Chapter- 1
Introduction

1.1 Background

The Orissa Tribal Empowerment and Livelihoods Programme (OTELP) is being implemented in selected tribal belts of Orissa where poverty and deprivation are passive. The purpose of the programme is to ensure that the livelihoods and food security of poor tribal households are sustainably improved through promoting more efficient, equitable, self –managed and sustainable exploitation of natural resources and their disposal through off-farm/ non-farm enterprise development. Livelihood enhancement includes land and water management, participatory forest management, improvement in agricultural productivity, improved access to rural finance services and development of community infrastructures. The land and water management sub-component in the programme has higher allocation of funds which is used at community level. The half yearly review mission had recommended for developing a land and water management manual for Subject Matter Specialists of ITDA, WDT members of FNGO and for the village leaders/ volunteers. The manual in English with technical details will be useful for the SMS/WDTs whereas for the villagers/village volunteers it has to be prepared in Oriya with more of illustrations in a user friendly manner.

1.2 Importance of Land and water management

Better land and water management are critical to improvement of human well being in the drought-prone areas. High-population pressure, highly variable and unreliable rainfall, and steep topography have accelerated the process of land degradation in the largely unprotected watersheds in tribal areas of the state. Rapid deterioration in land quality has reduced the already insufficient food production of the region. Integrated Watershed Management (IWM) is "a ***process*** of managing human activities in an area defined by watershed boundaries in order to protect and rehabilitate land and water, and associated aquatic and terrestrial resources, while recognizing the benefits of orderly growth and development." The integrated watershed management (IWM) approach is tested in many places to rehabilitate the watershed in Orissa. The major characteristics of the IWM approach are involvement of those most affected by the decisions (i.e., the stakeholders) in all phases of the development of their watershed, holistic planning, which addresses issues that extend across subject disciplines (biophysical, social, and economic), institutional divisions, and political boundaries. As part of the IWM the physical and biological soil and water conservation measures on the arable and non-arable land are very important. Keeping this in view this manual on land and water management has been prepared.

1.3 About this manual

The purpose of developing this manual is to provide a consistent approach to a variety of land and water management options that may be suitable to watershed dwelling communities in hilly and tribal areas of Orissa. The manual is directed at the management of land and water in new developments and redevelopment watersheds. This manual has been developed for WDT members of watersheds, engineers, planners, scientists and managers working in local government, state government agencies etc.

The manual comprises a suite of guiding papers that are relevant to the management of land and water in micro-watersheds in accordance with best management practices. The stand-alone chapters allow for ease of reference, handling and updating. The introduction outlines the purpose of the manual, its intended users and benefits while rests of the sections are dedicated to specific conservation measures. The manual provides a basket of options and a particular recommendation(s) need to be adapted to suit particular sites and circumstances. It is suggested that the recommendations are adopted after having carefully considered the circumstances prevailing within the watershed area and recognizing the fact that land and water management techniques should not be implemented in isolation, but as part of an overall management plan.

This manual has been prepared by the Team Consultants of Overseas Projects and Services Ltd with consultation, guidance and advice from the experts and findings of case studies. The team consists of highly experienced agricultural engineer and agriculturist. Each chapter has been prepared by the consultants with their expertise in particular areas. Prior to preparation of the manual there was vivid discussion with the PSU about the structure and contents of the manual. The OTELP appraisal report was also referred to while selecting the contents. Several reference materials were used to capture technical information on watershed rehabilitation, land and water management and dry land farming. Basing on the terms of references (Annex I) the manual was drafted and submitted to the PSU, OTELP for necessary comments. On receipt of feedbacks from the PSU the draft manual has been revised and reproduced in a presentable form. Designs, drawings, illustrations and estimates have been provided in the manual to make it user-friendly.

Chapter- 2
Land Resources in Watersheds

2.1 What is a Watershed?

Watershed is a geo-hydrological unit where all the excess rainwater empties through a common point in a given area; evidently it is covered by a ridge line. In any village the elevated area may be identified and with a good rain event the drainage lines can be recognized on a cadastral map. The area encompassing this drainage system is a watershed. Watershed has no physical dimension. It could be as small as 4-10 ha to as big as 25,000 ha.

