximately 40 Ha for a delivery system of one cusec. Water course generally takes off from a distributary. Capacity of a water course depends upon (a) Water allowance (b) running period of outlet and (c) Area to be irrigated.

The design capacity of water course can be calculated by

$$Q = \frac{AW}{IT} \quad X \quad \frac{1}{1-L}$$

where,

Q = Design capacity of water course in cumec
A = Area to be irrigated in square meters
W = Water requirement for one irrigation in meters
I = Rotation interval or irrigation interval in days
T = Time of irrigation in seconds per day
L = Water conveyance losses as a decimal

Manning's formulae are used to design canals, calculate velocity and discharge. In open channel system, the formulae for calculating velocity is:

$$V = \frac{k}{n} \; R_h^{2/3} \; S^{1/2}$$

where,

*V* = cross-sectional average velocity (ft/s, m/s)
*k* = conversion factor 1 $m^{1/3}/s$ or 1.4859 $ft^{1/3}/s$
*n* = Gauckler–Manning coefficient (unitless)- rugosity coefficient
$R_h$ = hydraulic radius (L; ft, m)
*S* = slope of the hydraulic grade line

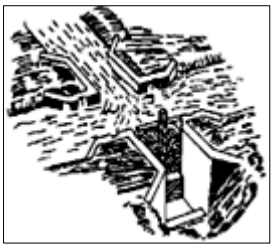
**Water management appraoches:** During water conveyance and distribution, many control and diversion structures are to be used to regulate the water flow. The important structures are:

**A. Erosion control structures:**

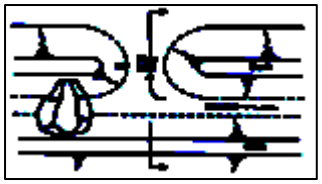
1. **Drop structure**: Drop structure is used to discharge water in a channel from a higher level to a lower level. They may be open type or pipe drops. A drop structure consists of an inlet, vertical fall section and the outlet. Open drop structure can be made of wood, concrete brick or stone masonry or by using discarded drums or barrels. Sometimes constructions of an open drop structure are not possible without disturbing an existing bund. In such cases, pipe drop is provided to discharge water from higher level to lower one
2. **Chute spillways:** Chute spillways carry the flow down steep slopes through lined channel rather than dropping the water in free fall. The chute spill ways consist of an outlet, Channel section and an inlet. These are made of concrete, brick or stone lay in cement mortar

**B. Control and diversion structures:** These are necessary to give an easy & effective control of irrigation water on the farm. The common structures are:

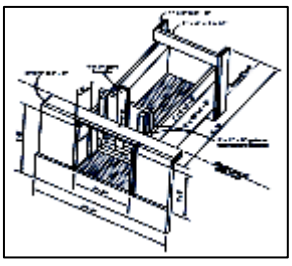
1. **Check gates:** Checks are placed in an irrigation channel to form an adjustable dam to control the elevation of surfaces in upstream. It is often necessary to raise the water level to apply irrigation to the elevated fields. Check gates consist of a masonry or metal wall across the channel and provided with a suitable gate. The gate may be made of wood or steel



2. **Diversions**: In carrying water to different farms / parts of same farm, it is necessary to divert the water coarse or channel. Two-way, 3-way or 4-way diversions made to control the flow at channel junction will permit the diversion of flow to all or any pre-determined direction
3. **Turnouts:** The water, delivered in an open canal or pipeline, can be supplied onto the fields with turnouts. Important turnouts are detailed below.

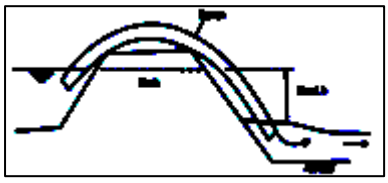


   a. **Bank breaching:** Bank breaching involves opening a cut in the bank of a field canal to discharge water onto the field. Although this method is practiced widely, it is not recommended, as the canal banks become weak because of frequent destruction and refill



   b. **Permanent outlet structures:** Small structures, installed in the bank of a field canal are used to release water from the field canal onto the fields. The structures can be made of timber with wooden stop logs or of concrete with steel gates. This method is especially used for border strip and basin irrigation

c. **Spiles:** Spiles are short lengths of pipes made from rigid plastic, concrete, steel, bamboo or other material and buried in the canal bank as shown in Figure. A plug is used to close the spile on the inlet side

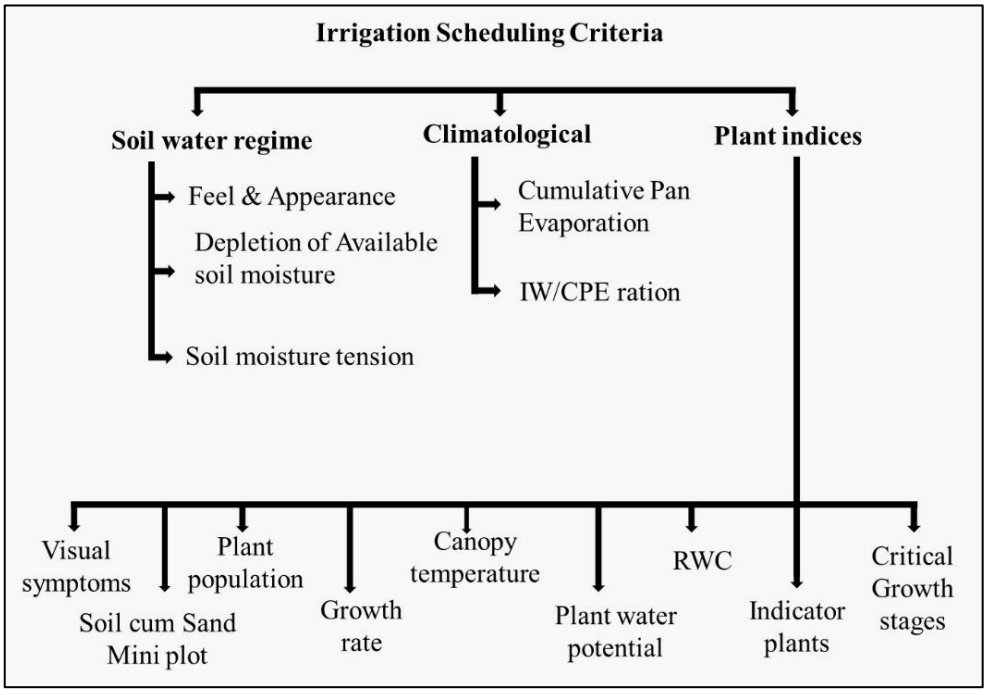


d. **Siphons:** Siphons are short lengths of pipe usually made of plastic, rubber hose, or aluminium and are used to convey water from open channels to the field. They are portable and easy to install and to remove without disturbing the canal bank

e. **Box turnouts:** They are portable wooden boxes with a gate at the inlet and a board at outlet. The gate slides in saw cut grooves in the box. It can be adjusted to divert any desired flow into the field or a secondary channel.

## 2. Irrigation Scheduling:

- Proper irrigation scheduling ensures that crops receive the right amount of water at the right time
- Monitoring soil moisture levels, weather conditions, and crop water requirements helps determine the optimal timing and duration of irrigation events
- Avoiding over-irrigation and providing water when the crop needs it the most improves water-use efficiency



**Advantages of irrigation scheduling:**

a. It enables the farmer to schedule water rotation among the various fields to minimize crop water stress and maximize yields
b. It reduces the farmer's cost of water and labor through fewer irrigations, thereby making maximum use of soil moisture storage
c. It lowers fertilizer costs by holding surface runoff and deep percolation (leaching) to a minimum
d. It increases net returns by increasing crop yields and crop quality
e. It minimizes water-logging problems by reducing the drainage requirements
f. It assists in controlling root zone salinity problems through controlled leaching
g. It results in additional returns by using the "saved" water to irrigate non-cash crops that otherwise would not be irrigated during water-short periods

**Water requirement:** It is defined as the quantity of water regardless of its source, required by a crop or diversified pattern of crops in a given period of time for its normal growth & development under field conditions at a given place. In other words, it is the total quantity of water required to mature an adequately irrigated crop. It is expressed in depth per unit time. Water requirement, if considered as a demand, it includes the quantity of water needed to meet the losses due to evapotranspiration (ET), plus the losses during the application of irrigation water (unavoidable losses) and the additional quantity of water required for special operations such as land preparation, transplanting, leaching of salts below the crop root zone, frost control etc.

**Water requirement of various crops:**

| *Crop* | *Water requirement (mm)* | *Crop* | *Water requirement (mm)* |
|---|---|---|---|
| Rice | 1200 | Tomato | 600 – 800 |
| Wheat | 450 – 650 | Potato | 500 – 700 |
| Sorghum | 450 – 650 | Pea | 350 – 500 |
| Maize | 500 – 800 | Onion | 350 – 550 |
| Sugarcane | 1500 – 2500 | Chillies | 400 – 600 |
| Sugarbeet | 550 – 750 | Cabbage | 380 – 500 |
| Groundnut | 500 – 700 | Banana | 1200 – 2200 |
| Cotton | 700 – 1300 | Citrus | 900 – 1200 |
| Soybean | 450 – 700 | Grapes | 700 – 1200 |
| Tobacco | 400 – 600 | Mango | 1000 – 1200 |
| Beans | 300 – 500 | Turmeric | 1200 – 1400 |

**Accurate crop water requirement data is essential in agriculture for:**

- Economic appraisal of irrigation projects
- Design and operation of irrigation schemes
- Fixing cropping patterns and irrigated areas
- Irrigation scheduling to crops
- Efficient use of limited water

**Critical growth period:** It is the stage or stages of growth of the crop at which moisture stress has the greatest effect on quality and quantity of yield. Therefore, any stress during these stages will irrevocably reduce the yield and provision of adequate water and other management practices at other growth stages will not compensate the yield lost". In general moisture stress during germination and early seedling stage may have deleterious effect on field crop emergence and plant establishment because of soil crusting and small root system resulting in low plant population per unit area. Stress during vegetative stage, has little effect on subsequent production unless it is so severe as to drastically reduce leaf area index and leaf area duration. Moisture stress during flowering causes flowers drop & pollen desiccation and affects fertilization; while that during grain development leads to production of shrivelled grains and low mean test weight. Critical stages for various fields, vegetable and fruit crops are presented below which serve as a guideline for management of limited water supplies.

| *Crop* | *Critical growth period for water supply* |
|---|---|
| Rice | Primordial development, Heading & Flowering |
| Sorghum | Booting, Blooming, Milky & Dough stages |
| Ragi | Primordial initiation & Flowering |
| Maize | Tasseling, Silking & Pollination |
| Bajra | Heading & Flowering |
| Wheat | Crown root initiation, Shooting & Earing |
| Groundnut | Flowering, Peg penetration & Pod development |
| Sesame | Flowering to Maturity |
| Sunflower | Star formation, Flowering & Seed development |
| Safflower | Rosette, flowering and Seed development |
| Soybean | Flowering & Seed formation |
| Cotton | Flowering & Boll development |
| Sugarcane | Formative & Stem elongation |
| Tobacco | Rapid growth & Topping stage |
| Chillies | Flowering & Fruit development |
| Potato | Tuber initiation to Tuber maturity |
| Onion | Bulb enlargement to Ripening |
| Tomato | Flowering & Fruiting |
| Citrus | Flowering, Fruit set & Fruit enlargement |
| Banana | Adequate soil moisture throughout growth period & fruit development |
| Mango | Flowering & fruit development |

3. **Smart irrigation systems**: Smart irrigation systems are becoming increasingly important due to their ability to optimize water usage in agriculture, landscaping, and gardening. These systems utilize advanced technologies such as sensors, weather forecasts, and automation to efficiently water plants while minimizing waste. Here's a breakdown of their importance and types:

**Importance of smart irrigation systems:**

a. **Water conservation**: Smart irrigation systems help conserve water by delivering the right amount of water directly to plants based on their needs, minimizing runoff and evaporation
b. **Cost savings**: By using water more efficiently, smart irrigation systems can reduce water bills and operational costs associated with traditional irrigation methods
c. **Environmental sustainability**: Conserving water helps preserve local ecosystems and reduces the strain on freshwater sources, promoting environmental sustainability
d. **Improved crop yield**: Providing plants with the optimal amount of water promotes healthier growth and can lead to higher crop yields in agriculture
e. **Convenience**: Automation features in smart irrigation systems make watering schedules more convenient for users, allowing them to remotely control and monitor watering activities

**Types of Smart Irrigation Systems:**

a. **Soil moisture-based systems**: These systems use soil moisture sensors to measure the moisture content in the soil. They adjust watering schedules based on real-time soil conditions, ensuring plants receive water only when necessary
b. **Weather-based systems**: Weather-based systems rely on local weather data to adjust watering schedules. They consider factors such as temperature, humidity, rainfall, and evapotranspiration rates to determine optimal watering times and durations
c. **Drip irrigation**: Drip irrigation systems deliver water directly to the root zone of plants through a network of tubes or pipes with emitters. They are highly efficient and can be automated to provide precise water delivery based on plant needs
d. **Smart sprinkler systems**: These systems utilize advanced sprinkler heads equipped with sensors and controllers to adjust water flow and coverage based on factors like wind speed, temperature, and soil moisture levels
e. **Remote-controlled systems**: Remote-controlled irrigation systems allow users to monitor and control watering activities from anywhere using a smartphone or computer. They provide flexibility and convenience for managing irrigation schedules
f. **Integrated systems**: Some smart irrigation systems integrate multiple technologies, such as soil moisture sensors, weather data, and automation, to provide comprehensive water management solutions tailored to specific needs and environments

By implementing smart irrigation systems, individuals, farmers, and landscapers can achieve efficient water management, conserve resources, and promote sustainable practices in agriculture and landscaping

**Adoption of micro-irrigation**: Drip irrigation envisages maintenance of optimum moisture by irrigating directly to the rhizosphere and minimize evaporation, reduce water wastage through seepage and percolation losses. Drip irrigation saves 30 to 60 per cent water over surface irrigation method in different crops. Similarly, sprinkler irrigation economizes water in closely spaced, short statured crops.

**Surface drip irrigation:** The application of water to the soil surface as drops or tiny streams through emitters with discharges rate for point-source emitters less than 8 L/h for single outlet emitter and for line-source emitters less than 4 L/h. Often the terms drip and trickle irrigation are considered synonymous.

Fig. Surface drip irrigation in bhendi and mango crop

**Subsurface drip irrigation**: The application of water below the soil surface through emitters, with discharge rate generally in the range of 0.6 to 3 L/h. This method of water application is different from and not to be confused with the method where the root zone is irrigated by water table control, herein referred to as subirrigation.

Fig. Subsurface drip irrigation in potato

**Advantages:** Many reports have listed and summarized potential advantages of drip irrigation as compared to other irrigation methods.

a. Enhanced plant growth, crop yield and premium quality produce
b. Water Saving due to increased beneficial use of available water and higher water application efficiency
c. Precise and uniform delivery of water to crops due to controlled water application

d. Maintenance of higher soil water potential in the root zone
e. Compact and efficient root system
f. Combined water and fertilizer (fertigation) application minimizes nutrient losses and improves fertilizer use efficiency and contributes to fertilizer saving in some crops
g. Reduced salinity hazards to crop plants when low quality saline water is used for irrigation
h. Suitable for irrigating high-value crops raised in greenhouses, plastic tunnels, potted plants and under plastic mulches
i. Lower operating pressures means reduced pumping energy costs
j. Limited weed growth because only a fraction of the soil surface is irrigated
k. Reduced operational and labour costs due to improved weed control and simultaneous application of water, fertilizers, herbicide, insecticide, fungicide and other additives through the drip irrigation system
l. Feasible to irrigate crops raised in small & irregularly shaped narrow lawns, and on undulated land terrains
m. Maintenance of dry foliage means improved disease and pest management
n. Suitable to highly permeable & low water holding sandy and desert soils, saline and slowly permeable alkaline soils, wastelands, slopy lands and rocky hills, road embankments, abandoned mine areas etc
o. Improved and continuous cultural operations such as spraying, weeding, thinning and harvesting of tree and row crops is possible without interrupting the drip irrigation cycle for any prolonged period of time.
p. Environmental protection and ecological security

**Limitations:** Despite observed successes, some important possible limitations of drip irrigation as compared to other irrigation methods have been encountered for some soils, water quality and environmental conditions, which include:

a. Sensitivity to emitter clogging
b. Salt accumulation in soil
c. Mechanical damage to system components
d. Lack of microclimate control such as frost protection and evaporative cooling.
e. Operational constraints such as high technical skills, stringent filtration and operating pressures etc.

4. **Conservation agriculture:** It is a resource saving agriculture crop production technology which aims to achieve sustained production with the conservation of natural resources while maintaining water balance in the field. Conservation agriculture practices, such as minimum soil disturbance and maintaining permanent soil cover, help reduce soil erosion. When soil erosion is minimized, less sediment is carried into water bodies, reducing sedimentation and improving water quality. Sedimentation can adversely affect groundwater recharge by filling in streambeds and reducing infiltration rates. By mitigating erosion, Conservation Agriculture supports groundwater recharge by allowing

rainwater to percolate through the soil and replenish aquifers. The practice of maintaining permanent soil cover, such as crop residues or cover crops, helps improve soil structure and porosity. This allows water to infiltrate into the soil more easily rather than running off the surface. As a result, more water can percolate downward to recharge groundwater aquifers. Additionally, reduced tillage practices minimize soil compaction, which can improve soil permeability and enhance infiltration rates, further facilitating groundwater recharge.

There are primarily three principles for conservation agriculture:

A. **Minimum soil disturbance**: This principal advocates for reducing or minimizing mechanical soil disturbance, such as ploughing or conventional tillage. Instead of turning over the soil through intensive tillage, conservation agriculture promotes techniques like no-till or reduced tillage. These methods leave crop residues on the soil surface and disturb the soil minimally, preserving its structure and organic matter content.

**Benefits**:

- **Soil erosion control**: By leaving crop residues on the soil surface, conservation agriculture reduces the risk of erosion caused by wind and water. The residues act as a protective layer, preventing soil particles from being carried away by wind or water runoff.
- **Soil structure preservation**: Intensive tillage can disrupt soil structure, leading to compaction and decreased water infiltration. Minimum soil disturbance helps maintain soil structure, ensuring better root penetration and water retention.
- **Soil organic matter preservation**: Crop residues left on the soil surface decompose slowly, contributing organic matter to the soil. This organic matter improves soil fertility, enhances nutrient cycling, and supports beneficial soil organisms.
- **Energy savings**: Reduced tillage practices require less energy compared to conventional tillage methods, leading to lower fuel consumption and reduced greenhouse gas emissions.

**B. Permanent soil cover**: The principle of permanent soil cover involves keeping the soil surface covered with residues from previous crops, cover crops, or mulch throughout the year. This practice helps protect the soil from erosion, conserve moisture, suppress weed growth, and promote soil health.

**Crop residue management**: Incorporation of crop residues into soil or retention on the surface has several positive influences on physical, chemical and biological properties of soil. These practices increase hydraulic conductivity and reduce bulk density of soil by modifying soil structure and aggregate stability. Mulching with plant residues raises the minimum soil temperature in winter due to reduction in upward heat flux from soil and decreases soil temperature during summer due to shading effect. Retention of crop residues on the soil surface slows the runoff by acting as tiny dams, reduces surface crust formation and enhances infiltration. The channels (macro pores) created by earthworms and old plant roots, when left intact with no-till, improve infiltration to help reduce or eliminate runoff. Reduced evaporation from the upper strata of soil coupled with improved soil characteristics essentially leads to higher crop yield in many cropping and climatic situations.

The crop residues act as a reservoir for plant nutrients, prevent leaching of nutrients, increase cation exchange capacity (CEC), provide congenial environment for biological N2 fixation, increase microbial biomass and enhance activities of enzymes such as dehydrogenase and alkaline phosphatase. Increased microbial biomass can enhance nutrient availability in soil as well as act as sink and source of plant nutrients. Leaving substantial amounts of crop residues evenly distributed over the soil surface reduces wind and water erosions, increases water infiltration and moisture retention, and reduces surface sediment and water runoff. The crop residues play an important role in amelioration of soil acidity through the release of hydroxyls especially during the decomposition of residues with higher C: N, and soil alkalinity through application of residues from lower C: N crops, including legumes, oilseeds and pulses.

The role of crop residues on carbon sequestration in soils would be an added advantage in relation to climate change and GHGs mitigation. Establishment and maintenance of soil health is inextricably linked to the achievement of effective and efficient nutrient management goal in conservation agriculture. The conservation agriculture builds a stratified layer of crop nutrients, especially P on or near the soil surface. While reduced tillage and soil organic C build-up contribute to stable soil structure, this undisturbed structure produces macro pores and preferential flow channels that can direct nutrients, including P, downward into deeper parts of the soil profile. The choice of cropping systems can have a strong influence on the soil quality through processes such as nutrient depletion and/or enrichment through production of biomass/crop residues, need for external inputs and impact on environment. Conservation tillage can reduce overall nitrogen loss by reducing ammonium-nitrogen loss and organic-nitrogen loss

with sediment; however, it may not reduce nitrogen leaching in the nitrate form. Yield response with residues management varies with soil characteristics, climate, cropping patterns, and level of management skills. Higher yields with crop residues application result from increased infiltration and improved soil properties, increased soil organic matter and earthworm activity and improved soil structure after a period of 4-7 years.

**Mulching**: Covering the soil minimizes evaporation and maximize *in-situ* rain water conservation. Mulching has to be promoted both under rainfed and irrigated situation by covering soils with organic residues (crop residues, unflowered weeds, tree leaves etc.) and polythene sheets. Polythene mulching can be made mandatory in widely spaced high value vegetables and flowers with drip irrigation. The base of widely spaced trees should be mulched with organic residues. The efficiency of mulch depends on various factors such as the type of mulch used, application method, climate, soil type, and maintenance practices. Generally, mulching is highly efficient in conserving water, suppressing weeds, moderating soil temperature, and improving soil health when applied correctly.

**Mulching Importance:**

- **Moisture conservation**: Mulch helps retain soil moisture by reducing evaporation, thus minimizing the frequency of watering and promoting healthier plant growth, especially in areas prone to drought
- **Weed suppression**: Mulch acts as a barrier, suppressing weed growth by preventing sunlight from reaching weed seeds and inhibiting their germination. This reduces the need for manual weeding and herbicide use
- **Soil temperature regulation**: Mulch insulates the soil, moderating temperature fluctuations and protecting plant roots from extreme heat or cold, which is particularly beneficial during hot summers and cold winters
- **Soil erosion prevention**: Mulch protects the soil from erosion caused by wind and water runoff, maintaining soil structure and fertility while preventing nutrient loss
- **Improved soil health**: As organic mulches decompose, they enrich the soil with organic matter, enhancing its structure, nutrient content, and microbial activity, which promotes overall soil health

**Benefits of permanent soil cover:**

- **Erosion control**: Soil cover provides a physical barrier that shields the soil from the erosive forces of wind and water. it helps prevent soil particles from being dislodged and transported away.
- **Moisture conservation**: Covering the soil surface reduces evaporation and helps retain soil moisture, especially in arid and semi-arid regions. This benefits crop growth and reduces irrigation requirements.
- **Weed suppression**: A continuous soil cover inhibits weed germination and growth by limiting access to light and space. This reduces the need for herbicides and

manual weeding, thereby lowering production costs.

- **Temperature regulation**: Soil cover moderates soil temperature fluctuations, providing a more stable environment for soil microorganisms and plant roots.

**C. Crop rotation and diversification**: Crop rotation and diversification involve growing different crops in sequence or in combination within the same field. This practice helps break pest and disease cycles, improve soil fertility, optimize resource use, and enhance ecosystem resilience.

**Benefits**:

- **Pest and disease management**: Rotating crops disrupts the buildup of pests and pathogens specific to certain crops, reducing the need for chemical pesticides and promoting biological control mechanisms
- **Nutrient management**: Different crops have varying nutrient requirements and root structures. Crop rotation helps balance nutrient uptake and replenish soil fertility by alternating crops with different nutrient demands
- **Biodiversity enhancement**: Diversifying cropping systems promotes biodiversity above and below ground, supporting a wide range of beneficial organisms such as pollinators, natural enemies of pests, and soil microbes
- **Risk reduction**: Growing a variety of crops reduces the risk of yield losses due to adverse weather conditions, pests, or market fluctuations. It enhances the resilience of farming systems to environmental stresses and economic uncertainties

**5. Nutrient management:**

- Proper nutrient management ensures that crops receive the necessary nutrients for growth and development, improving water-use efficiency
- Balanced fertilization based on soil and plant nutrient analyses helps optimize nutrient uptake and reduces water stress on crops

**Bulky organic manure**s: Bulky organic manures are those materials of plant and /or animal origin, which when added to the soil have tendency to decrease bulk density and to increase soil volume, thus providing better physical conditions for plant growth especially in coarse textured soils and also provide essential nutrients in smaller quantities than the chemical fertilizers The effect of bulky organic manures on soils are:

i. Since these manures contain plant nutrients, they have direct effect on plant growth like any other commercial fertilizer. Bulky organic manures contain nutrients in small quantities, therefore large quantities of these are needed. Besides the major nutrients, they also contain traces of micro-nutrients
ii. Bulky organic manures increase organic matter content and hence improve the physical properties of soil. This effect is very important in case of most of our arable land. Such manures increase the humus content of soil and consequently water holding capacity of sandy soils also increased and the drainage of clayey soils is improved.
iii. Bulky organic manures provide food for soil microorganisms. This increases the

activity of microbes which in turn help to convert unavailable plant nutrients into available form. Organic manures have been the traditional means of improving soil fertility. The organic matter that is applied thorough organic manures has very complex effect on soil and on plant growth. The main effects are Effect of organic matter on soil properties: 1. Improvement of soil physical properties: (a) Improvement of soil structure, (b) Improvement of water holding capacity, (c) Improvement of soil aeration, (d) Reduction of soil loss through erosion; 2. Improvement of chemical properties: (a) Supply of essential plant nutrients in balanced ratio, (b) Slow release of nutrients, (c) High residual value; 3. Improvement of biological activity: (a) stimulation of soil fauna and flora

**Concentrated organic manures**: Like bulky organic manures, these organic manures contain plant nutrients and considerable amount of organic matter. They have direct effect on plant growth. Nitrogen content is higher in concentrated organic manures and varied from 2.5 per cent in mahua cake to 7.9 per cent in decorticated safflower cake. In addition to nitrogen all the oil cakes contain P2O5 (0.8 to 2.9 %) and K2O (1.2 to 2.2%) since they contain nitrogen in relatively large quantities, they are usually classified as organic nitrogenous manures. By virtue of this high nitrogen content, they enrich the nitrogen status of soil.

**Green manuring:** Green manuring can be defined as the growth of a crop for the specific purpose of incorporating it into soil while green, or soon after maturity with a view to improve the soil and benefiting subsequent crops or Practice of ploughing or turning in to the soil un decomposed green plant tissues for the purpose of improving physical condition as well as fertility of the soil.

**Objectives of green manuring:**

a. Increasing organic matter content of soil
b. Maintain and improve soil structure
c. Reduce the loss of nutrients, particularly nitrogen
d. Provide a source of nitrogen for the following crop
e. Reduce the soil loss by erosion

**Types of green manuring:** The practice of green manuring is adopted in various ways in different states of India to suit soil and climatic conditions. Broadly speaking, the following two types of green manuring can be differentiated.

**Green manuring *in-situ*:** In this system, green manure crops are grown and buried in the same field which is to be green-manured, either as a pure crop or as intercrop with the main crop. This is most common green manure crops grown under this system are sunnhemp (*Crotalaria juncea*), daincha (*Sesabania aculeata*), Pillipesera (*Phaseolus trilobus* ) and guar ( *Cyamopsis tetragonoloba* ). Green manuring can be safely adopted for irrigated and irrigated dry crops viz., rice, sugarcane, tuber crops, vegetables and orchards. In case of dry crops, it is unsafe because of limiting moisture. But when rains are sufficient and evenly distributed green

manuring could be followed even under rain fed conditions when the rain fall is above 900 mm

**Green leaf manuring**: Green leaf manuring refers to turning into the soil green leaves and tender twigs collected from shrubs and trees grown on bunds, waste lands and nearby forest areas. The common shrubs and trees used are Glyricidia, *Sesbania speciosa*, Karanj (*Pongamia pinnata*).

**Soil health improvement**: Increasing soil organic carbon content helps to improve water holding capacity, conserve rain water by increasing infiltration rate and minimize evaporation loss. The organic carbon content in the soil is to be increased to 0.75 per cent through (a) promotion of organic and natural farming practices, (b) green manuring can be encouraged with pre monsoon rain, (c) promotion of pulses in the cropping system, (d) incorporation of green leaf wastes *viz*., tree biomass, unflowered weeds etc., and (e) avoiding burning of crop residues *viz*., sugarcane/maize trash, paddy residue etc.

**Soil health challenges:**

- **Erosion**: Soil erosion is a significant concern in Karnataka, particularly in hilly regions and areas with intensive agricultural practices. Improper land management, deforestation, and monsoon rainfall contribute to soil erosion
- **Salinity and alkalinity**: Some areas in northern Karnataka face salinity and alkalinity issues, affecting soil fertility and crop productivity. Irrigation without proper drainage management can exacerbate these problems
- **Nutrient depletion**: Continuous cultivation without adequate soil fertility management leads to nutrient depletion, especially in red and laterite soils. Imbalanced fertilizer use and poor organic matter addition contribute to this issue
- **Waterlogging**: In certain regions, poor drainage systems result in waterlogging, which reduces soil aeration and leads to root suffocation, affecting crop growth and productivity

Improving soil health is essential for sustainable agriculture and ecosystem resilience. Agronomic measures focus on practices that enhance soil fertility, structure, biological activity, and overall health. Here are some key agronomic measures to improve soil health:

6. **Crop management:** Crop management practices directly influence groundwater recharging by preserving soil health, enhancing water infiltration, optimizing water use efficiency, managing nutrients effectively, accumulating organic matter, and promoting diversification. By adopting sustainable crop management strategies, farmers can play a significant role in safeguarding groundwater resources for future generations while maintaining agricultural productivity and resilience.

**Crop rotation and intercropping** Crop rotation and intercropping are some of the best agricultural crop management practices that have long been used in organic farming and now in conventional farming. Crop rotation is an agricultural practice of growing different or dissimilar crops on the same farmland in different seasons. On the other hand, intercropping is a multiple cropping system whereby two or more crop species are planted simultaneously on the same farmland in one planting season. These agricultural crop planting practices assist in varying the set of soil nutrients, thereby reducing the likelihood of soil erosion. They also contribute positively to the stability of the soil structure, reducing the outbreak of pests, weeds and other diseases on the farmland. Crop rotation and intercropping reduce the reliance on chemical fertilizers, minimize agricultural crop production dangers and heighten crop yield in com parison with monoculture practices.

**Crop diversification:** Crop diversification influences groundwater content through a combination of factors related to soil health, water retention, and hydrological dynamics. By cultivating a variety of crops, farmers can significantly alter the physical and biological characteristics of the soil, leading to enhanced water infiltration and reduced runoff. Diverse root systems from different crops can improve soil structure by creating a network of channels that facilitate the movement of water deeper into the soil profile. This process, known as percolation, is critical for recharging groundwater aquifers. For instance, deep-rooted crops can penetrate compacted soil layers, breaking them up and allowing water to seep into lower soil horizons where groundwater reserves are stored.

Additionally, crop diversification contributes to the organic matter content of the soil, which plays a crucial role in water retention. Crops such as legumes can fix nitrogen and add organic material to the soil, improving its capacity to retain moisture. Enhanced soil organic matter increases the soil's porosity and its ability to hold water, thereby reducing the amount of water lost to surface runoff and evaporation. This retained water gradually infiltrates the soil, reaching the groundwater system over time. Furthermore, cover crops and mulching practices associated with diversified cropping systems can reduce soil erosion and surface runoff, further promoting groundwater recharge.

Another significant impact of crop diversification on groundwater content is through the modulation of evapotranspiration rates. Different crops have varying water needs and transpiration rates, and a diversified cropping system can optimize water use efficiency.

For example, crops with lower water demands can be interspersed with those requiring more water, ensuring that water use is balanced and more efficient overall. This balanced water use means less groundwater extraction for irrigation purposes, allowing more natural recharge processes to occur. Moreover, diversified cropping can lead to more resilient agricultural systems that are better equipped to handle droughts and extreme weather events, thereby reducing the pressure on groundwater resources during such periods.

**Redesigning of cropping system**: The water requirement and productivity largely varies with the crops and cropping system. Cropping system to be redesigned based on water availability, climate and soil.

**Crop selection:** Selecting appropriate crops for rainfed conditions is crucial for ensuring successful agricultural production without the reliance on irrigation. Rainfed agriculture depends solely on rainfall for water, making it essential to choose crops that are well-suited to local climatic conditions, soil types, and the variability of rainfall. Here are some important considerations and crop options for rainfed conditions:

**Considerations for crop selection:**

1. **Rainfall patterns:** Understand the local rainfall patterns, including the total annual rainfall, its distribution throughout the year, and the likelihood of drought periods
2. **Soil characteristics:** Assess the soil type, fertility, drainage capacity, and water-holding capacity. Some crops are better suited to certain soil conditions
3. **Growing season length:** Determine the length of the growing season, which is the period between the last frost of spring and the first frost of fall. This affects which crops can reach maturity
4. **Temperature extremes:** Consider the range of temperatures during the growing season, as some crops are more tolerant of heat or cold
5. **Crop resilience and drought tolerance:** Choose crops that are known for their drought tolerance and ability to thrive with minimal water
6. **Market demand and economic viability:** Ensure that the selected crops have a market demand and can provide economic returns

**Crop Options for Rainfed Conditions**

***Cereals and Grains***

1. Sorghum
    - Highly drought-tolerant and well-suited for semi-arid regions
    - Can be used for food, fodder, and biofuel
2. Millets (Pearl Millet, Finger Millet)
    - Adapted to dry and low-fertility soils
    - Nutritionally rich and used for human consumption and animal feed
3. Maize (Corn)
    - Suitable for regions with moderate rainfall
    - Varieties available that are bred for drought tolerance
4. Barley
    - Can tolerate lower rainfall and poor soil conditions
    - Often used for animal feed and brewing

***Legumes and Pulses***

1. Chickpeas (Garbanzo Beans)
    - Deep-rooted and can access moisture from deeper soil layers
    - Nitrogen-fixing properties improve soil fertility

2. Pigeon Peas
    - Drought-resistant and can be grown on marginal soils
    - Provides protein-rich food and improves soil fertility through nitrogen fixation
3. Cowpeas
    - Thrives in hot, dry climates and improves soil through nitrogen fixation
    - Used for human consumption and as fodder
4. Lentils
    - Tolerant to dry conditions and improves soil fertility
    - High in protein and marketable

***Oilseeds***

1. Groundnuts (Peanuts)
    - Suitable for sandy soils and moderate rainfall
    - Dual purpose: edible seeds and oil production
2. Sesame
    - Highly drought-tolerant and can be grown on marginal soils
    - Valuable for its seeds and oil

***Tubers and Root Crops***

1. Cassava
    - Extremely drought-tolerant and can grow in poor soils.
    - Important source of carbohydrates in tropical and subtropical regions

2. Sweet Potatoes
    - Tolerates poor soils and varying rainfall.
    - Nutritious and versatile in the kitchen.

***Forage Crops***

1. Alfalfa
    - Deep-rooted and drought-resistant.
    - High-protein forage for livestock.
2. Buffel Grass
    - Well-adapted to arid regions and used for grazing and hay.

**7. Precision farming technologies:** It offer a suite of innovative tools and practices designed to optimize agricultural inputs and improve the efficiency of water use, thereby enhancing groundwater content. These technologies leverage data, advanced machinery, and sensor systems to make precise and informed decisions about crop management, which can significantly impact groundwater recharge and conservation.

Here are several key precision farming technologies and how they contribute to improving groundwater content:

**a. Soil moisture sensors:** Soil moisture sensors are devices placed in the ground to monitor the moisture content of the soil in real time. These sensors provide accurate data on the amount of water available to crops at various soil depths. By using this information, farmers can precisely manage irrigation schedules, applying water only when and where it is needed. This targeted approach reduces over-irrigation, minimizes water waste, and prevents excessive water extraction from groundwater sources. Consequently, more water remains available for natural infiltration and groundwater recharge

**b. Automated Irrigation Systems:** Automated irrigation systems, such as drip or sprinkler irrigation, can be integrated with soil moisture sensors and weather forecasts to deliver water efficiently. These systems ensure that water is applied uniformly and at optimal times, reducing the likelihood of water runoff and deep percolation losses. Drip irrigation, in particular, delivers water directly to the root zone, enhancing water use efficiency and minimizing evaporation losses. By optimizing irrigation practices, automated systems help maintain soil moisture levels that support groundwater recharge while conserving water resources

c. **Geographic Information Systems (GIS) and Remote Sensing:** GIS and remote sensing technologies use satellite imagery and aerial photography to monitor crop health, soil conditions, and water use over large areas. These technologies can identify variations in soil moisture, crop stress, and areas with potential waterlogging or drought. By analyzing this spatial data, farmers can make informed decisions about water management, targeting specific areas that need attention. This precision reduces unnecessary water application, promotes efficient water use, and supports groundwater recharge by ensuring water is distributed according to actual field conditions

d. **Variable Rate Technology (VRT):** VRT allows for the variable application of inputs such as water, fertilizers, and pesticides based on the specific needs of different field zones. By using detailed field maps and sensor data, VRT systems adjust the application rates in real time. For irrigation, this means water can be applied more precisely, reducing excess use and promoting efficient water distribution. The reduction in over-application helps prevent water runoff and leaching, thus protecting groundwater quality and enhancing recharge

e. **Crop Modeling and Decision Support Systems (DSS):** Crop modeling and DSS use algorithms and simulation models to predict crop water requirements, growth stages, and yield outcomes under varying conditions. These tools integrate data from weather forecasts, soil moisture sensors, and historical crop performance to provide recommendations on optimal irrigation scheduling. By using these models, farmers can anticipate water needs more accurately and apply water strategically, minimizing unnecessary extraction and promoting groundwater sustainability

f. **Drones and Unmanned Aerial Vehicles (UAVs):** Drones equipped with multispectral and thermal cameras can survey fields to assess crop health, soil moisture levels, and irrigation system performance. The high-resolution data collected by drones enable precise monitoring and management of water use. For instance, drones can identify areas of the field that are over-irrigated or suffering from water stress, allowing for targeted adjustments to irrigation practices. This precise monitoring helps conserve water and supports efficient groundwater recharge

g. **Integrated Water Management Systems:** Integrated water management systems combine multiple precision farming technologies to create a holistic approach to water use. These systems coordinate data from soil sensors, weather stations, and irrigation controllers to manage water resources comprehensively. By optimizing water distribution and reducing wastage across the entire farm, integrated systems enhance water use efficiency and promote groundwater recharge

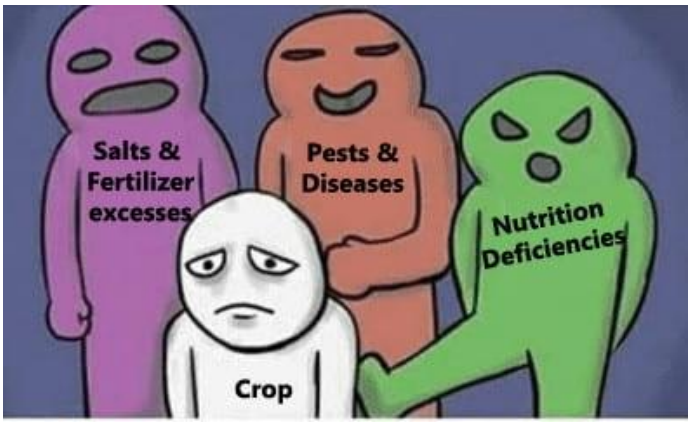
h. **Ground Water:** Though groundwater is considered ubiquitous, it is not uniformly available. Weathered hard rocks account for 97% of the aquifers, the great majority being granite (90%) and the remainder Deccan trap basalts. Alluvial coastal flood plains account for only 2% of aquifers and other formations for just 1%. Tube and bore wells irrigate a net area of 12.5 lakh ha, contributing 37% to the state's net irrigated area. The replenishable groundwater is 15.9 billion $m^3$ and annual groundwater availability 15.3 billion $m^3$. The groundwater draft stands at 10.7 billion $m^3$ out of which 91% is for irrigation alone. The increasing dependence on groundwater has already led to a 70% of groundwater development against 58% in the country

i. **Minimization of groundwater exploitation:** Efforts must be made to minimize groundwater usage across agricultural, domestic, and industrial sectors through the adoption of efficient practices. This can be achieved by raising awareness, implementing regulated water supply, and imposing charges for usage exceeding specified standards. Furthermore, rural areas should focus on adopting practices such as conjunctive use of treated water and rainwater harvesting, alongside enforcing strict regulations on water usage by industries. Industries in rural regions must prioritize water-efficient practices and invest in rainwater harvesting, groundwater recharge, and wastewater treatment for reuse. It is imperative to rigorously enforce regulations governing water use by industries. To accurately monitor groundwater extraction, all borewells must be equipped with digital water meters, with data collected in real-time. Effective groundwater management strategies are essential in situations where demand surpasses availability or contamination threatens quality. Given the extensive use of groundwater for irrigation in the study area, the uneven distribution of resources exacerbates demand. Thus, there is an urgent need to develop sustainable and scientifically-driven groundwater management approaches to ensure resource longevity and equitable distribution.