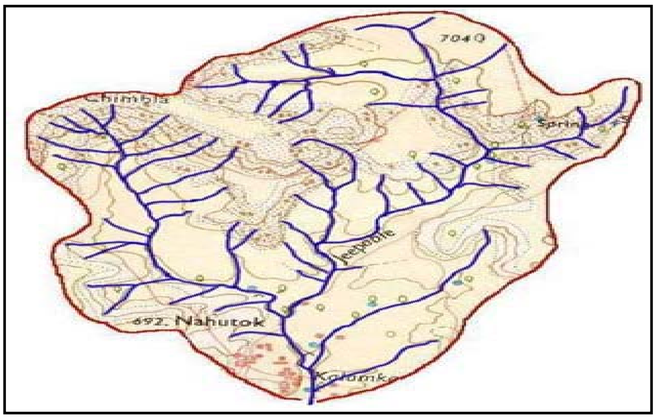


Fig. 2.1 A typical hydrological unit, the watershed

Land, water and biological features are important resources in a watershed. Land could be arable or non-arable. Therefore land capability classification is very important from watershed planning point of view.

2.2 Land Capability Classification

The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), has distinguished eight classes of land capability according to the risk of land damage or the difficulty of land use.

Table2.1 Land Capability Class Rating

Class	Texture	Soil depth	% of slope	Erosion class and symbol		
				Effect of erosion	Susceptibility to erosion	Permeability class
I	H,L,SL	d5	A	e_1	Very far away	2
II	H, SL	d4	A/B	e_2	Minimum 60 m	2/3
III	H, SL	d3	B/G	e_2	6-60 m from A class slope	1 to 3
IV	H, S	d2	B/C	e_3	-	All classes
V	As in Class I			e_4	Marginal land	3
VI	-	d1	C/D	e_4	Gully sides and sand dunes	-
VII	-	d1	C/D	e_4	Gully sides and beds	-
VIII	-	Rock	C/D	-	-	-

Increased Land Use Intensity →

Increased limitations and hazards ↑ Decreased choice of crops ↓

Land Capability	Wild Life/Recreati	Forestry/ Dry land Fruits	Grazing			Cultivation			
			Limited	Moderate	Intensive	Limited	Moderate	Intensive	Very Intensive
I									
II									
III									
IV									
V									
VI									
VII									
VIII									

Capability subclasses are soil groups within one class. They are designated by adding a small letter, *e, w, s,* or *c,* to the class numeral, for example, 2e. The letter *e* shows that the main hazard is the risk of erosion unless close-growing plant cover is maintained; *w* shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); *s* shows that the soil is limited mainly because it is shallow, droughty, or stony; and *c* shows that the chief limitation is climate that is very cold or very dry. In class 1 there are no subclasses because the soils of this class have few limitations. Class 5 contains only the subclasses indicated by *w, s,* or *c* because the soils in class 5 are subject to little or no erosion. They have other limitations that restrict their use to pasture, rangeland, forestland, wildlife habitat, or recreation.

General types of conservation practices and uses recommended for different land capability classes which are shown in Table.

Table 2.2 General Types of Conservation Practices Required for Different Arable Lands

LCC	Sub-class	Suitable for	Special needs or precautions
Light green on map- very good soil	Deep	Intensive cultivation	No special difficulty in farming
Yellow on map-Good cultivated land	IIe	Cultivation with precaution	Protection from erosion. Use conservation irrigation method
	IIw	Cultivation with management of excess water and selection of crops	Drainage improvement
	IIs	Cultivation with selection of crops to soil limitations	Treatment to offset soil limitations and to conserve irrigation water
Red on map- Moderately good cultivated land	IIIe	Cultivation with precaution against permanent land damage	Special attention to erosion control and conservation irrigation

	IIIw	Cultivation with careful management of excess water and selection of crops	Intensive drainage improvement or protection from flooding
	IIIs	Cultivation with careful selection of crops adapted to soil limitations	Intensive treatment to offset or overcome soil limitations and conserve irrigation water
Blue on map- Fairly good land	IVe	Occasional cultivation with pasture and orchards	Intensive erosion control when in cultivation
	IVw	Cultivation of special summer crops	Intensive drainage
	IVs	Occasional cultivation with rotation	Very intensive treatment
	IVc	Cultivation during wet years	Conserve all rainfall-develop water for irrigation or put for grazing use