# Chapter-3
# LRI based Nutrient Management

## Major nutrients, their role and deficiency symptoms in crop

Unlike pests and diseases with visible damage, nutrient deficiencies often show subtle signs that can be easily missed. By the time they're readily apparent, the plant's growth and development may already be significantly compromised and nutrient deficiencies are a common problem for all types of crops, regardless of location or climate. Even mild deficiencies can have long-term consequences, reducing plant health, yield potential, and overall crop quality. Plants require a specific set of nutrients for healthy growth and development. Among these, three macronutrients are crucial in large quantities for robust crops: Nitrogen (N), Phosphorus (P), and Potassium (K).




### 1. Nitrogen (N): The Building Block

- **Function:** Nitrogen is a fundamental element in chlorophyll, the pigment responsible for capturing sunlight energy for photosynthesis. It also forms the backbone of amino acids, building blocks of proteins, which are vital for all plant structures and functions.
- **Deficiency Symptoms:** Pale or yellowing of leaves, stunted growth, and reduced yields are common signs of nitrogen deficiency. When young corn leaves turn pale yellow or light green, have thin stalks and are slow to come to flower, it might be a nitrogen deficiency. The older plants exhibit a "V – shaped" yellowing at the tips of leaves and older leaves show symptoms first, with these tips and mid-ribs eventually senescing occurs.

## 2. Phosphorus (P): The Energy Source

- **Function:** Phosphorus plays a critical role in energy transfer within plants. It's a key component of ATP (adenosine triphosphate), the primary energy currency in cells, and is essential for root development, seed formation, and overall plant growth.

- **Deficiency Symptoms:** Stunted growth, delayed maturity, poor flowering or fruiting, and weak root systems can indicate insufficient phosphorus. Initially, plants with P nutrition deficiency appear darker green with reduced growth affecting the leaf size and stem thickness. As phosphorus nutrition deficiency continues, the older, lower leaves develop irregular spots of brown to dark brown dead tissue. In some plants, reddish to purple pigmentation may appear on the under or upper surface of leaf margins, lower leaves, and stems. Eventually, death of older leaves may occur. In most cases, lack of phosphorus delays flowering in plants.

## 3. Potassium (K): The Regulator

- **Function:** Potassium acts as a vital regulator within plant cells. It governs the movement of water and nutrients across cell membranes, impacting various physiological processes. Additionally, potassium activates enzymes involved in metabolism and disease resistance.

- **Deficiency Symptoms:** Weak stems, wilting during droughts, and poor fruit quality are potential signs of potassium deficiency. Light green or streaked with yellow leaves can indicate a potassium deficiency. This yellowing or "scorching" of the leaf margins, more common on the lower leaves, turns to necrosis, and in older plants, leaf tips and margins turn brown.

Ensuring a balanced supply of these essential macronutrients (N, P, K) is paramount for optimal crop performance. By understanding their specific roles, farmers can implement targeted nutrient management strategies to promote healthy plant development and maximize yields.

## Secondary and micronutrients and their role in crop growth

While nitrogen, phosphorus, and potassium are essential for plant growth, they're not the only players on the field. Secondary and micronutrients, although needed in smaller quantities, are crucial for optimal crop health and yield.

### Secondary Nutrients: The Supporting Cast

Plants need more than just the "big three" nutrients (nitrogen, phosphorus, and potassium) to thrive. Secondary nutrients – calcium (Ca), magnesium (Mg), and sulfur (S) are like the helpful assistants, playing a vital role in keeping your crops strong and productive and play vital supporting roles in plant development.

4. **Calcium (Ca): Strong Bones for Plants**

- **Function:** Calcium strengthens cell walls, aids in root development, and improves nutrient uptake. It is a component necessary for plant cell division. It neutralizes the effects of various toxins such as organic acids also help in the protein production of plants. It stimulates the transport of starch and sugar in plants.
- **Deficiency Symptoms:** Calcium is an immobile element. Therefore, the deficiency often begins at the soft part or near the young shoots. The shoots and flowers of the plant wither and curl. Young leaves will roll the edges of the leaves together but the tip of the leaves is curled to the back of the leaves. Sometimes brown spots may appear on the leaves. The top of the plant will die and when new shoots are formed, they will die again. Therefore, the plant looks bushier than normal plants. Blossom end rot in tomatoes and peppers (deformed, sunken fruit bottoms), weak stems that bend or break easily are most common crop specific symptoms.

## 5. Magnesium (Mg): The Heart of Chlorophyll

- **Function:** Magnesium is a central element in chlorophyll, the green pigment in leaves responsible for capturing sunlight energy for photosynthesis. It also activates numerous enzymes involved in various plant functions, including respiration, protein synthesis, and nutrient uptake.
- **Deficiency Symptoms:** Yellowing between leaf veins (interveinal chlorosis) is a telltale sign of magnesium deficiency. Leaves begin to yellow between their veins (like a net) while the veins themselves remain green. This happens because magnesium is mobile within the plant, and it gets transported from older leaves to support newer growth during a deficiency with a marbled appearance. Magnesium deficiency can lead to stunted plant growth due to reduced photosynthesis and impaired metabolic processes. In some cases, magnesium deficiency can cause leaves to develop a mottled appearance, with yellow patches interspersed with green areas.

## 6. Sulphur (S): Building Blocks and Defense

- **Function:** Sulphur is a key component of amino acids, the building blocks of proteins essential for all plant structures and functions. It's also involved in the formation of coenzymes, which help enzymes to function properly. Additionally, sulphur plays a role in plant Défense mechanisms against diseases and pests.

- **Deficiency Symptoms:** Unlike nitrogen deficiency, where the lower leaves yellow first, sulphur deficiency typically causes younger leaves to turn a pale yellow. Similar to other deficiencies, stunted growth is a common symptom as sulphur deficiency limits protein synthesis and overall plant development. It plays a role in seed formation, and its deficiency can lead to reduced seed production and potentially lower yields.

**Micronutrients: Tiny But Mighty**

Plants are like intricate machines, each part requiring specific components to function optimally. While macronutrients are the building blocks, micronutrients, despite their minute quantities, are the essential vitamins and minerals that keep these machines running smoothly. Micronutrients, including iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), boron (B), molybdenum (Mo), and chlorine (Cl), are required in minute amounts but have significant impacts.

## 7. Iron (Fe): The Oxygen Carrier

- **Function:** Iron is essential for chlorophyll production and plays a critical role in respiration (cellular energy production), the process by which they convert oxygen and sugars into usable energy. Think of iron as the hemoglobin of plants. It's a vital component of enzymes involved in chlorophyll production, allowing plants to capture sunlight energy for photosynthesis.

- **Deficiency Symptoms:** Yellowing of young leaves (interveinal chlorosis) with green veins remaining, stunted growth are most common symptoms. This occurs because iron is immobile plant, and limited supplies are transported to new growth.

## 8. Zinc (Zn): A Guardian for Growth

- **Function:** Zinc is a true multi-tasker. It's essential for seed formation, promoting healthy cell division and embryo development. It also plays a role in stem growth, maintaining structural integrity, and helps plants utilize other nutrients effectively. Additionally, zinc strengthens the plant's defense system, making it more resistant to diseases.

- **Deficiency Symptoms:** Zinc deficiency can manifest in various ways, including stunted growth, rosettes (bunched leaves) at the top of the plant, and small, chlorotic (yellowing) leaves in newer growth.

  **The following diseases are commonly notice:**

  i. **Khaira of paddy:** The entire older leaves show rusty brown appearance (due to chlorosis) and ultimately die.
  ii. **White bud (tip) of maize:** Unfolded newer leaves are often pale yellow to white. There will be appearance of light-yellow streaks between the veins of older leaves followed by white necrotic spots.
  iii. **Rosette of fruit trees:** It is also called as little leaf disease. Yellow mottling of leaves, reduction of leaf size with rosette appearance (due to reduced internodal distance) and die back of the affected branches are symptoms of the disease.
  iv. **Frenching of citrus:** Initially, yellow spots develop between the veins. Leaves become evenly smaller and develop chlorophyll at the basal end of mid rib.

## 9. Copper (Cu): A Catalyst

- **Function:** Copper acts as a catalyst in numerous plant functions, including respiration, seed production, and maintaining healthy stems and leaves. It also plays a role in lignin synthesis, a component that strengthens cell walls and provides structural support.

- **Deficiency Symptoms:** While less common, copper deficiency can cause wilting, bleaching of young leaves, and dieback of shoot tips. It causes necrosis of the tip of the young leaves, both vegetative and reproductive growth is retarded, wilting of terminal shoots occur which is followed by frequent death, leaf color is often faded due to reduction of carotene and other pigments, foliage shows burning of margins or chlorosis or rosetting and multiple bud formation, gumming may also occur (gummosis), younger leaves wither and show marginal chlorosis (yellowish grey) of tips which is called as Yellow tip or reclamation disease.

  **Following two diseases are common:**

  i. **Exanthema or die back of fruit tree:** It is commonly found in citrus, plum, apple and pear. The symptoms include formation of strong water-shoots bearing large leaves, gummous tissue or the bark and longitudinal breaks. Fruits become brown, glossy and splitted. Affected shoots lose their leaves and die back and lateral shoots produce bunchy appearance.

  ii. **Reclamation disease:** It is also called as White Tip disease and is found in legumes, cereals, oats and beet. The tips of leaves become chlorotic followed by a failure of the plants to set seed.


## 10. Manganese (Mn): The Photosynthesis Powerhouse

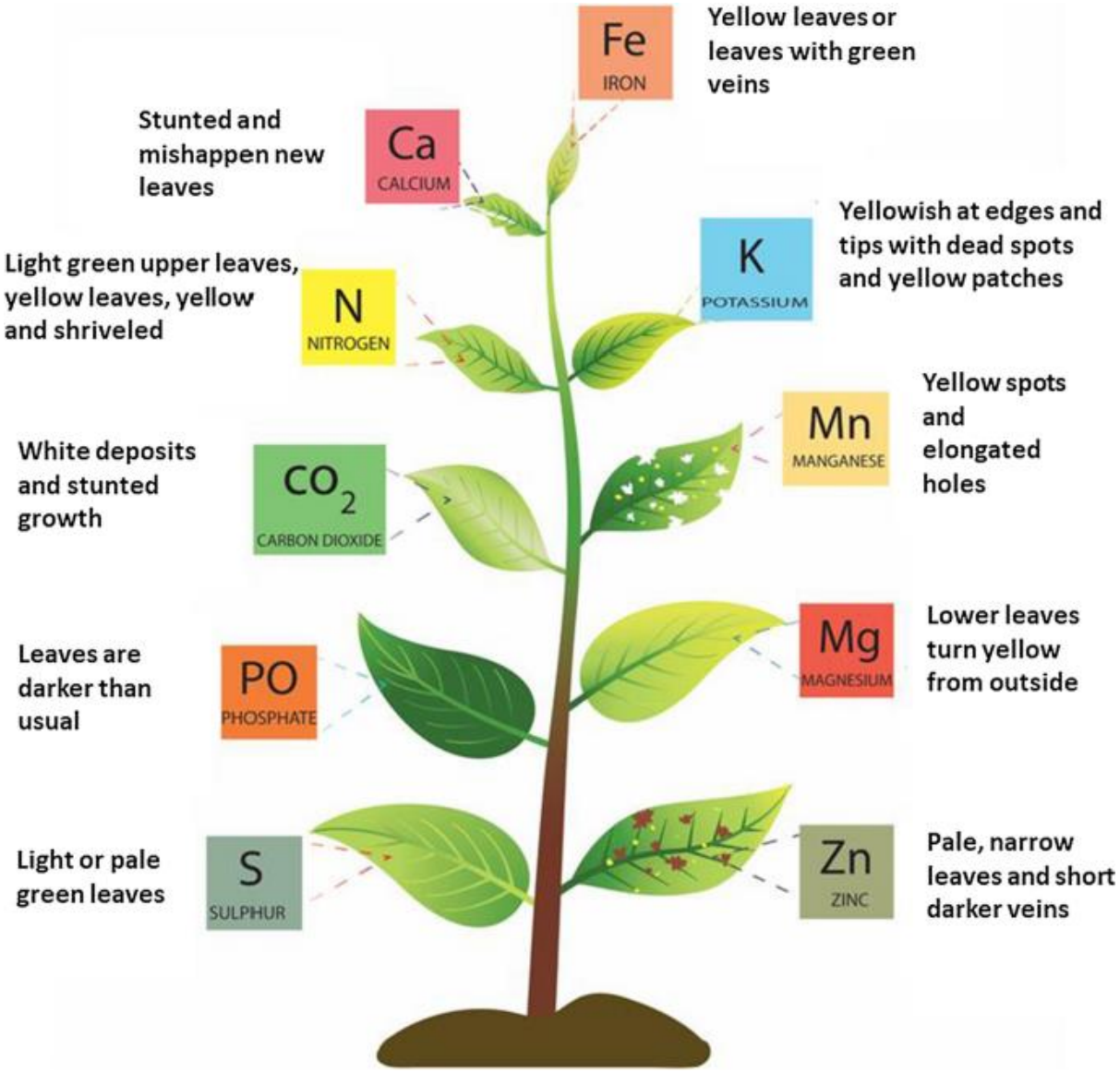
- **Function:** Manganese is a key player in the efficient functioning of photosynthesis. It activates enzymes involved in splitting water molecules, a crucial step in the process. Additionally, manganese contributes to nitrogen utilization and disease resistance.

- **Deficiency Symptoms:** Early signs of manganese deficiency include yellowing or mottling of younger leaves, with brown spots potentially developing later. Stunted growth and delayed maturity are also common symptoms. Grey Speck also called as grey stripe, grey spot or dry spot in oats, pahla blight of sugarcane, marsh spot of pea and speckled yellow of sugar beet are most common crop specific symptoms.

## 11. Boron (B): The Architect of Structure and Reproduction

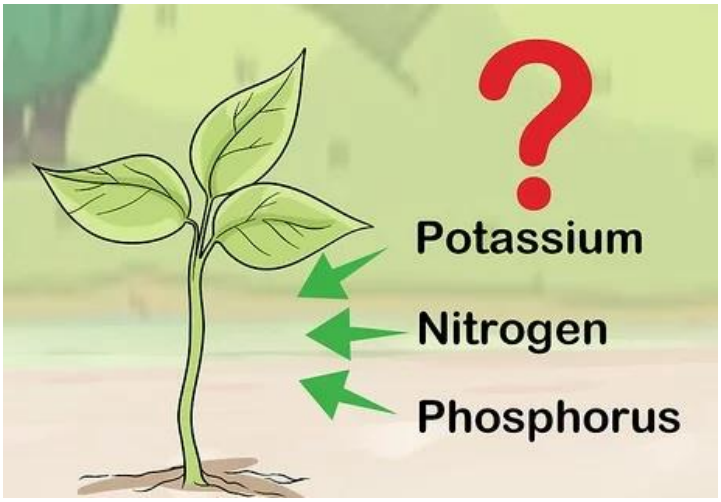
- **Function:** Boron is like a skilled architect for plants. It plays a vital role in cell wall development, influencing the structure and integrity of plant tissues. Boron is also crucial for seed formation and proper flower and fruit development.

- **Deficiency Symptoms:** Boron deficiency can manifest in various ways depending on the crop. Common signs include cracking or disfiguration of fruits and vegetables, weak stems, and yellowing or death of growing points. Diseases like heart rot of sugar beet and marigold, canker and internal black spot of garden pea, browning of cauliflower, top sickness of tobacco, hard fruit of citrus are most common crop specific symptoms.


Fe
IRON
Yellow leaves or leaves with green veins
Stunted and mishappen new leaves
Ca
CALCIUM
Yellowish at edges and tips with dead spots and yellow patches
K
POTASSIUM
Light green upper leaves, yellow leaves, yellow and shriveled
N
NITROGEN
Yellow spots and elongated holes
Mn
MANGANESE
White deposits and stunted growth
CO2
CARBON DIOXIDE
Lower leaves turn yellow from outside
Mg
MAGNESIUM
Leaves are darker than usual
PO
PHOSPHATE
Pale, narrow leaves and short darker veins
Zn
ZINC
Light or pale green leaves
S
SULPHUR

## Major nutrients recommendation for major crops

Determining the appropriate fertilizer and its quantity for plants is crucial in agriculture. Agricultural experts typically recommend specific fertilizers and quantities for different crops based on various factors such as crop nutrient requirements, developmental stages of the plants, soil fertility, rainfall patterns, irrigation, and other fundamental principles of agriculture. This helps avoid over-fertilization, which can lead to production imbalances and plant losses. Thus, it is essential to consider both the nutritional needs of the plants and the soil conditions to make informed decisions in agricultural practices. Major nutrient recommendations for major crops are not a one-size-fits-all solution. By understanding the science behind these recommendations, farmers can make informed decisions about nutrient management practices, maximizing crop yields while maintaining soil health and environmental sustainability.

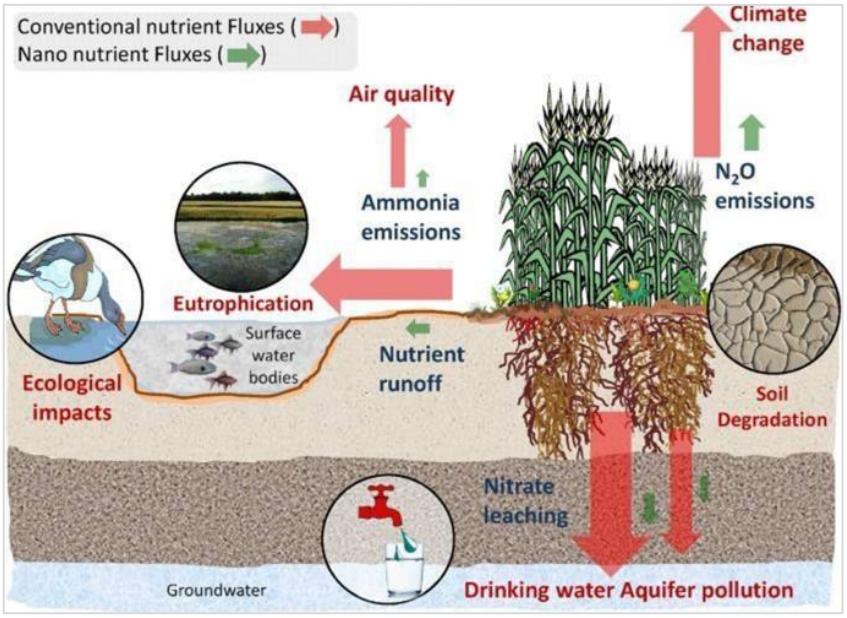



| ***Crop*** | ***Nitrogen (N)*** | ***Phosphorus (P)*** | ***Potash (K)*** |
|---|---|---|---|
| | ***(kg/acre)*** | | |
| Finger Millet | (20) 40 | (16) 20 | (15) 20 |
| Maize | (40) 60 | (20) 30 | (10) 15 |
| Pigeon Pea | (10) | (20) | (10) |
| Groundnut | (10) | (20) 30 | (10) 15 |
| Sunflower | (15) 36 | (20) 36 | (15) 25 |
| Tomato | 100 | 100 | 100 |
| Chilli | (40) 60 | (20) 30 | (20) 30 |
| Cotton | (32) 60 | (16) 30 | (16) 30 |
| Ginger | 40 | 20 | 20 |
| Turmeric | 60 | 50 | 100 |

*Note: The number in parentheses () is the nutrient recommended for crops under rainfed condition for Karnataka. The dosages need to be changed as recommended to Odisha State*

# Ill effects of Indiscriminate use of Inorganic fertilizers

Fertilizers play a vital role in enriching soils and boosting crop but indiscriminate overapplication of chemical fertilizers comes with many environmental and health consequences that compound over time. Indiscriminate use of synthetic fertilizers can result in soil contamination by heavy metals, reduction in the nutritional value of crops, reduction in soil fertility etc.




**Impact of excessive use of fertilizers:**

**Soil health - Improper use of fertilizers can lead to negative consequences. Disrupt the natural balance of nutrients in the soil, leading to nutrient imbalances and reduced soil quality. This can result in the loss of soil organic matter, decreased soil fertility and increased susceptibility to erosion**

**Heavy metal contamination -** Fertilizers contaminate the soil with impurities, which come from the raw materials used for their manufacture. Mixed fertilizers often contain ammonium nitrate ($NH_4NO_3$), phosphorus as $P_2O_5$, and potassium as $K_2O$. The Arsenic, Lead and Cadmium present in traces in rock phosphate mineral get transferred to super phosphate fertilizer. Since the metals are not degradable, their accumulation in the soil above their toxic levels due to excessive use of phosphate fertilizers becomes an indestructible poison for crops

**Nutritional value of the crops-** Over use of NPK fertilizers reduces the quantity of vegetables and crops grown on soil over the years. It also reduces the protein content of wheat, maize, grams, etc., grown on that soil. The carbohydrate quality of such crops also gets degraded. Excess potassium content in soil decreases Vitamin C and carotene content in vegetables and fruits. The vegetables and fruits grown on overfertilized soil are more prone to attacks by insects and disease

**Increasing soil acidity**- Overusing chemical fertilizers can acidify soils over time and cause essential nutrients like potassium, calcium, and magnesium to leach away. With unbalanced nutrition, soils lose their fertile structure and ability to support diverse microbial ecosystems essential for plant growth. Crop yields then decline unless even more fertilizers are applied

**Groundwater contamination -** When chemical fertilizers are applied to farmlands, excess nutrients not taken up by plants may leach into the soil, eventually reaching groundwater reserves. Additionally, rainfall or irrigation can lead to runoff, carrying these nutrients into nearby rivers, lakes, and oceans. This excessive nutrient influx disrupts the natural balance of aquatic ecosystems, leading to harmful algal blooms and oxygen-depleted dead zones

**Health risks though water contamination -** The contamination of drinking water supplies by chemical fertilizers poses threats to human and animal health. Nitrate leakage, for example has been linked to *blue baby syndrome* that decreases oxygen transport in infants' blood. Nitrogen in drinking water may also increase risks for thyroid problems, cancer, birth defects and miscarriages

**Disruption of Aquatic Life -** The influx of nutrients from chemical fertilizers fosters rapid growth of algae in water bodies. While this may seem beneficial at first, the subsequent decay of these algae consumes oxygen, leading to hypoxic conditions harmful to fish and other aquatic organisms. This disruption can cause population declines, affecting entire aquatic food chains

**Salt burns -** These burns indicate excessive use of chemical fertilizers. Fertilizers with a high saline index and chemicals like sodium nitrate are the ones that get the most attention or follow-up to avoid salt burns

**Atmosphere** - Improper use of fertilizers also have implications for the atmosphere, primarily through the release of nitrogen-based gases. Inorganic fertilizers, particularly those containing ammonium or urea, can contribute to the emission of nitrous oxide ($N_2O$), a potent greenhouse gas that contributes to climate change. Additionally, excessive nitrogen application can lead to ammonia ($NH_3$) volatilization resulting in air pollution and respiratory health issues

**Excessive growth -** Because of the excessive and uncontrolled application of chemical fertilizers, the proportions and growth of the plants may exceed typical criteria. When this point is reached, the harvest and survival of the plants are jeopardized, rather than improving productivity

# Adjustment of recommended dose of fertilizer based on soil nutrient status


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

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

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

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

### If the soil nutrient status is Very Low

**Fertilizers in kg per acre**

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

### If the soil nutrient status is Medium

**Fertilizers in kg per acre**

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

### If the soil nutrient status is Very High

**Fertilizers in kg per acre**

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

# Land Resource Inventory (LRI) Card interpretation

## What is LRI card?

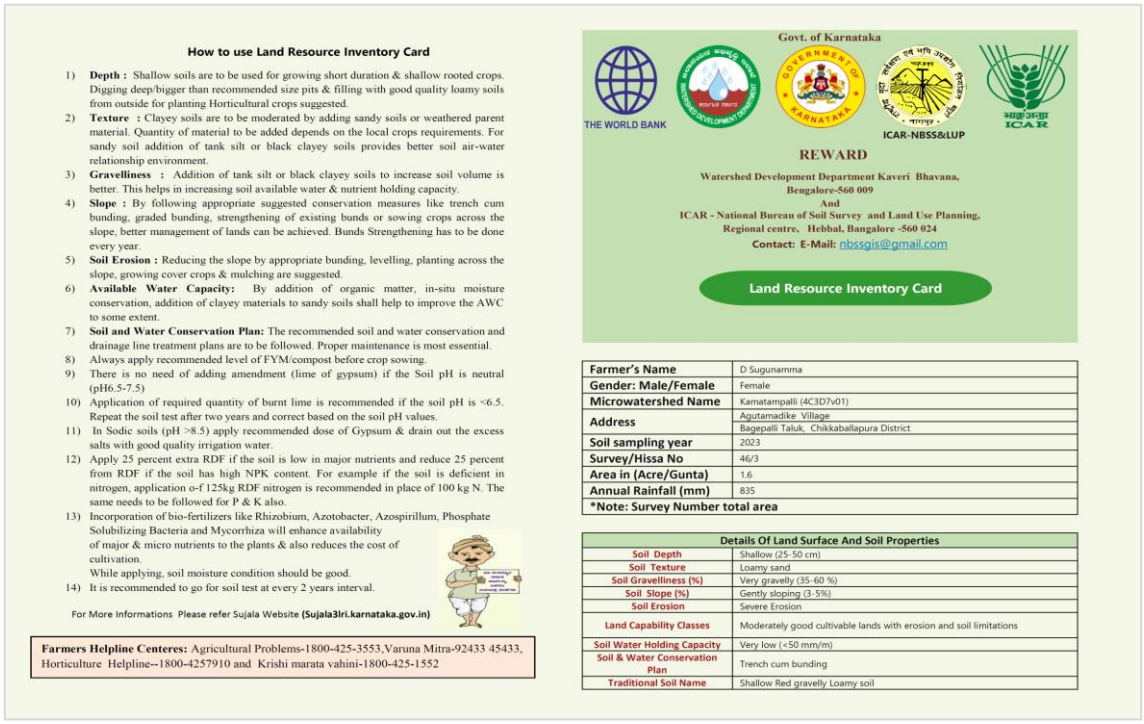
Land resource inventory card is a printed document given to a farmer for each of his land holdings. It provides information about the soil's health condition based on soil physical and chemical properties. It helps farmers assess the quality of their farm soil and improve its productivity in the long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

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

## Land resource inventory card contains the following information:

1. Farmers general information
    - Name
    - Gender
    - Micro watershed name
    - Adress
    - Soil sampling year
    - Survey/ Hissa No.
    - Area in (Acre/ gunta)
    - Annual rainfall (mm)
2. Details of land surface and soil properties
    - Soil depth
    - Soil texture
    - Soil gravelliness (%)
    - Soil slope (%)
    - Soil erosion
    - Land capability classes
    - Soil water holding capacity
    - Soil and water conservation plan
    - Traditional soil name
3. Soil test results: pH, Electrical conductivity, Organic carbon, Available nitrogen, Available Phosphorus, Available potassium, Sulphur, iron, manganese, zinc, copper and boron
4. Secondary and micronutrients recommendations for deficient soils
5. Soil nutrient classification for very low, low, medium, high and very high soils

6. Suggested crop plan (Highly suitable, moderately suitable, marginally suitable and not suitable) based on land resource information



### How to use Land Resource Inventory Card

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

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

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

Govt. of Karnataka

THE WORLD BANK

ICAR-NBSS&LUP

**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<br>Bagepalli Taluk, Chikkaballapura District |
| **Soil sampling year** | 2023 |
| **Survey/Hissa No** | 46/3 |
| **Area in (Acre/Gunta)** | 1.6 |
| **Annual Rainfall (mm)** | 835 |
| ***Note: Survey Number total area** | |

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

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

**Soil Test Results**

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

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

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

**Secondary and Micronutrients Recommendation for Deficient Soil**

| Sl.no | Parameter | Fertilizer |
|---|---|---|
| 1 | Sulphur (S) | Gypsum |
| 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

# Chapter-4
# Micro-enterprises and Livelihood Improvement

## Planning and developing community micro-enterprise

Micro-enterprises provide off-farm employment and income in rural areas and benefit poor families, women, and disadvantaged groups. Although they require minimal capital, the requirements to start a micro-enterprise are nevertheless too high for the poor to afford. Therefore, micro-enterprise development requires thoughtful, careful planning

### Stages in planning a community micro-enterprise

1. **Identify micro-enterprise activities or projects, set goals, and identify target groups**
    - Set the goals of the micro-enterprise and a programme for its development
    - Identify where the operation will be located
    - Define and decide the target groups
    - Identify potential partners and other local organizations
    - Organize and mobilize identified target groups into interest groups
    - Agree on the process of developing the enterprise with the identified partners; set partner roles and responsibilities

    For facilitators such as professional staff of non-government organizations, government agencies, business association members, extension workers, and others, it is important to understand the goals that the target groups have set for developing a micro-enterprise. Integrate these goals into the planning and development process

2. **Select products and services and assess the markets**

    Selecting products and services
    - *Identify products and/or services:* Consult community members through focus group discussions, key informant interviews and other methods, and refer to useful reference materials such as books, websites, others in preparing the products/services list
    - *Shortlist products and services:* Narrow down the list to realistically possible products and services based on social, economic, and environmental considerations. Social considerations include community interest, gender, social equity, access, tenure, policy, and institutional support requirements. Economic considerations include technology and the requirements of the market. Environmental considerations include impacts on the environment of sustainable harvest limits, ecology standards, pollution, hazards and risks of producing the products, among others
    - *Make a final list:* Select the final products or services to develop together with the target groups. A sub-sector ranking table can be used to make a final list of around 2-3 micro-enterprise products and services

Studying their markets

Carry out market studies to:

- Identify market demand for the selected product/s and/or services including market prices and volume demand
- Identify market requirements in order to sell the products (standards; certification, laws, regulations, procedures),
- Study the competition (competitors and competing products), and
- compare costs with similar products already in the market

Carry out further market research to:

- Obtain the necessary information for making decisions on marketing
- Identify specific buyer requirements and demand trends
- See actual market opportunities for the products and services

**3. Map and analyse the product/s' value chain**

A value chain describes the many different activities required to bring a product or service through the different stages of production, transformation, and delivery to the final consumers

Value chain mapping, draws a basic map of activities and actors or operators involved in producing and transforming the products and bringing them to the final consumers. A detailed value chain map allows us to explore key issues, constraints, and opportunities and identify where the target groups are in the chain. (Participatory market chain analysis [PMCA] is an approach used by Practical Action, which is defined as a method of engaging market chain actors in sharing knowledge and building trust in order to generate joint innovations).

Participatory value chain mapping and analysis is done to draw an outline of the value chain and is prepared by facilitators together with the target group/s and specific actors or operators in the chain. It helps in calculating the financial returns to operators of the chain (especially the target group), identifying important operators and ways in which returns are distributed among different operations. The value added at each stage is calculated

**4. Design an upgrading strategy**

Developing a strategy or action plan to achieve the common goal/s set by the target groups is important in putting the micro-enterprise plan into operation. Develop a vision and strategy for upgrading, together with target group and stakeholders. Tap the opportunities or address the constraints in the value chain

The following steps may be taken to design the enterprise's value chain strategy.

1. Develop a goal and strategy for improving the status of target groups and to facilitate their participation in the value chain
2. List the different strategies.

- Shortlist a few (2-3) effective strategies to address problems in the value chain and meet the goals
- For each of the strategies review the factors for economic, social and environmental aspects to analyze the strengths and weaknesses of each strategy. This can be used as the baseline information for future evaluation
- Select the best strategy for implementation

3. Identify important areas of influence that can stimulate change. For example, simplifying processes and regulations for accessing credit in the rural areas creates interest among target groups to participate in the development of micro-enterprise
4. Assess Business Development Services (BDS). These are any non-financial services provided to businessmen either on a formal or informal basis. They relate to research, production, processing, marketing, quality control, accounting, management, training, and other activities required by micro-enterprises at different stages. Business chambers, the private sector, specialised institutions in local areas can provide business development services to starting micro-enterprises
5. Source credit. At present, financial services are available for entrepreneurs from micro- credit institutions. Self-help groups may also be formed to generate savings and provide loans among members

**5. Make an enterprise development plan**

Develop a business plan for the enterprise. A step-by-step process showing the elements to include in the business plan is shown below:

- *Background and overall goals of the enterprise* - Examine the current situation, the rationale for the micro-enterprise, how it will change or improve the situation
- *Production* - Describe the product/s to be produced or service to be provided, the supply and collection of raw materials needed, sustainable raw material production, quality control (for example, organic cultivation), harvesting, storage, product production process (primary and secondary processing), production capacity; in the case of crops, description of the site for the potential enterprise, communication facilities, infrastructure, others
- *Technology* - Identify tools, equipment, machinery, packaging, infrastructure, energy, supplies needed, other technologies required
- *Marketing and sales* - Incorporate the results of market research in the plan and how to appeal to the identified market, the market mix; develop a market strategy including how to develop customer relationship, get feedback, purchase and supply terms and conditions, promotion schemes, sales target, a sales plan, other marketing and sales details
- *Management* - The plan should include the legal status of the micro-enterprise, its interface with regulatory bodies, skills, experiences and competencies of the community or staff in relation to the enterprise, management structure and

team, decision making, operations, compensation, monitoring and supervision, relationship with stakeholders, interface with the community, distribution of benefits, and other management considerations

- *Finance* - Start-up costs and capital needs, gross profit, net cash income and net profit, proposed financing plan with a loan repayment schedule, payback period, breakeven point, return on investment, profit and loss statements, cash flow projection, are some key elements
- *Risk analysis* - Anticipate and analyse the major risks to the enterprise specific to the industry and its geographic location
- *Regulatory environment* - This includes general policies, business laws and regulations, legal acceptance, export/import requirements, access to resources, tenure, others

**6. Begin the pilot phase and build competency**

- Mobilise financial resources to start the enterprise
- Build the capacities of entrepreneurs and stakeholders by organising training programmes and exposure trips
- Provide and seek support in establishing the enterprise
- Form an entrepreneurs' association, federation or similar body and facilitate the process of drafting the by-laws and registering the enterprise through related government departments
- Facilitate linkages with government agencies, input suppliers, chambers of commerce, markets, research agencies, banks, transporters, I/NGOs, other sectors
- Document the results, problems faced, and share impacts and achievements with various stakeholders

**7. Evaluation, adjustment, or exit**

- Evaluate the enterprise's result in terms of economic, social, and environmental aspects
- Based on the evaluation, identify the constraints with the aim of overcoming them or further developing the sectors over the long run
- Formulate a new/adjusted strategy and start a new cycle. or
- Where chances of success appear bleak, end the project and exit. Try to identify other areas or potential micro-enterprises through which the goals of the facilitating institution and target groups can be fulfilled

## Factors of sustainable livelihood systems


The sustainable livelihoods framework presents the main factors affecting people's livelihoods, and typical relationships between these. The framework can be used in both planning new development activities and assessing the contribution to livelihood sustainability made by existing activities. The inter relationships of factors affecting sustainable livelihoods are discussed below:

1. **Assets** are what people use to gain a living. They are the core aspects of a livelihood. Assets can be classified into five types - human, social, natural, physical and financial
    a. Human capital is the part of human resources that is determined by people's qualities, e.g. personalities, attitudes, aptitudes, skills, knowledge, also their physical, mental and spiritual health. Human capital is the most important, not only for its intrinsic value, but because other capital assets cannot be used without it.
    b. Social capital is that part of human resources determined by the relationships people have with others. These relationships may be between family members, friends, workers, communities and organizations. They can be defined by their purpose and qualities such as trust, closeness, strength, flexibility. Social capital is important because of its intrinsic value.
    c. Natural capital is made up of the natural resources used by people such as air, land, soil, minerals, water, plant and animal life. They provide goods and services, either without people's influence, (forest wildlife, soil stabilization) or with their active intervention (farm crops, tree plantations). Natural capital can be measured in terms of quantity and quality (acreage, head of cattle, diversity and fertility).
    d. Physical capital is derived from the resources created by people. These include buildings, roads, transport, drinking-water, electricity, communication systems and equipment and machinery that produce more capital. Physical capital is made up of producer goods and services and consumer goods that are available for people to use.

e. Financial capital is a specific and important part of created resources. It comprises the finance available to people in the form of wages, savings, supplies of credit, remittances or pensions. It is often, by definition, poor people's most limiting asset.

**2. The Vulnerability Context**

The extent, to which people's assets can be built up and how they contribute towards their livelihoods, depends on a range of external factors that change people's abilities to gain a living. Some of these factors will be beyond their control and may exert a negative influence. This aspect of livelihoods can be called the vulnerability context.

a. Trends: These are gradual and are relatively predictable. Changes may relate to population, resources, economy, governance or technology. They can have a positive effect, although negative effects are described below. The examples are:
   - Gradual degradation of natural resource quality. The processes of desertification can lead to the loss of valuable plant and animal species.
   - Excessive population increase because of migration, which can lead to increased pressure on local resources resulting in unsustainable use and depletion.
   - Inappropriate developments in technology may displace local crop or livestock species or varieties.
   - Undesired changes in political representation might lead to political systems that exploit local natural resources.
   - General economic stagnation may lead to increased poverty, and result in the unsustainable management of local resources.

b. Shocks - Some external changes can be sudden and unpredictable. They may be related to health, nature, economy, or relations. Generally, they are far more problematic. The examples are:
   - Climatic extremes (drought, flood, earthquake), which could wipe out existing plant or animal resources.
   - Civil disturbance (revolution) could affect social structures. May result in the interruption of knowledge transfers for the management of animal or plant genetic resources.
   - Outbreaks of disease, e.g. Corona/ other pandemics could lead to changes in labour resources for agricultural activities. Certain crops might be abandoned along with the related knowledge of their management.

c. Seasonality: Many changes are determined by the seasonal effects of crop production, access and living conditions. Although short-term, enduring for a season, they can be critical for poor people who have a subsistence livelihood. Examples are changes in:
   - Prices - could make production of certain products, and their related plant resources, too expensive and therefore unattractive. In turn, this may lead to their abandonment.