Soil Characteristics

Land capability classification is done on the basis of soil characteristics such as soil texture, depth, erosion, permeability and slope. Soil provides physical anchorage to plants and act as store house for water and nutrients needed. Soil environment is needed for better germination, growth and yield of crops. Soil fertility is the inherent capacity of soil to supply nutrients to plants in adequate amount. Soil productivity is the capacity of soil to produce crops. All productive soils are fertile, but all fertile soils may not be productive. The physical, chemical and biological properties of soil need to be favourable for crop production. Soil inventory in watershed should include:

- Colour
- Depth
- Texture of top soil
- Permeability of top soil
- Permeability of sub-soil
- Slope
- Erosion status

Soil Colour

Soil colour may be red, black, grey, brown, yellowish, whitish or their mixtures like reddish brown, yellowish red etc.

Depth

The soil depth classes are generally notified as follows.

Symbol	**Class**	**Depth range**
d1	Very shallow	0-7.5 cm
d2	Shallow	7.5-22.5 cm
d3	Moderately deep	22.5-45.00 cm
d4	Deep	45.00-90 cm
d5	Very deep	Above 90 cm

Soil Texture

Soil texture can be determined by feel method or laboratory method. By feel method a lump of soil collected from plough zone is squeezed to form a ball and as per feel of the ball soil texture could be determined as explained below.

Feel of finger	Ball formation	Stickiness	Ribbon formation	Texture	Texture class and symbol
Very smooth	Hard ball when dry	Sticky, strains finger	2-5 cm ribbon	Fine	Clay (C), Silty clay (SiC), Sandy Clay (SC)
Smooth	Moderately hard ball	-do-	-do-	Moderately fine	Silty Clay Loam (SCL), Clay Loam (CL)
Floury	Firm Ball	-do-	No	Medium	Loam (L)
Moderately gritty	Easily breakable ball	Strains finger	No	Coarse	Loamy Sand (LS)
Gritty	No ball formation	Slightly strains finger	No	Coarse	Loamy Sand (LS)
Very gritty	No ball formation	Does not strain finer	No	Very coarse	Sandy (S)

For the purpose of land classification four classes, i.e., Heavy (H), Loam (L), Sandy Loam (SL), and Sandy (S) are considered. Group 1 and 2 as heavy, 3 as loam, 4and 5 as sandy loam and 6 as sandy are taken.

Depending on particle size 12 textural classes of soils are recognized. The proportion of different soil separates in different textural classes is mentioned in Table 2.3.

Table: 2.3Textural Status of Soil

Sl. No.	Textural class (from light to heavy)		Clay percentage		Silt percentage		Sand percentage	
			Min.	***Max.***	***Min.***	***Max.***	***Min.***	***Max.***
1.	Sand	S	0	9	0	7.5	88.5	100
2.	Loamy sand	Ls	0	13	3	25	72	97
3.	Sandy loam	Sl	8	21	0	13	66	92
4.	Loam	L	11	26	9	25	49	80
5.	Silt loam	Sil	0	26	25	50	24	75
6.	Silt	Si	0	26	50	100	0	50
7.	Sandy clay loam	Scl	17	31	0	9	60	83
8.	Clay loam	Cl	21	40	6.5	25	38	72
9.	Silty clay loam	Sicl	26	40	25	26	0	49
10.	Sandy clay	Sc	26	51	0	6.5	42.5	74
11.	Silty clay	Sic	40	75	26	60	0	38
12.	Clay	C	31	100	0	25	0	69

Permeability

The entry of rainwater into the soil is through its surface which is called permeability. The permeability classification is given below.

Symbol	Permeability class	Rate of flow (cm/ hr)
1	Very slow	Less than 0.13
2	Slow	0.13-0.5
3	Moderately slow	0.5-2.0
4	Moderate	2.00-5.00
5	Moderately rapid	5.00-13.00
6	Rapid	13.00-25.00
7	Very rapid	Above 25.00

For land classification we may divide the above classes into three broad classes viz. slow (1to2), moderate (3&4), and rapid (5, 6 & 7).

Soil water

It is also important to know the availability of soil moisture in soil.