- Employment opportunities - could change the availability of labour resources, for agricultural production in important seasons, leading to the loss of some agricultural practices and crops.

**3. Transforming - Policies, Institutions and Processes (PIPS)**

In addition to the factors that determine the vulnerability context, there is a range of policies, institutions and processes designed to influence people and the way they make a living. If designed well, these influences on society should be positive. However, depending on their original purpose, some people may be affected negatively.

Policies, institutions and processes, within the livelihoods framework, are the institutions, organizations, policies and legislation that shape livelihoods. Their importance cannot be over-emphasized. They operate at all levels, from the household to the international arena. They function in all spheres, from the most private to the most public. They effectively determine (a) access to various types of capital, to livelihood strategies, and to decision-making bodies and sources of influence, (b) terms of exchange between different types of capital and, (c) returns, economic and otherwise, to any given livelihood strategy.

In addition, they directly impact people's feelings of inclusion and wellbeing. Because culture is included in this area, PIPs account for other unexplained differences in the way things are done in different societies.

Examples of PIPs include:

- Policies - on plant genetic resource use and biodiversity management.
- Legislation - on patenting of plant genetic resources, property rights.
- Taxes, incentives, etc. - incentives for growing cash crops or improved varieties that could replace local varieties.
- Institutions - extension or research institutions that promote external innovations, and represent the interest of prosperous farmers who depend less on agrobiodiversity.
- Cultures - concerning gender relationships, which may affect access and decision-making on crop and livestock selection and management.

**4. Strategies**

To sum up the features of livelihoods: people use assets to make a living. They cope as best they can with factors beyond their control that make their livelihoods vulnerable. They are affected by existing policies, institutions and processes, which they can partly influence themselves. There are three main types of strategies, which can be combined in multiple ways:

- Natural resource based: The majority of rural people will plan on ways to make a living, based directly on the natural resources around them e.g. subsistence farmers, fishers, shepherds, etc.

- Non-natural resource based: Some rural people, and most urban-based people, will opt to make a living based on created resources ranging from begging, service jobs, drivers, government jobs to shop-keeping.
- Migration: If there are no appropriate opportunities for people to make a living, then a third option may be to migrate away from the area to a place where they can make a living. This migration can be seasonal or permanent.

**5. Outcomes**

The aim of these livelihood strategies is to meet people's needs, as efficiently and effectively as possible. These needs can be expressed as desired livelihood outcomes of a chosen livelihood strategy. When considering "poor" people, there are five basic outcomes that will usually be most important to them. The priority given to each will depend on the individual's perception of his or her circumstances. They are as follows:

- Increased food security: A basic requirement for any livelihood is to achieve food security. It is not enough to have adequate food for part of the year and insufficient in another. There must be a secure supply all year round.
- Increased well-being: An increased feeling of physical, mental and spiritual well-being is an important and basic need. To a certain extent, it is dependent on other needs being met.
- Reduced vulnerability: As far as possible, a chosen livelihood should help reduce the effect of the various factors that make life more vulnerable, e.g. drought, conflict.
- Increased income: Clearly, most poor people will want their income increased to an adequate level, and to have the maximum flexibility in meeting their needs.
- Sustainable natural resource use: Since many livelihoods of the rural poor depend on access to natural resources, it is important that their strategies lead to more sustainable use of these resources.

**Exercise**

The participants to break into small groups of 4–5 people.
Select a livelihood activity which the group feel to implement in the watershed area
Using the sustainable livelihoods framework as a guide, "map" out:

1. What are the different assets the activity need? What degree of control do different people in the village have over them?
2. These factors outside the immediate control of the village people, which could make them vulnerable (e.g. trends, shocks, seasons)?
3. What policies, institutions and processes affect the current and future management of their assets?
4. Identify different livelihoods strategies based on the exercise done.

After this exercise is completed, the groups are invited to present their findings, and to discuss differences and similarities between them.

# SWOT Analysis for Identification of Potential Enterprises

**Introduction:**

SWOT analysis is a strategic planning method used to evaluate the strengths, weaknesses/ limitations, opportunities, and threats involved in a project or in a business venture. It involves specifying the objective of the business venture or project and identifying the internal and external factors that are favourable and unfavourable to achieve that objective. The technique is credited to Albert Humphrey, who led a convention at Stanford University in the 1960s and 1970s using data from Fortune 500 companies.

**Meaning of SWOT:**

*Strengths:* characteristics of the business, or project team that give it an advantage over others. The first step is to identify and list business strengths. This can include internal strengths, such as unique selling points, teams, processes, technical expertise, tools, and other factors contributing to business success. Then identification of external strengths, such as supplier relations, advantage in the market over others, marketing, and online presence, additional services offered/value-adds, etc.

*Weaknesses*: are characteristics that place the team at a disadvantage relative to others. This is the tough part of the four quadrants since it's difficult to confront the strengths and weaknesses of a business objectively. But one's main priority here is to identify the company's weaknesses both internally and externally. Think of this as the building blocks to help you convert weaknesses into strengths. This could include external environment factors such as pricing, competition, lowered demand, and more. It can also include internal weaknesses that negatively affect the business, such as lack of budget, small teams, etc.

*Opportunities:* external chances to improve performance (e.g. make greater profits) in the environment. Now that one has done a deep dive into his business's strengths and business's weaknesses, it's time to identify potential opportunities. Based on the strengths and weaknesses y laid out, where does the company have the advantage? Are there markets where you're performing well that can be further expanded? Do you have a strong marketing strategy that you could ramp up to drive demand? Think of the external factors you've identified and where your business might have an opportunity to grow.

*Threats:* external elements in the environment that could cause trouble for the business or project. The threats part of SWOT analyses can also scare off many. Essentially, the goal here is to look at potential threats that could negatively impact one's business. Again, this can include internal issues and external threats that you identify. Internal threats can include lack of staff, budgetary constraints, and other threats. External threats, as an example, can include markets you are not taking advantage of, negative reviews, strong competitors, and supplier issues.

**Importance of SWOT Analysis:**

Analysts can solve a number of problems using this method such as (a) what internal potentials of the enterprise can become fortes? (b) how fully are the existing strengths of the company used? (c) do weaknesses make a company vulnerable? (d) are the weaknesses of the enterprise impeding the full use of favourable circumstances? (e) what weaknesses need adjustment? (f) what opportunities are open to the firm when accessing certain resources and applying the available qualifications?

With the help of SWOT-analysis the strengths and weaknesses of the enterprise, it's potential and threats are identified and systematized. This is the starting point of any segmentation. In fact, managers compare internal resources and weaknesses with market opportunities. Based on the results of the comparison, the conclusion is drawn: "where does the enterprise need to move on?"

**The Internal and External Environment of the Organization in SWOT Analysis**:

The internal components of the analysis relate directly to the organization of activities in the enterprise. It can be: (a)manufacturing process; (b) marketing and storage;(c) transport and logistic;(d) marketing department; (e) innovation and technology; (f) labor resources; (g) security organization; (h) material and technical basis, etc.

External elements refer to the environment "surrounding" the enterprise. It can be: (a)legislation; (b) policy; (c) competition; (d) socio-demographic situation; (e) demand; (f) ecological situation in the region, country, world, etc.

**SWOT-Analysis of the Enterprise:**

Possible strengths of the company: (a) high availability of material resources; (b) high professionalism and qualification of the staff; (c) established status in the market environment ("name"); (c) own elaborations and technologies; (d) effective advertising campaign; (e) low production prime cost; (f) financial stability, etc.

Possible weaknesses: (a)absence of a forward-looking development plan and clear goals; (b) poor working conditions; (c) obsolete equipment; (d) high prime cost; (e) lack of qualified personnel; (f) low profitability; (g) unsustainable sales channels; (h) a narrow range of goods, works and services and so on.

Opportunities are factors that will help an enterprise to develop effectively. For example: (a) expansion of the range of goods, works and services; (b) entering a new market; (c) the forthcoming of investment funds; (d) growth in demand for products, etc.

Threats are the circumstances in which the organization may suffer damage. For example: (a) unfavorable economic situation in the country; (b) increase in the tax burden; (c) emergence of a powerful competitor; (d) "bad" and unprofitable currencies exchange rates; (e) changes in the tastes and preferences of potential customers, etc.

**SWOT-Analysis of Enterprises:**

Sequence of analysis: Determination of parameters for the analysis of strengths and weaknesses. You can create a table in the first column of which will be a parameter for the characteristics of the enterprise. In the second will be strengths and in the third will be weaknesses. The company chooses parameters at its discretion:

| *Parameter* | *Strengths* | *Weakness* | *Opportunity* | *Threats* |
|---|---|---|---|---|
| Manpower | | | | |
| Raw material | | | | |
| Innovations/ Technologies | | | | |
| Financial resources | | | | |
| Product quality | | | | |
| Production quantity | | | | |
| Competition | | | | |
| Demand | | | | |
| Socio-cultural situations | | | | |
| Ecological implications | | | | |

Then compile the matrix of factors. An assessment in scores is carried out for impact (for strengths and weaknesses) and probability of use (for opportunities and threats). Several experts should conduct the ranking of factors. For each position put from 1 to 6 points (depending on the degree of influence). Next is the average. Matrix of factors for the analysis of strengths. By the same principle matrixes of factors are formed for the analysis of weaknesses, threats and opportunities.

Analyzing an enterprise using the SWOT method is easily and quickly. But this simplicity is also the negative side of this method: the analyst can come to wrong and hasty conclusions
SWOT analysis is just one method of categorization and has its own weaknesses. For example, it may tend to persuade companies to compile lists rather than think about what is actually important in achieving objectives. It also presents the resulting lists uncritically and without clear prioritization so that, for example, weak opportunities may appear to balance strong threats

Use of SWOT analysis**:** The usefulness of SWOT analysis is not limited to profit-seeking organizations. SWOT analysis may be used in any decision-making situation when a desired end-state (objective) has been defined. Examples include: non-profit organizations, governmental units, and individuals. SWOT analysis may also be used in pre-crisis planning and preventive crisis management. SWOT analysis may also be used in creating a recommendation during a viability study/survey.

**Example of SWOT Analysis:** SWOT analysis of an Enterprise-Bakery

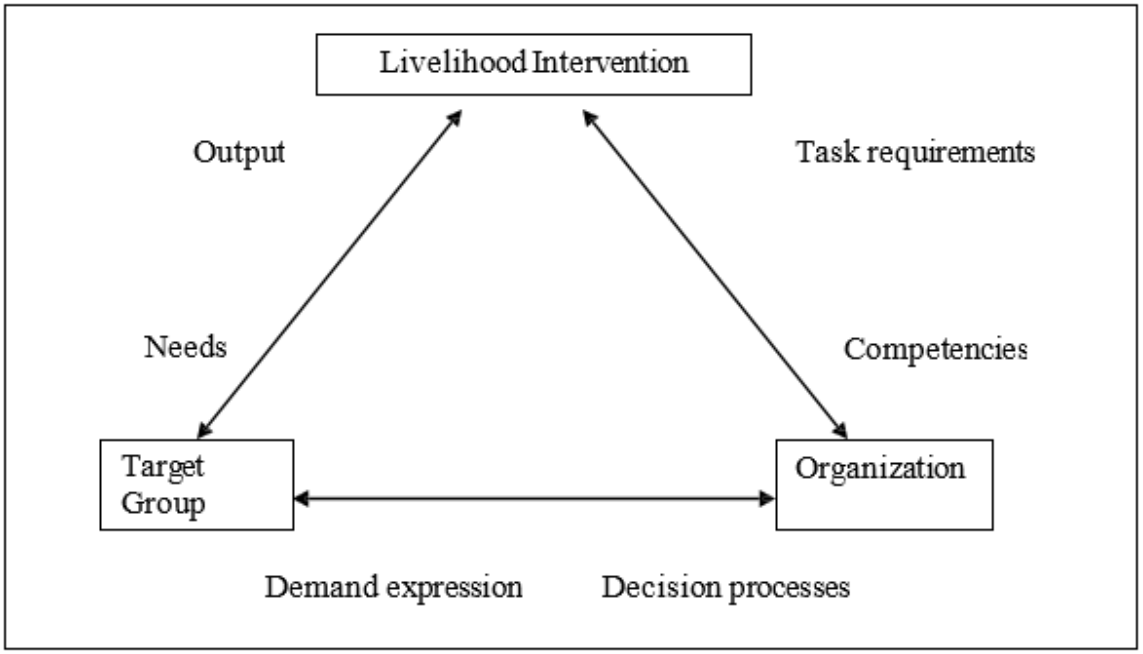
| *Strengths* | *Weakness* | *Opportunity* | *Threats* |
|---|---|---|---|
| • Availability of family labour to manage the enterprise<br>• Appropriate place available to hire in the market area to establish bakery<br>• Finance available from the bank to establish and run the enterprise<br>• Scope for good business due to location advantage<br>• Required raw material available at reasonable cost | • Not trained in commercial bakery techniques<br>• Required power and water supply not available at the identified location.<br>• Not able prepare a proper business plan to submit to the finance institution and to apply for license from competent authority | • Scope to get required training to all those who are going to involve at an appropriate training place<br>• Obtaining the services of experts to prepare business plan and to get license<br>• Installing a generator for power backup<br>• Hiring a water supplier in the event of shortfall of water supply | • Poor business if quality and tasty products are not prepared<br>• Poor business may lead to nonpayment bank EMIs and staff salaries<br>• During peak business years, the owner of the building may ask to vacate |

## Intervention Plan Development

Choosing the appropriate intervention for livelihood promotion is based on the need of the families and competency of the assisting organization, intervention should be identified from all the possible interventions. The intervention identification process will require the following steps to be followed:

1. Understanding the intervention context which will have the following components
   a. Understanding the organizational context in terms of long-term objective of the organization, competency and skills existing of the organization and the funding possibilities.
   b. Understanding the area context – the level of development, characteristics of the target group, nature of political economy prevailing, the social structure and the cultural practices within the area.
   c. Understanding the macroeconomic and policy context
2. The prioritization of people's needs based on the existing scenario of the rural poor in the area. While the sub-sector approach will ensure that the gaps are identified across the value chain right from the pre-production stage to the post-harvest marketing stage it is very important to identify the critical issues and gaps. The gap to be addressed immediately should appeal to the rural poor and also be able to provide immediate relief and better livelihood within the entire value chain. The other important means to choosing the intervention points and mechanism is to go for strategic planning exercise which will ensure that they develop the priority areas and also form the objectives based on which the intervention can be designed.
3. The three critical variables to be finalized for setting the boundary of intervention is the likely scale of intervention, the point of intervention and relative importance of the intervention to the rural poor. Once the intervention is identified, develop strategies and business plan for successful implementation of the intervention.

From the opportunities and gaps identified through the livelihood analysis, a livelihood intervention plan has to be prepared for the learning to take form into an intervention. However, there is a need to understand, in the beginning itself, that the success of livelihood intervention depends on the fit achieved between families, livelihood plan and supporting organization. This means that livelihood intervention will fail in promoting the livelihoods of the poor unless there is a close relationship between: target group needs and livelihoods intervention output, livelihoods intervention task requirements and the competencies of the supporting organization; and the mechanisms for family demand expression and the decision processes of the supporting organization.




The target group and the organization staff need to share their knowledge and resources to create a fit between needs, actions and the capacities of the assisting organizations. Both, families and staff need to spend time on an idea on pilot basis, try it, get the result and correct its errors. Organization staff/ team leader needs to spend time in the village on that idea. In the learning process approach, the ideas need to be tried, tested, modified and scaled-up.

The learning process approach has three main stages for successful implementation of intervention plan

1. Stage 1: learning to be effective: One or two staff spends time with families to understand the problem and develop an idea with them. The idea is tried and modified/corrected based on the errors and successes; thus, a final idea emerges.
2. Step 2: learning to be efficient: Efforts are focused on eliminating activities which are non-productive and working out simplified problem-solving routines for handling critical activities for a layman or less qualified staff.
3. Step 3: learning to expand: Efforts are to build the skills, management systems, structures and values in the assisting organization to carry out the prescribed activities on a large scale.

Hence, on the one hand there should be a fit between the needs of the community, the organizational capacity and the livelihood intervention. And on the other hand, the livelihood intervention should follow the steps outline above.

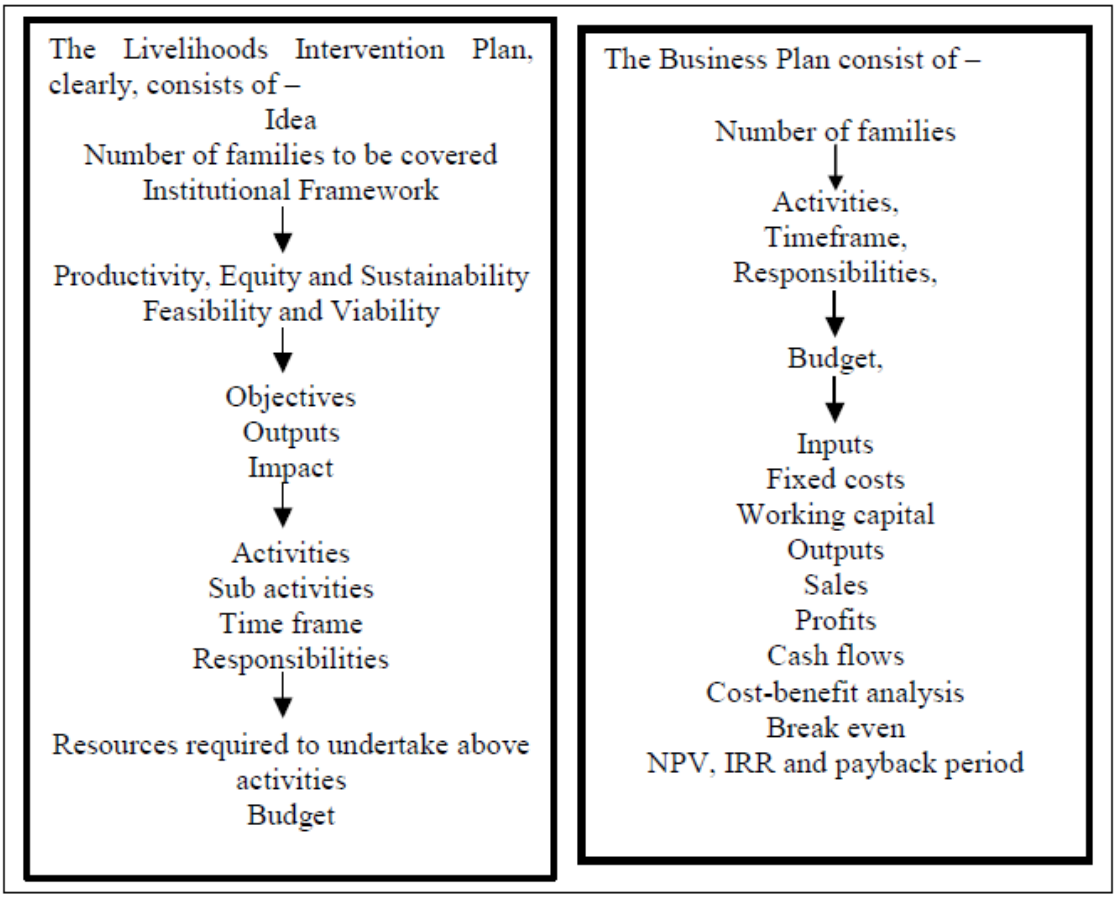
**Elements of Livelihoods Intervention Plan (LIP)/ Business Plan (BP)**

Livelihood Intervention Plan – This involves systematic planning of objectives, activities, institutional framework, timeframe, responsibilities and budget.

Business Plan – Business plan is prepared for micro-enterprises or business activity. This mainly involves planning for activities, timeframe, responsibilities, budget, forecasting costs, inputs, outputs, sales, profits and cash flows.

**Difference between Livelihood Intervention Plan and Business Plan:** Business plan is part of Livelihood Intervention Plan. Business plan is mainly related to economic - estimation of production, cost and profits, finances. However, the livelihood intervention plan deals with social and economic aspect of the intervention.

| *Livelihood Intervention Plan* | *Business Plan* |
|---|---|
| LIP helps in assessing<br>1. Number of families to be supported<br>2. Activities to be undertaken and resources required<br>3. Financial support required<br>4. Various sources to arrange resources and methods to raise it.<br>5. Make a stepwise progress in developing systems, arranging resources, establish infrastructure, initiate intervention, monitoring the activities and take corrective action.<br>6. Responsibilities, assign them to right persons and monitor it<br>7. Timeframe and deadlines to start the work on time.<br>8. Training need for families and staff. | BP is mainly prepared<br>• To show the creditors so that the credit can be ascertain on the basis of soundness of the business.<br>• To assess the potential of micro-enterprise to make profit in future.<br>• To assess the financial support required<br>**It also helps in assessing**<br>1. Activities to be undertaken and resources required<br>2. Various sources to arrange resources and methods to raise it.<br>3. Shortcomings of micro-enterprise need to be improved.<br>4. The requirement of money on certain point of time during production |




**Steps in Livelihoods Intervention Plan**

1. *Idea* - Livelihoods system of a village is analyzed at micro and macro level to identify potential activity in existing or new livelihoods to improve the incomes of a family or group of families. That potential activity is an idea for suitable livelihood intervention. Before selecting this idea for further work, one should ensure that it meets the requirement of the family/group of families as well as the competency of the supporting organization. Once it is ensured, the idea should be selected for further work with the concerned family or group of families. This idea would be central for livelihood intervention and the entire livelihood Intervention Plan would be woven around it.

2. *List of families and their expected business under that idea* – Once the idea is identified, discussions with all the families, whose needs for livelihood promotion will meet from it, need to be conducted to finalize the list of the families. Based on this list, assess the quantum of livelihood activity for each of the family to arrive at a total quantum of activity. This will be the input for selecting the appropriate institutional form to undertake the livelihood activity, plan for activities, assess the resources required and finalize the budget.

3. *Institutional framework required implementing this idea* – based on the idea, number of families and quantum of the livelihood activity, the appropriate institutional form should be selected. It can be an enterprise or collective action. If one or small number of families are coming together, micro or small enterprise would be suitable, however for large number of families, collective is a better idea. Collective can also be of various institutional form – society, trust, cooperative, producer's company, etc.

4. Before moving further and doing any more work, it is essential to ascertain that the idea qualifies for productivity, equity, sustainability, feasibility and viability. Although, this will be undertaken in-depth and with rigorously during the appraisal of the plan, the rapid assessment of plan with regard to this is essential at this stage. This will save time, energies and resources from being wasted in detailed planning, if the idea would fail on these parameters later. The details with regards to assessment of plan on these parameters are discussed in detail in the next chapter. The method for assessment would be same here, but for the intensity and rigor.

5. Main objective of livelihood intervention, its outputs and impact on poor families – once the idea passes the rapid assessment with regard to above parameters, the main objectives of undertaking the idea should be clearly spelt out in a joint meeting with all the families. This is very important, as it will help in refining the choice of institutional model further and finalizing the activities and sub activities that will further affect the resource requirement and budget. While defining the objective, output of each objective and impact of overall idea should also be defined. This will be helpful for monitoring as well as evaluation of the project later on.

6. Defining the activities and sub activities – For achieving the main objectives of the idea, activities and sub activities need to be defined. For this, identify the activities to each objective separately and break these activities down into sub activities.

7. Specify time frame (starting and end date) for each activity and sub activities -This will be helpful in preparing for the upcoming activities, arranging and coordinating the resource, implementing the activities smoothly and accomplishing the task on time.

8. Along with planning for activities, sub activities and timeframe, assign the responsibility of each activity to families and concern staff of supporting organization. This will help in reducing the confusion, make people accountable, and smoothly carry out the activities without hassles. This will also hasten the process.

This should be prepared in the form of following table for the convenience and presentation of entire activity sub activity plan, time frame and responsibility at a glance.

Activity Plan:

| # | *Activity* | *Sub activity* | *Time frame* | *Responsibility* |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

9. The next step is to assess the requirement of resources and external support. The resources include human, financial, physical, infrastructure, assets, technology, skills, knowledge, etc. The external support means support from out of the community, either from supporting organization or from other institutions/individuals. The assessment is important for making arrangement for it, sourcing it and coordinating the resources (as they are usually limited). This also has implications on the budget, therefore on the finance required.

10. Detailed budget should include unit, unit description, unit cost, total cost, year wise and source wise distribution for each activity and sub activity.

    Detailed Budget:

| # | *Activity/ sub activity* | *Unit description* | *Unit* | *Unit cost* | *Total* | *Year* | | | *Source* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *1* | *2* | *3* | *1* | *2* | *3* |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | *Total* | | | | | | | | | | |

11. If livelihood intervention is for income generating activity like micro enterprise, marketing, shop, a detailed business plan also needs to be made. The business plan is discussed in detail below.

**Steps for developing Business Plan for micro enterprise**

The business plan also includes a brief mention of number of families, activities, sub activities, timeframe, responsibilities and budget. These are same as discussed above in livelihood investment plan. In addition to this, the main and important parts of Business Plan are:

1. Production cost: All the cost related to the enterprises must be considered. Even the long-term expenses related to equipment, annual depreciation, should be worked out so that the entrepreneur knows the full costs before venturing into the business. The steps for this are:
    a. Identify all the items needed to produce or sell
    b. Calculate the quantities of all these items – total production
    c. Calculate the cost of getting them for the production of a specific quantities
    d. Identify Production inputs:
        - Raw material: these are required to produce a product.
        - Equipment: These are the tools, machineries or implements required to produce a product.
        - Labor
        - Transport
        - Other expenses: utilities like water, fuel, repairs, interest on loan
        - Wastage/defects
    e. Calculate the total production cost - Total production cost will arrive at by adding the above costs
    f. Costs per unit – total cost divide by number of units produced.

2. Total Sales value and profit: The total sales value is the function of total units sold and the per unit price. It is important to notice that the total sales value should cover all the production costs, labor expenses, maintenance and replacement costs for tools, equipment, implements and machinery. The difference between the sale revenue/ total sale value and total costs is profit. For estimating costs and sales, following formats can be used:

| # | *Month/ Item* | *Jan* | *Feb* | *Mar* | *Apr* | *May* | *Jun* | *Jul* | *Aug* | *Sep* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sales | | | | | | | | | |
| | Quantity | | | | | | | | | |
| | Price | | | | | | | | | |
| | Total value | | | | | | | | | |
| 2 | Cost of Sales | | | | | | | | | |
| a. | Raw Material | | | | | | | | | |
| | Quantity | | | | | | | | | |
| | Price | | | | | | | | | |
| | Total Cost | | | | | | | | | |
| b. | Labor | | | | | | | | | |
| | Number Employed | | | | | | | | | |
| | Wages | | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total Cost | | | | | | | | | |
| c. | Power | | | | | | | | | |
| | Quantity | | | | | | | | | |
| | Cost | | | | | | | | | |
| d. | Other Production Cost | | | | | | | | | |
| e. | Depreciation* | | | | | | | | | |
| | Total Cost of sales | | | | | | | | | |
| 3 | Operating Profit (1-2) | | | | | | | | | |
| 4 | Less: | | | | | | | | | |
| a. | Interest | | | | | | | | | |
| b. | Selling, general, administrative Expenses | | | | | | | | | |
| 5 | Profit before taxation (3-4) | | | | | | | | | |
| 6 | Provision for income tax | | | | | | | | | |
| 7 | Net Profit (5-6) | | | | | | | | | |

3. Cash flow: Cash flow refers to the amount of cash being received and spent by an enterprise during a defined period. A cash flow plan is a forecast which shows how much cash is expected to come into and go out of the enterprise in a given period. The cash flow plan helps the entrepreneur to make sure that the enterprise/institution does not run out of the cash at any time and has enough cash to pay its costs. An institution can make a profit in a year but can still run out of the cost. But adverse cash flows or shortage affects profits. There are several reasons why an institution runs out of cash:

    - The business has to buy raw material before it makes finished goods and sells. This means that cash goes out before cash comes in
    - If the business gives credit to its customers, repayment may not happen regularly in stipulated time. But business has to run before these credit customers pay
    - Business needs cash to invest in infrastructure, equipment the benefits of some of which are not immediate but have long-term implications. But still business has to incur these expenses before any cash flow through sales.

**The cash flows are of three types:**

1. Operational cash flows: Cash received or expended as a result of the company's core business activities
2. Investment cash flows: Cash received or expended by making capital expenditures (i.e. the purchase of new machinery), the making investments or acquisitions
3. Financing cash flows: Cash received or expended as a result of financial activities such as receiving or paying loans, issuing stock, and paying dividends

A cash flow statement is the financial report showing the cash inflows and outflows and used in understanding the short-term viability of an enterprise, especially its ability to meet its costs. It helps an entrepreneur to make sure that the enterprise does not run out of cash at any time. In other words, this can be used to make sure that the enterprise always has enough cash to pay its costs. The cash flow plan 1) gives a warning in advance about the future cash shortage, 2) facilitate more control over the flow of cash, 3) prepare to solve or avoid the problems before they happen and in 4) managing the working capital. To make cash flow plan, one needs to forecast the amount of cash, which will come in and go out. For this, use the following table.

| *Months* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **In flow:** | | | | | | | | | | | | |
| Cash at the start of the month | | | | | | | | | | | | |
| Cash in from sales | | | | | | | | | | | | |
| Any other cash in | | | | | | | | | | | | |
| **Total cash in** | | | | | | | | | | | | |
| **Out flow:** | | | | | | | | | | | | |
| Cash out for direct material cost | | | | | | | | | | | | |
| Cash out for direct labor cost | | | | | | | | | | | | |
| Planned investment in equipment | | | | | | | | | | | | |
| Cash out for paying loans, dividends, issue of stocks, etc. | | | | | | | | | | | | |
| Any other cash out | | | | | | | | | | | | |
| **Total cash out** | | | | | | | | | | | | |
| **Net in and out** | | | | | | | | | | | | |
| **Cash at the end of the month** | | | | | | | | | | | | |

4. Total working capital requirement: Working capital also known as operational capital refers to the amount required to run the day-to-day operations of the business. In this context, we are talking about the net working capital which is the difference between current assets and current liabilities.

   In estimating the working capital requirement, operating expenses directly or indirectly related to the production and sales operations are taken into account. Inventory, work-in-progress, receivables, creditors and contingency are the main components of working capital. Working capital requirement are calculated for a business cycle, which is the time period between purchase of raw material to realization of the money from sales. While estimating the working capital requirement sometimes, the interest on working capital is not included. This happens because in the case of a sound business enterprise, the financers believe that the interest on working capital should be generated from the business activities and should not be borrowed as a loan.

   Working Capital = Current Assets – Current Liabilities

**Terms**

Current Assets: Current assets include cash, cash equivalents, accounts receivable (debtors), inventory, which will be used within a year and can be easily converted into cash when required.

Current Liabilities: Accounts payable for goods (Creditors), services or supplies that were purchased for use in the operation of the business and payable within one year would be current liabilities.

Inventory: Raw material, Finished goods and Work-in-Progress (semi- finished goods)

Debtors: Are the people/institutions who owe money to the enterprise

Creditors: Are the people/institutions to whom the enterprise owes money

Liquidity: In this context, liquidity means the possibility of converting into cash quickly

Format for working capital estimation

| *Working capital estimates* | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Norm in months* | *M-01* | *M-02* | *M-03* | *M-04* | *M-05* |
| 1 | Raw materials | | | | | | |
| 2 | Work-in-progress | | | | | | |
| 3 | Finished Goods | | | | | | |
| 4 | Book Debts | | | | | | |
| | **Total current assets** | | | | | | |
| 1 | Working capital margin @ 25% of total current assets | | | | | | |
| 2 | Trade credit | | | | | | |
| 3 | Bank credit for working capital | | | | | | |
| | **Total current liabilities** | | | | | | |
| | | | | | | | |
| 1 | Interest rate on Working Capital Loan (%) | | | | | | |
| | **Total working capital** | | | | | | |

5. Break-even: The breakeven point for a product is the point where total revenue received equals total operating costs associated with the sale of the product. Break- even analysis is a tool to calculate at which point of sales volume the variable and fixed costs of producing your product will be recovered. Another way to look at it is that the break-even point is the point at which the product stops costing you money to produce and sell, and starts to generate a profit for your company. The breakeven point helps in:

- Setting the price levels
- Optimal fixed and variable costs combination
- Products to be manufactured or dropped
  Break even quantity = Total Fixed cost / (Unit selling price – Unit variable cost)

**Terms**

Fixed Cost: It does not change with the change in the production and long- term in nature. It varies only when there is additional capital investment. It has to be incurred even when the production is not happening

Variable Cost: Variable cost varies directly with the production and is incurred only when the production happens. Unit variable cost is the variable cost of the single unit of the product/service

Unit Selling Price: It is the sales price of a single unit of product/service

Unit selling price-Unit Variable cost is called the contribution margin. It explains the relationship between the variable cost and the selling price. Estimation of break-even helps in determining the sales per day, per month and per year. Knowing the required time and quantity of break-even will give an idea whether to start the business or not.

**Project selection methods:** The projects are selected based the time period to get back the investment. Higher the profits, it is easier to get back the investment in short period. Apart from the financial benefits, risk, environmental concerns, distribution of the benefits (equity) and regularity of income are some of the other criteria used. The following methods for project selection based on financial soundness are detailed below:

**Cost Benefit Analysis:** In simple words, cost benefit analysis compares the cost of the project and returns from the projects for a period and reflects whether the total benefits from the project would be higher or lower than the total cost of the project in the long run. For a project to be taken-up, the benefits should be more than the costs. Here the cost includes not only the monetary costs but also the social and environmental costs.

Cost Benefit Analysis include:

| *Cash Flow Analysis* | *Year 1* | *Year 2* | *Year 3* | *Year 4* | *Year 5* |
|---|---|---|---|---|---|
| Total Cash Inflow (A) | | | | | |
| Total cash Outflow (B) | | | | | |
| Net Cash Flow (A-B) | | | | | |
| Cumulative Cash Flow | | | | | |
| Payback Period | Year | | | | |
| IRR | | | | | |
| **NPV** | | | | | |

**Methods to judge the merits of Investment:** The most commonly used method of appraisal for the viability of the project is looking at the rate of return i.e. the money generated by the project. It indicates the overall financial viability of the project/intervention. The three important measures used are: 1) Payback method, 2) Net Present Value Method and 3) Internal Rate of Return Method.

a. **Payback Period:** The best way to judge the investment is to calculate the amount of time it takes to recover the investment. According to this criterion, the shorter the duration of the recovery of initial investment, the more desirable the project is. Longer the payback period, the greater is the risk associated with the project. For example –

| # | *Particulars* | *Year 1* | *Year 2* | *Year 3* | *Year 4* | *Year 5* |
|---|---|---|---|---|---|---|
| 1 | Net Cash Flows | -18005 | 12470 | 12470 | 12470 | 21803 |
| 2 | Cumulative Cash Flows | -18005 | -5535 | 6935 | 19405 | 41208 |
| 3 | **Pay Back Period** | 3rd Year | | | | |

In this case, the payback period is less than 3 years. The only shortcoming of this method is that it does not account the time value of money as it just adds the cash flows and does not look at the timing of the cash flows. Also, in the case of few projects, the cash flows may continue even after covering the initial investments. For example, two projects with initial investment of Rs.1,00,000 each, will recover the initial investment in 2 years. One project may cover the initial costs faster and provide no cash flows at all after 2 years, whereas the other project may continue to provide inflows even after 2 years.

Hence, to overcome this problem, Net Present Value (NPV) & Internal rate of return (IRR) method is used for sub project selection.

**b. Net Present Value (NPV):** The NPV method estimates the projected earnings from an intervention for the entire life of the intervention and also the residual/salvage value that can be obtained at the end of the project. Thereafter, the earnings are discounted at an appropriate interest rate to bring the earnings of all the years to a common comparable date, which is the state of the project. This is done because the value of money that is hand is more than that is anticipated in the future. Hence, the future value of money is discounted.

The process of discounting is the reverse of compounding of interest rate. For example, Rs.1000 in a safe investment will yield Rs.1100 in the next year and Rs. 1210 in the second year and so on at an interest rate of 10%. Discounting reverses the process and finds out the present value of Rs. 1220 that we will get after two years. The current value of future money that we get after discounting is called the present value and is calculated by:

$$\text{Present Value} = \frac{\text{Future Sum}}{(1+i)\ n}$$

Where i is the rate of interest and n is the number of periods or years.

The NPV of a business plan is the sum of the present value of net cash flows (Positive/negative) of each year that is expected to occur over the business plan period. In this method year wise net cash flows are converted in to their present values (PV) by multiplying with suitable discounting factors. It is the most accurate and theoretically correct method. If NPV is positive, accept the business plan. If it is negative, reject the business plan.

Example:
Two projects A and B's earnings over 5 years are discounted with an interest rate 10%. The initial investment available is Rs.1000.

| *Year* | *Project A* | | *Project B* | |
|---|---|---|---|---|
| | *Earnings* | *Present value* | *Earnings* | *Present Value* |
| Year 1 | 200 | 181.80 | 500 | 454.50 |
| Year 2 | 300 | 247.80 | 400 | 330.40 |
| Year 3 | 500 | 375.50 | 100 | 75.10 |
| Year 4 | 200 | 136. 60 | 200 | 136.60 |
| Year 5 | 200 | 124.20 | 200 | 124.20 |
| **Total** | | **1065.90** | | **1120.80** |

By deducting the initial investment from Project A, the surplus is Rs. 65.90 (1065.90-1000) and from Project B is Rs.120.80 (1120.90-1000). From Project B, the institution is able to pay back the loan in 5 years and also able to make a surplus more than the Project A. Hence, Project B should be taken up.

c. **Internal Rate of Return (IRR):** IRR method is the modification of NPV method. NPV method does not furnish exact rate of return. IRR is that rate at which the sum of discounted cash flows is equal to the original investment. It makes the present value of earnings equal to the investment or makes the NPV zero. The calculation of discount rate (IRR) involves a trial and error. Accept the sub project if the IRR is greater than the cost of capital (interest rate of loan amount). Reject the business plan, if it is less than the cost of capital.

## Livelihood activities undertaken under PMKSY-WDC 2.0 in Karnataka

1. Establishment of amruth stalls
2. Oil extraction unit
3. Ragi cleaning/processing & packing unit
4. Chilli pounding machine/pepper processing unit
5. Animals/ poultry feeding unit
6. Vermicelli making machine
7. Arecanut plates making/ processing unit
8. Dal processing unit
9. Mushroom cultivation
10. Dragon fruits processing & packing unit
11. Sugarcane juice extraction unit
12. Honey bee /apiary unit & honey extraction unit
13. Flour mill
14. Back yard poultry unit/sheep /goat/cattle/pig rearing unit(shed)
15. Bamboo products manufacturing unit
16. Nut sheller / nut processing plant
17. Drum stick powder manufacturing unit
18. Popcorn/jowar flakes making unit
19. Bakery products/milk products/paneer/dry products manufacturing unit
20. Solar drier for Anjur fruits
21. Roti making unit
22. Rava making unit
23. Millets malt preparation unit
24. Agarbatti/candles/camphor manufacturing unit
25. Coconut oil extraction unit
26. Establish nursery unit
27. Phenol/dish washer/liquid blue manufacturing unit
28. Silk production unit
29. Milking machine
30. Organic jaggery manufacturing unit
31. Wheat processing unit
32. Banana/Tapioca processing unit (Jamoon making from Banana powder)
33. Arecanut harvester/ Arecanut tree climbing ladder
34. Mango pulp processing unit
35. Ginger & Garlic paste manufacturing unit
36. Paddy transplanter
37. Turmeric manufacturing unit
38. Stitching machine/ embroidery/ kasuthi machine
39. Drinking water purification unit
40. Handicrafts/ carpentry works
41. Electric service /cycle & moped service centre
42. Cement bricks manufacturing unit
43. Paper and bags making unit

## Distribution of budget under PMKSY-WDC 2.0

| *Major Head* | *Sub Heads* | *Percentage of Budget* |
|---|---|---|
| Administrative | Management Cost | 10 |
| Monitoring & Evaluation | | 2 |
| Preparatory Phase | Entry Point Activity | 2 |
| DPR Preparation | | 1 |
| Institution &Capacity Building | | 3 |
| Works Phase | Natural Resource Management | 47 |
| Production System | | 15 |
| Natural Resource Management & Governance | | 2 |
| Livelihood Activities for the asset less persons, Micro Enterprises & Business Development | | 15 |
| Consolidation & Withdrawal Phase | | 3 |
| Total | | 100 |

1. Budget for llivelihood activities for the asset less persons, micro enterprises & business development is 15 % of the total treatable area in hectares
2. *Out of total IGA amount 60% for revolving fund to SHGs*
3. Out of Total IGA amount 40% for business activities to Individuals or for group or for federations
4. For SHGs Rs. 50,000
5. Out of IGA amount, 2% for Individuals for small enterprise (Max @20000/member)

# Guidelines for Livelihood Component of Watershed Development Projects (WDC-PMKSY2.0)[1]

## 1.0 Introduction

The watershed approach has been seen as the most effective tool for development of the rainfed/degraded areas. The Watershed Framework recognizes a balanced use of five capital assets namely human, natural, financial, social and physical resources. Community participation and securing livelihoods have emerged as important dimensions in planning, implementation andmanagement of the current generation watershed projects. Effective watershed development relies on the bottom-up approach at various levels of the project cycle involving local community and their integration with other employment generation and poverty alleviation programmes for generating more livelihood options.

The WDC-PMKSY 2.0 is being implemented in 28 States and 2 UTs from 2021-2026. The objective of watershed projects under WDC-PMKSY 2.0 is to maintain the social, economic and ecological functions in a balanced manner, and thereby to contribute to the sustainable development. One of the key features of the program includes focus priority on livelihood activities for landless/ assestless persons. Fifteen percentage of the total project cost has been assigned to support the livelihood activities for landless/ assestless households. This component aims to maximize the utilization of potential generated by watershed activities, creation ofsustainable livelihoods and enhances income for households within the watershed areas. Thiswill facilitate inclusiveness through enhanced livelihood opportunities for the poor throughinvestment into assets, improvements in productivity & income, and excess of the poor to common resources and benefits and augment the livelihood strategy at household level.

Based on this new generation guidelines, a revised broad livelihood guideline has been prepared for adoption in the country. The revised livelihood guidelines are an inclusive way for expanded livelihood approach to the categories of landless/asset less persons. This will also facilitate to achieve higher incomes for farmers.

## 2.0 Framework for Livelihood Approach

A livelihood *comprises* the capabilities, assets, and activities required for a means of living. Itis deemed sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities, assets, and activities both now and in the future, while not undermining the natural resource base.

Sustainable livelihoods *refer* to people's capacity to generate and maintain their means of living, and enhance their own well-being as well as that of future generations. Households have sustainable livelihoods when they can cope with and recover from shocks and

[1] Guidelines issued on 26.09.2023 by the Joint Secretary (WM), DoLR, GoI

economic stress, and can maintain their capabilities and assets without undermining their natural environment.

The sustainable livelihoods *approach* is based on evolving thinking about the way the poor and the vulnerable lives their lives and the importance of policies and institutions. It helps formulate development activities that are:

- People-centric;
- Responsive and participatory;
- Multilevel;
- Conducted in partnership with the public and private sectors;
- Dynamic; and
- Sustainable

The sustainable livelihoods approach facilitates the identification of practical priorities for actions that are based on the views and interests of those concerned but does not replace other approaches such as participatory development, sector-wide approaches, or integrated rural development.

Livelihood *strategies* bring out how people access and use these assets, within the aforementioned social, economic, political and environmental contexts form a livelihood strategy.

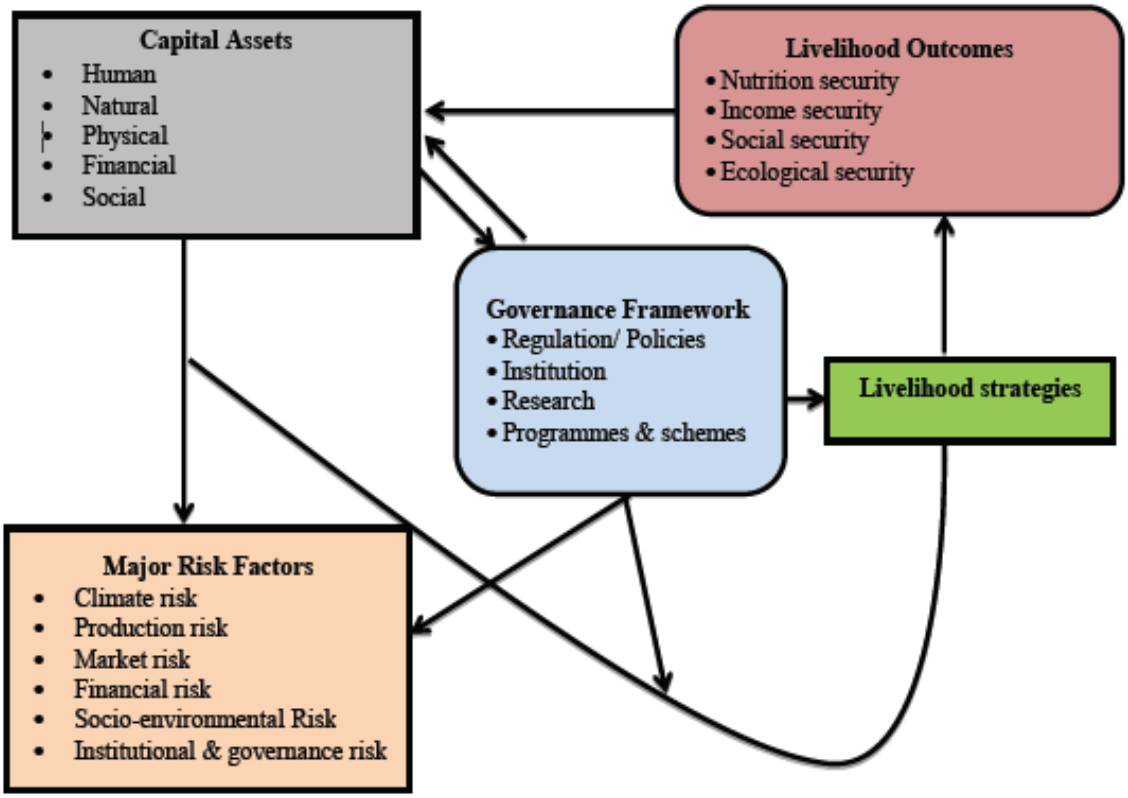



**Fig 1. Sustainable livelihood concept in integrated watershed management area**

### 2.1. Capital Assets for livelihood

| | |
|---|---|
| **Human capital** | Education, training, skills, knowledge, and ability to work |
| **Natural capital** | Land, soil, water, forests, apiculture and fisheries |
| **Physical Capital** | Infrastructure relating to roads, electricity, agricultural production processing, post-harvest & marketing, ICT, livestock, fisheries, handicraft and other primary processing and secondary agriculture |
| **Financial Capital** | Grant, credit, savings, income, remittance, seed money |
| **Social capital** | Social resources, informal networks, membership of formal groups, trust based relationships and co-operation for socio-economic activities |

### 2.2. Major risks posed to livelihood

| | |
|---|---|
| **Climate Risk** | Drought, flood, cyclone, Forest fire, landslide, incessant rains, Hail storm, unseasonal snow, deforestation, desertification, salinization,etc., |
| **Production Risk** | Pest and diseases, substandard input, Inappropriate production practices, low productivity, Soil degradation, poor quality soil, water contamination, and other climatic factor risk etc., |
| **Market Risk** | Low Price, Volatility of Price, Lack of demand, low shelf life etc. |
| **Financial Risk** | Lack of access to finance, High interest rate, Requirement of high collateral, non-performing assets |
| **Socio-environmental Risk** | Riots, Law and order, Pandemic/epidemic, National emergencies |
| **Institutional and Governance Risk** | Unpredictable changes in polices / regulations, sudden change in tax laws, etc. |

### 2.3. Governance Framework

| | |
|---|---|
| **Regulation/ Polices** | Laws, polices, acts, rules etc., |
| **Institutions** | Government (State/Central), Local self-government, NGO, Financial Institutions, NBFCs, Private corporate, Village level institutions etc. |
| **Programs and Schemes** | Central and state government schemes and programs, CSR etc. |

### 2.4 Livelihood Outcomes

| | |
|---|---|
| **Nutrient security** | Higher and sustainable production / productivity leading to higher per capita consumptions of nutritional food, etc. |
| **Income security** | Basic universal income, Growth in disposable income, reduction in expenditure and production cost, savings, etc. |

| | |
|---|---|
| **Social security** | old age pension, Health and life insurance, property / crops insurance, Accidental protection, disability benefits, survivor benefits, etc. |
| **Ecological security** | Conservation of soil, water and other natural resources, Conservation of bio-sphere, combating and reversing land degradation, reduction of green-house gases and improve soilorganic carbon etc. |

***Sustainable livelihood system optimally integrates various capitals around the rural eco-system to leverage the potential, for improving the income as well as social life.***

### 3.0 Livelihood Component in WDC-PMKSY 2.0

The Guidelines for new generation watershed development projects (WDC-PMKSY 2.0) which was issued during 2021 shows a transition from the predominant practice of mechanical treatments to farmer and environment friendly approaches to ensure sustainable, equitable and economic development. It emphasizes on the importance of creating farm and non-farm- based livelihood options. A provision of 15 percent budget has been made for livelihood component. This provision is made to increase the income of rural poor focussing on their livelihood aspects related to farm and non-farm activities. The revised guidelines provide inclusive ways to expand the livelihood options of the landless/asset less inhabitants and other marginal communities ofthe watershed.

### 3.1. Objective of Livelihood Promotion

a) To support the landless / assetless poor, SC / ST, marginalized communities and women, etc., with sustainable livelihoods opportunities for their socio-economic development.
b) To improve household income, participation and division of labour, access to information, knowledge, appropriate technologies and resources leading to their empowerment.

### 3.2. Key Features

a) One member (preferably a woman) from assetless rural poor household would be brought under the Self-Help Group (SHG) network. SHGs would be federated at village level and higher levels to provide space, voice and resources and to reduce dependence on external agencies.
b) Training and capacity building of the SHG member, particularly in relation to managing the institutions, livelihoods, credit absorption and credit-worthiness.
c) Provision of Community Investment Support Fund (CIF) to the SHGs through the Federations to advance loans and/or undertake common/collective socio-economic activities.

d) Convergence with various departments and agencies dealing with poverty reduction of rural poor.
e) Close involvement of various line departments, banks and public sector institutions is essential for monitoring the flow of credit, its utilization and recovery.
f) Integration of SHGs with collectives and producers' cooperatives, ATMAs, KVKs and corporate agencies to provide them an access to information, credit, technology, markets etc. for promotion of livelihood activities in watershed areas.

### 3.3. Guiding principles of Livelihoods Improvement

The guiding principle for livelihood improvement rest upon the integrated and participatory approach and encompasses the natural resources and ecological conservation for ensuring nutritional security, income security and ecological security for the targeted beneficiaries in the watershed areas.

- **Natural Resource Based**: Livelihood improvement initiatives should emphasize on natural resource based and activities and must conform to principles of equity, gender sensitivity and transparency.
- **Participatory approach:** Assess, plan, design, implement and monitor with the participation of affected communities, paying particular attention to gender roles, responsibilities, as well as the specific needs, vulnerabilities and capacities of men and women.
- **Integrated approach:** Recognize that needs for livelihoods, food security, health, shelterand water and sanitation are integrated suitably.
- **Quality assessments:** Take a holistic (whole) view of household and community vulnerabilities and capabilities that includes a sound analysis of their coping strategies and the external environment. These include SC/ST, landless/assetless people, women, etc., to be considered on priority.
- **Form good partnerships:** Recognize the expertise of others and include coordination with local authorities and opportunities for advocacy.
- **Respect the local context:** Build on National Society and community capacities.
- **Result Oriented:** The Livelihoods improvement initiatives should able to increase household income, participation and division of labour, access to information, knowledge, appropriate technologies and resources.

When livelihoods are sustainable, vulnerable people can better cope-up with and recover fromstresses and shocks, maintain or enhance their capabilities and assets, and provide benefits to other livelihoods locally, and more widely, without damaging the natural resource base.

## 4.0 Planning and Implementation

### 4.1. Livelihood Planning

i. The agency selected for implementing the watershed programmes will also be responsible to implement the livelihood component of WDC-PMKSY 2.0.

ii. An awareness drive should be undertaken at Gram Sabha level for communication & sensitization of the target beneficiaries.

iii. A "Livelihood Action Plan" (LAP) will be a prerequisite for availing the funds under the livelihood component.

iv. The LAP is to be developed within six months after the initiation of watershed development period of 4 years.

v. The LAP should be prepared during the preparatory phase by the Project Implementing Agency (PIA) in consultation with WDT, WC and the members of SHGs, SC/ ST, women, landless/ assetless households. This plan should be an integral part of DPR. PIA may also take assistance of livelihood expert of the team/ agency specializing in livelihood sector who can be engaged on a time bound contract basis, expenditure on which may be incurred from administrative component of the project. PIA should prepare livelihood action plan for the project area before the release of 2nd instalment.

vi. To promote convergence, the PIA should work in close association with other employment generating programmes such as MGNREGS, NRLM, etc.

vii. The livelihood action plan should analyze socio-economic conditions and existing livelihood capitals of the watershed village during the situation analysis by means of PRA and focus group discussion in order to facilitate collection of information to feed into the livelihood action planning process. Livelihood action plan should contain schedule of activities, interventions, no. of SHGs to be assisted and expected outcome. An illustrative list of Livelihood options is provided in **Annexure-I** for reference.

viii. A copy of the livelihood action plan should also be made available to the concerned SHGs and Gram Panchayats.

ix. The plan may be reviewed by the PIA, if need to be, and revised in consultation with the stakeholders.

### 4.2. Mode of Operation/Implementation of Livelihood action plan

i. The livelihood action plan will be implemented through Self Help Groups and/or their federation/ FPOs/FPOs Federation.

ii. Livelihood activities can be carried out either through the existing SHGs having good performance or new SHGs formed.

iii. SHGs selected for implementing livelihood action plan should be homogeneous in-terms of their existing livelihood capitals, common interest and need.

iv. SHGs can undertake any permissible activity jointly as a group or the group may decide to support individual(s) for the activities under the umbrella of the main SHG.

## 5.0 Livelihood Sustainability

In order to sustain the vulnerable SHGs and their livelihoods, the Revolving fund of WDC-PMKSY 2.0 will have final ownership with concerned SHGs/SHG federation at GP level for need based rotation to SHGs. The option of village council shall be considered for this purpose where GP is not present.

## 5.1. Social Mobilization and Formation of Self-Help Groups (SHGs)

Mobilizing the socially and economically marginalized vulnerable communities into SHGs and imparting requisite capacity building is the first and foremost step in the livelihood improvement process. The Institutions of the poor – SHGs, their federations and livelihoods collectives - provide the poor the platforms for collective action based on the principle of self-help and mutual cooperation. They become a strong demand system and build linkages with mainstream institutions, including banks, and Government departments to address their core livelihoods issues and other dimensions of poverty. These institutions provide savings, credit and other financial services to meet their priority needs.

SHGs have proved successful across the country, particularly as centers of microcredit. Further, they have also taken up variety of livelihood activities in diverse fields. Promoting alternate livelihood activities being an important objective of a watershed project, conscious efforts should be made to make the existing SHGs as active partners in development strategy within the project area. While strengthening the existing ones, need based/resource based new ones may also be formulated. Efforts may be made to federate all SHGs to improve business opportunities.

### 5.1.1. Budget Allocation

i. 15 per cent of the total project fund is earmarked as the Livelihood Activities for the assetless persons, micro enterprises & business development under the livelihood component for the benefit of marginalized communities, including SC/ST, landless/assetless people, women, etc.

ii. The provision for livelihood activities shall be taken out of the total project fund as a grant to Watershed Committee (WC) in its bank account, which in turn will be used to provide financial assistance, (seed money for revolving fund to SHGs and a grant -in -aid for enterprising SHGs/ SHG federations to undertake major livelihood activities). However, State/UT shall have the flexibility to implement the livelihood component of WDC-PMKSY 2.0 through State agencies implementing the NRLM programme of Government of India. In such cases, the beneficiary SHGs will be selected by concerned Watershed Committee from the watershed project area only and the funding shall be made to such selected SHGs / federations with the approval of respective Watershed Committee. The benefits should be extended within the

financial limits prescribed in this Guidelines.

iii. At least 60% of this livelihood fund will be used to support revolving fund for SHGs, anda maximum of 40% for supporting grant–in–aid to enterprising SHGs/ SHG federations.

The list of activities to be promoted in the watershed area under this revolving fund is indicated at **Annexure-1**. This is only an indicative list and not an exhaustive list. WC may also consider for financing for additional emerging activities based on the local agro-climaticand ecological environment.

**5.1.2. Seed Money or Revolving Fund for SHGs**

Seed money or revolving fund may be provided to the eligible SHGs to enable them to meet the immediate credit requirements for sustenance; this mechanism will promote the entrepreneurial options among the SHG members.

This provision will facilitate the SHG members to inculcate the habit of thrift and accumulate their own funds to meet their credit requirements.

**Criteria for availing benefits:**

i. Each SHG shall make an application for financial assistance to the WC. The WC in its regular meeting will consider these applications and pass resolution regarding its approval of financial assistance to SHGs based on merit of the case. The representatives of applicant SHGs may also be present in such meetings of the WC. The resolution will clearly rank the approved cases, based on the priorities and preferences, so that the support may be extended to all the eligible SHGs in order of ranking. In case, State/UT isimplementing the livelihood component of WDC-PMKSY 2.0 through State agencies implementing the NRLM programme of Government of India, the beneficiary SHGs will be selected by concerned Watershed Committee and the funding shall be made to SHGs with the approval of respective Watershed Committee.

ii. The initial amount up to Rs.50,000 may be given as seed money to a SHG as the revolving fund after their proposed activity(s) are approved by the WC in its meeting and included in the resolution.

iii. The SHGs will return the seed money on monthly basis and that could be reinvested inthe same or other SHGs as per the resolution passed in meeting of WC. The amount and number of monthly instalments may be decided by WC based on the type of activity, capacity of the group and their savings. The amount may be returned in a maximum of 18to 24 months.

iv. The payment will be made through Direct Benefit Transfer (DBT) in the beneficiary account after the respective SHG has opened a joint bank account with two signatories from the SHG members.

v. The SHGs may use the amount for a combined activity and/ or shall provide the

above amount to the concerned members as individual loan against a specific activity for improving income.

### 5.1.3. Eligibility of SHGs

- The size of SHG should be as indicated below and not necessary to register:
  - 10 to 20 members in plain area projects.
  - 5 to 20 members in difficult/hilly areas and in IAP districts.
- From one family, only one person should be considered for membership.
- Members shuld have ideally the same social and financial background.
- The group should meet regularly (at least once a fortnight).
- Compulsory attendance (more than 80 per cent) by members with minutes book beingmaintained.
- Simple and clear books for all transactions to be maintained along with Savings and loanRegister.
- Promote individual member saving passbooks.
- 'Savings first - Credit later' should be the motto of every group member.

### 5.1.4. Criteria for Revolving Fund to SHGs

Revolving fund is the seed money provided by WDC-PMKSY 2.0 program to the SHGs functioning under WDC-PMKSY 2.0 project. The revolving fund is provided only to the eligible SHGs as per the following terms and conditions.

a) SHG or the village to which the particular SHG belongs to should stay within the projectarea.
b) The 75% SHG members should be small, marginal and landless farmers and micro-entrepreneurs
c) SHG should have undergone all the basic trainings along with the Entrepreneurial and skill trainings.
d) SHGs should be under the fold of concerned Gram Panchayat Level Federation (GPLF) or Cluster Level Federation (CLF). SHG to give a undertaking that, it will use the revolving fund for initiating livelihood promotion activities.

### 5.1.5. Funding of Major Livelihood Activities for SHGs

i. The funding for major livelihood activities will enable the enterprising SHGs/ SHG federations (with at least 5 enterprising SHGs) to avail a composite loan for undertaking major livelihood activities or to expand/upscale activities as recommended by the WC and approved by WCDC in consultation with line Departments and Bank.
ii. For such activities, a composite loan (grant in aid and bank loan) can be availed depending upon the type of activity. The grant-in-aid will be 50 % of the cost of the activity or Rs. 4.00 lakh whichever is less. However, grant in aid shall not exceed 40

% of the livelihood component of the project.

iii. SLNA may issue detailed modalities for payment of grant-in-aid for funding major livelihood activities.

iv. SLNA should ensure that the interest earned by SHGs federations on the Grant-in-aid amount will be deposited in the WDF account of WC by the concerned SHGs federation.

### 5.1.6 Seed Money for Enterprising Individuals

i. The enterprising individual shall apply for financial assistance to the WC, along with a viable livelihood proposal. While selecting beneficiaries under this component preferencemay be given to local artisans. WC in its regular meeting, will consider such applications and recommend to WCDC, through PIA. The amount is to be provided as seed money to such individual(s) after their proposed activity(s) has been approved by the WC in its meeting and included in the resolution, based on the merits of the case.

ii. The applicants may also be present in such meetings of the WC. The resolution will clearly rank the approved cases, based on the priorities and preferences, so that the support may be extended to all the eligible enterprising individuals in order of ranking.

iii. The WC may release financial assistance to these enterprising individuals after approval by WCDC. Such individuals will return the seed money on monthly basis and that could be reinvested further as per the resolution passed in meeting of WC. The amount and number of monthly instalments may be decided by WC based on the type of activity and capacity of the individual. The amount may be returned in a maximum of 18 to 24 months. The returned amount will be deposited in the WDF account by the WC.

iv. The amount for enterprising individuals is upto Rs. 20,000 per individual. Funding for this activity shall not exceed 2% of the revolving fund earmarked (60% of the livelihood component of the project) for the SHG.

v. The payment will be made in the individual bank account through DBT.

## 6.0 Support through Convergence of Schemes

Several government schemes are directed towards promoting the livelihood of the small, marginal, landless and marginalized rural population both at the central and state level. As the priorities of government both at the central and state level focuses on poverty alleviation, socio- economic development, social equity and nutritional security, there is need to leverage these relevant schemes in convergence to achieve these objectives in the watershed/springshed/ desert/mountain areas including that of north east and Himalayan regions. There is also a need ofconvergence between various government schemes and institutional financing through Financial Institutions & NBFCs.

**7.0 Capacity Building:**

a) The capacity building needs of the beneficiaries for livelihood generation in the watershed areas should be included in the action plan prepared during baseline survey. The capacity building should aim at skill enhancement and not just knowledge and information. The capacity building component should be decided in consultation with WC for making necessary budgetary provision on annual basis.
b) The expenditure for such trainings may be met from 3% of the budget provided for institution & capacity building in the project.
c) The capacity building aspects will have field visits/ exposure visit to successful livelihood activities/SHGs and SHG Federations.
d) The capacity building may relate to book keeping/financial management, post-harvest management and secondary agriculture, crafts development, marketing of minor forest products, packaging, branding, marketing, export promotion, organizational behaviour and development etc., as relevant to promoting activities of SHGs, entrepreneurs in the watershed areas.

**7.1. Key Elements of Capacity Building Strategy:**

Following may be the key components of capacity building strategies:

a) Dedicated and decentralised institutional support and delivery mechanism.
b) Annual Action Plan for capacity building.
c) Pool of resource persons.
d) Well prepared training modules and text materials.
e) Mechanism for effective monitoring and follow-up.
f) E-resources and self-learning modules in the web.

The DoLR / National Level Nodal Agencies (NLNA) may use the services of National Rainfed Area Authority (NRAA) as Knowledge Partner for capacity building activities.National Institute of Rural Development & Panchayati Raj (NIRD&PR) could help developing training schedules, operational strategies and cost norms for capacity building for States/UTs in consultation with State Level Nodal Agencies (SLNA) and other relevant organizations.

NIRD&PR will act as nodal training institution for developing various training modules and Audio-Video training programmes.

A separate segment for livelihood development programmes can be created for better monitoringof the livelihood programmes.

### 8. Livelihood Development Process

The livelihood development process takes care of the institutional framework and the interactions among the various organizations and agencies for approving the project and fund flow for overall monitoring for the development of sustainable livelihood while ensuring nutritional security, income security and ecological security. While ensuring the guiding principles of livelihood development, it follows the livelihood activities as brought out in **Annexure 1.** While the National Nodal Agency overall directs the watershed development in thecountry, the district, panchayats and watershed committee plays the crucial role in ensuring the sustainable livelihood development in the country. The entire livelihood development flowprocess is given in the Figure 2.0 below.

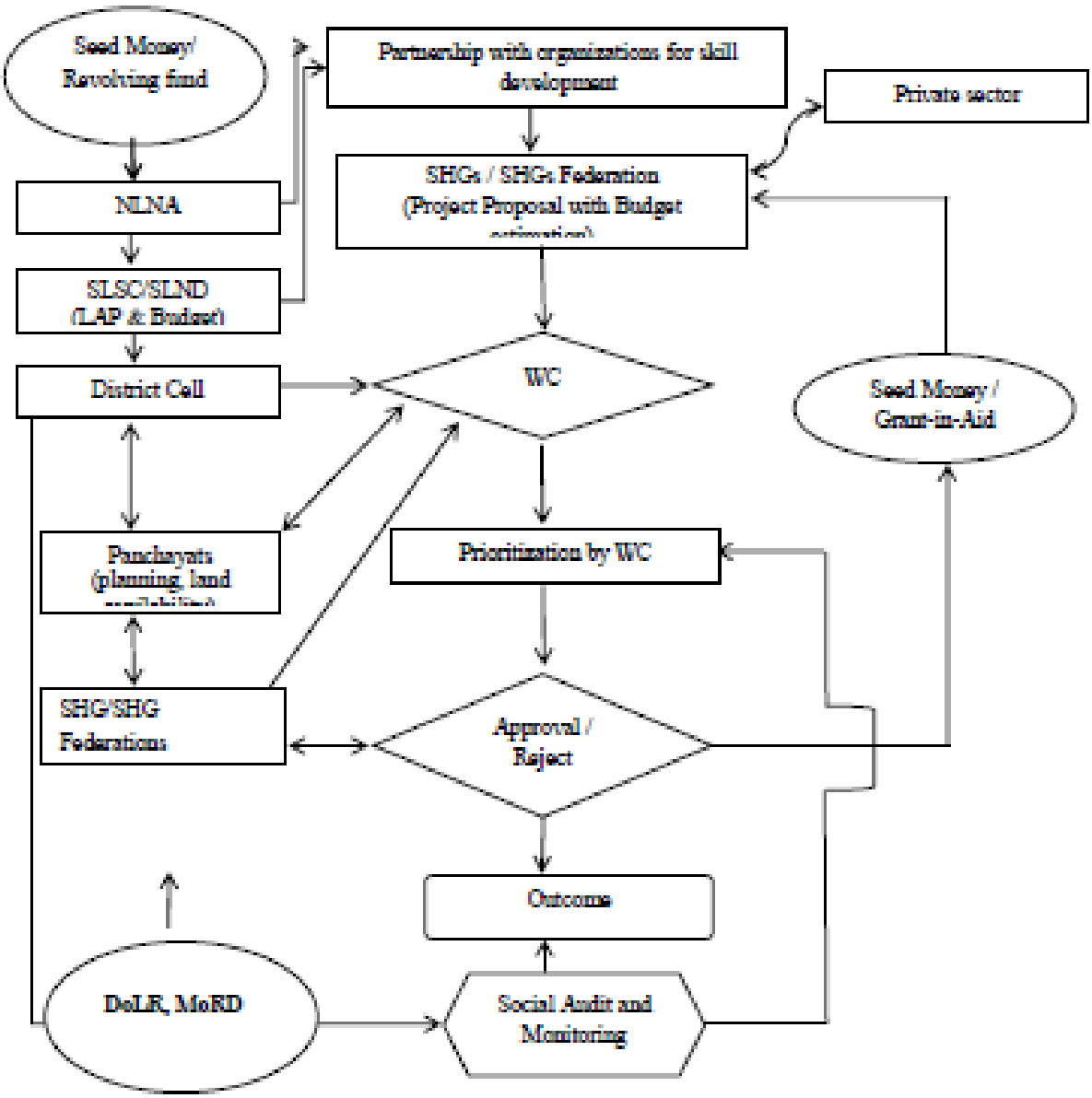



**Fig. 2.0 Livelihood Development Process**

## 9. Project Monitoring

It is essential to monitor the livelihood development in the watershed areas to bring qualitative improvements in effective execution of targeted activities at field level. The Project Monitoring Cell will be set up at State/District/Block level involving the representatives of respective organizations.

The PIA shall submit quarterly progress reports (countersigned by the Watershed Committee (WC) President/competent authority) to SLNA. The designated Nodal Officer may be nominatedfor this purpose.

The district level officials have to ensure that the monthly progress report is uploaded by all blocks. The consolidated information at the district level may be perused for monitoring the scheme progress.

**Annexure-I**

## Indicative list of livelihood options under PMKSY-WDC 2.0

In a scenario wherein the per-capita income of a rural household is far less than that of urban household, especially in the age of booming e-commerce, the increasing flow of money from rural to urban areas is a cause of concern. The need is to transform the situation from 'rural people as consumers of industrial goods' to 'rural people as producers of industrial grade output, especially the population related to farming. Secondary Agriculture in such a case is expected to bring about a shift in the direction of flow of money from urban to rural areas, especially through meeting the demand for value addition or pre-conditioning services from the food processing industries in urban areas. The various avenues for earning a sustainable livelihood are listed below.

Broadly, the avenues of Secondary Agriculture can be categorised into three types:

1. **Type I:** Value addition to Primary Agriculture Production Systems
2. **Type II:** Alternative Enterprises
3. **Type III:** Enterprises that use crop residues and wastes of Primary Agriculture

### 1. Type I: Value addition to Primary Agriculture Production Systems

This category broadly contains activities with respect to **(a)** inputs; **(b)** production systems; and **(c)** harvest / post-harvest segments of the agriculture value chains.

This category summarizes crafts that add value to the primary agriculture activity. Alternatively stated, the activities of secondary agriculture in this sphere principally hinge on the agricultural activities. In the process of augmenting the productivity improvement in crop cultivation or other production systems of primary agriculture, these options also produce supplementary income for the rural youth.

### A. On-farm input production

1. Nursery for field crops, horticulture crops, forest species including medicinal, aromatic anddye plants;
2. Certified organic seeds;
3. Vermicompost, vermi-wash;
4. Components of Natural Farming/Organic Farming: *Beejamrit*, *Jeevamrit*, *Agniastra*, *Ghanajeevamrit;*
5. Anaerobic digested compost - FYM, compost;
6. Bio-fertilizer production *e.g.*, Azolla, Blue Green Algae;
7. Green manure and its seed production *e.g.*, Dhaincha (*Sesbania*), Sunnhemp *etc*.;
8. Animal feed/fodder including urea enriched straw blocks;
9. Bio-pesticides: ITK based-concoctions, bio/plant extracts, *etc*.;

**B. On-farm production**

B.1. Organic / natural products - high value flowers, fruits, vegetables, spices, condiments, tea,coffee, medicinal, aromatic and dye plants *etc*.

**B.2. Organic/natural or conventional production including milk and meat processing**

2.1. Dairy;
2.2. Poultry, ducks, goats, turkey, sheep, rabbit farming, piggery, Emu farming;
2.3. Composite pisciculture; and prawns, shrimp, lobster farming;
2.4. Canine/pet breeding; and
2.5. Equine breeding.

**C. Harvest / Post harvest processing and value addition of farm produce**

i. Primary and secondary value addition: pre-conditioning produce for markets of fruits,vegetables, flowers, spices, *etc*.;
ii. Assaying, packaging, pre-cooling and dispatch hubs/units;
iii. Micro and Small Enterprises for garlic extracts / paste, ginger processing (flakes, powder), turmeric powder, products, pickles, jams, canning, solar drying, *etc*.;
iv. Makhana (Prickly water lily, *Euryale ferox*) products;
v. Edible oil expellers;
vi. Mills for pulses (*Dāl* mills);
vii. Ornamental breeding;
viii. Flavouring agents;
ix. Natural dyeing agents;
x. Ayush medicine units;
xi. Aromatic/essential oil production - lemon grass, patchouli, eucalyptus, *etc*.;
xii. High value oil production - lavender, periwinkle, drumstick, thyme, primrose, clove *etc*.;and
xiii. Confectionery - indigenous specialty products;

**2. Type II: Alternative enterprises**

Different professions that can create income without competing for the resources (land and manpower) engaged in primary agriculture comprise the Category 'B' of Secondary Agriculture avenues. While these vocations have been adopted in different parts of the country, mainstreaming them through specific promotional activities and incorporating into various department schemes and funding support opportunities are equally important. Since, these vocations need specific skill sets and equipment, special provisions that support the vocations areto be put in place. For the fact that several of these vocations do not have mature markets, efforts to establish their supply chains and integrating them into the markets need to be addressed/ensured.

**Indicative list of alternative enterprises for sustainable livelihood**

1. Apiary incl. beeswax, royal jelly *etc*.
2. Mushroom production
3. Coir/fibre-based products - banana, sunnhemp, coconut *etc*.
4. Snake venom farming
5. Hydroponics
6. Agro-processing (corn powder production, pulses, turmeric, ginger, lac, forest produce)
7. Fruit and vegetable processing
8. Custom hiring centers
9. Rural tourism/organic agri eco-tourism/ homestays
10. Palmyra palm products
11. Broomstick production
12. Kitchen gardening / Terrace farming
13. *Aloe vera* farming
14. Ram servicing
15. Bull servicing
16. Eucalyptus / mint farming
17. Bamboo products
18. Mahua products - wine, plates *etc*.
19. Integrated farming (bee-keeping, piggery, goat rearing, duck rearing, back-yard poultry)
20. Babui grass products
21. Cosmetics/toiletries production (MSME based)
22. Incense stick production
23. Lac cultivation - gums and resins products
24. Sericulture and silk products
25. Weaving - fibre crops (cotton, rabbit, sheep and yak wool *etc*.)
26. Black smithy
27. Handicrafts/carpentry/sculpting – wood craft (MSME based)
28. Handloom/tailoring/knitting/candle making *etc*. (MSME based)
29. Beverage units
30. Winery/breweries based on location-specific grains/fruits/flowers
31. Skin and hides products (MSME based)
32. Local petty shop
33. Repairing shop
34. Tent house business
35. Brick kiln

**3. Type III-Enterprises that rely on residues and wastes of primary agriculture**

These enterprises of secondary agriculture establish several income generation activities thatutilize residues and wastes of different field crops, horticulture crops, products of animal originand forest produce on the concept of "waste to wealth" completing the circular economy emanating from agriculture. The economic products of primary agriculture activities directly contribute to the economy and to the income of rural households; while periodically the residues and wastes of crops and animals also offer prospects of income generation.

Several crop residues such as corn cobs, cashew apples, groundnut shells, are employed for the production of industrial chemicals. The production of chemicals from such agricultural waste invites huge investments and infrastructure; whereas, the activity of the waste aggregation, pre- conditioning and supply (supply chain management) to the industries can be a prospective opportunity to create employment and income generation in the rural areas that can supplement the existing income levels of rural households. These possibilities of rural-urban industrialisation appear practicable; however, their techno-commercial feasibility requires evaluation and piloted before such avenues are explored for rural households.

1. Cotton stalk products;
2. Dung logs, bio-gas, leather extracts, *etc*.;
3. Fibre boards *etc*., from rice straw, corn stover *etc*.;
4. Urea enriched fodder block from rice straws;
5. Agave/banana fibre extraction and products; and
6. Cutlery from wheat husk, arecanut leaves, *etc*.

***Note:*** *This list is an indicative but not exhaustive. The District Watershed Cell, GP & local WCs may promote other relevant livelihood activities based on geographical, agro-climatic and economic conditions prevalent in the area.*

**Annexure-2**

**List of Institutes**

1. Krishi Vigyan Kendras (KVKs)
2. State Agricultural Universities (SAUs)
3. National Institute of Rural Development & Panchayati Raj (NIRD&PR), Hyderabad.
4. National Institute of Agriculture Marketing (NIAM), Jaipur
5. National Remote Sensing Centre (NRSC)
6. Central Institute of Post-Harvest Engineering and Technology (CIPHET), Ludhiana
7. National Institute of Food Technology Entrepreneurship and Management (NIFTEM),Sonipat
8. Agricultural and Processed Food Products Export Development Authority (APEDA)
9. Central Food Technological Research Institute (CFTRI)
10. Indian Institute of Technologies (IITs)
11. Indian Institute of Management (IIM)
12. Sill Development Universities in the States
13. Agriculture Skill Council of India, Gurugram
14. National Institute of Technology (NIT),
15. National Institute of Agricultural Extension Management (MANAGE), Hyderabad.
16. Central Arid Zone Research Institute (CAZRI), Jodhpur.
17. Indian Institute of Soil and Water Conservation (IISWC), Dehradun.
18. Central Research Institute for Dry land Agriculture (CRIDA), Hyderabad.
19. Water Technology Centres (WTCs)
20. Institute of Rural Management (IRMA), Anand
21. Indian Institute of Forest Management (IIFM), Dehradun
22. Soil and Land Use Survey of India (SLUSI), Delhi.
23. Central Agro-forestry Research Institute (CAFRI), Jhansi.
24. Indian Council of Forestry Research and Education (ICFRE)
25. National Bureau of Soil Survey & Land use Planning (NBSS&LUP), Nagpur.
26. Bankers Institute of Rural Development (BIRD)
27. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad
28. Indian Grassland & Fodder Research Institutes (IGFRI), Jhansi

**References:**

Alyssa Gregory, 2019, How to Conduct a SWOT Analysis for Your Small Business: https://www.thebalancesmb.com/swot-analysis-for-small-business-2951706

Basic module on business planning for livelihood promotion-Practitioners guide, February 2008

FAO, 2006, Building on gender, agrobiodiversity and local knowledge-A training manual, Module-2

Guidelines for New Generation Watershed Development Projects (WDC-PMKSY 2.0), 2021, Department of Land Resources, Ministry of Rural Development, sGovernment of India, Page 65 & 66

Institute of Agricultural Technologists,2006, Manual on Comprehensive Watershed Development, Department of Agriculture, Government of Karnataka

Myra Nizami, 2021, SWOT Analysis Examples: https://smallbiztrends.com/2021/11/swot-analysis-examples.html

Planning and Developing Community Micro-Enterprise, Dyutiman Choudhary, Ahmad Javid Ghyasi, Sima Rezai

Training Manual Soil and Conservation and Watershed Management. 2007. V. N. Sharda, G. P. Juyal, Chandra Prakash and B. P. Joshi. Central Soil and Water Conservation Research and Training Institute, Dehradun Uttaranchal India