In addition to laboratory methods, in field we can judge the moisture level by **appearance and feel method** which is explained hereunder:

Available soil moisture (in %age)	Feel or appearance of soil		
	Coarse texture	**Medium texture**	**Fine texture**
0-25	Dry, loose, flow through fingers	Powdery, dry, may be slightly crusted, but easily broken down to powder condition	Hard, baked, cracked, sometimes have loose crumbs on surface
25-50	Appears to be dry, but do not form ball	Somewhat crumby, but holds together from pressure	Somewhat pliable, forms ball under pressure
50-75	Tends to ball under pressure, but not holds	Forms a ball somewhat plastic and slightly stick with pressure	Forms a ball, ribbons out between thumbs and fore finger
75-100 (field capacity)	Forms weak ball, breaks easily	Forms ball, very pliable, sticks readily if relatively high in clay	Easily ribbons out between fingers
At field capacity	On squeezing no free water appears on soil but wet outline of ball is left on hand	On squeezing no free water appears on soil but wet outline is left on hand	On squeezing no free water appears on soil but wet outline of ball is left on hand
Saturated	Water appears on ball and hand	Water appears on ball and hand	Water appears on ball and hand

Slope

Slope of the land determines most of the land management systems. Generally speaking no soil conservation measures are needed if the slope is less than 1% in heavy soil and 2% in light soil. Under field condition an 'A' frame could be used for measuring the slope. For field conditions the slope can be categorized as follows.

Symbol	Slope class	Slope %	Land management
A	Nearly level	0-2%	No conservation measure
B	Moderate slope	2-6	Bunding/ terracing
C	Steep	6-33	Half moon terracing

D	Very steep	Above 33	Permanent vegetation

Soil Erosion

Soil erosion is the process of detachment of soil particles from the parent body and transportation of the detached soil particles by water and/ or wind. **Water erosion** causes severe soil erosion and this category of soil erosion can be distinguished in three forms, namely sheet erosion, rill erosion, and gully erosion.

Sheet erosion, although less noticeable than other types of erosion, typically is the main erosive force. Sheet erosion is less noticeable, as it does not leave obvious cuts in the soil surface as with rill or gully erosion. Sheet erosion is the removal of a relatively uniform, although thin, layer of soil from the land surface by unchannelled runoff, or sheet flow. This type of erosion is very menacing, since it keeps the cultivator almost ignorant of its ill effects. It is usually neglected, although the soil deteriorates slowly and unnoticeably. Its existence, however, can be detected by the muddy colour of the run-off from the fields.

Rill erosion is the process by which numerous small channels--less than three inches in depth--are formed. This type of erosion results from concentration of overland water flow associated with sheet erosion.

Sheet and rill erosion leads to gully erosion as shown in Fig 2.2 & 2.3.

Fig. 2.2 Sheet and rill erosion leading to gully formation

Gully erosion, including ephemeral gully erosion, refers to the cutting of narrow channels resulting from concentration of sheet and rill flow of runoff water. Ephemeral gullies are small channels of approximately 3 to 12 inches deep. Gullies may be one to several feet deep. Gully erosion occurs when rill erosion is neglected (Fig 2.4). The tiny grooves develop into wider and deeper channels, which may assume a huge size. This state is called ‘gully‘ erosion. Gullies are the most spectacular evidence of the destruction of soil. The gullies usually deepen and widen with every heavy rainfall. They cut up large fields into small fragments and, in course of time, make them out of shape for cultivation.

Stream-bank erosion occurs when torrents or hill streams come down by wide-spreading beds on emergence from the hills with ill-defined banks, flashy flows and swift currents (Fig 2.5). Usually, they are dry watercourses, except during the rainy season when with every downpour in their catchment areas, they get exceedingly swollen with flood and subside almost to its normal tiny size immediately after the storm is over.

Fig.2.3 Sheet and Rill Erosion

Fig.2.4 Severe gully erosion

Fig.2.5 Stream bank erosion

Ravine formation begins along river sides and encroaches upon the catchment area by headward growth. Active gully systems commonly develop in unconsolidated materials due to changing patterns of land use and associated change in catchments hydrology. Monitoring gully development has provided important information on processes, rates and geomorphologic controls of gully initiation and its growth.

Fig.2.6 Ravine erosion

Wind erosion takes place normally in arid and semi-arid areas that is devoid of vegetation, where the wind velocity is high. The soil particles on the land surface are lifted and blown off as dust storms. When the velocity of the dust-bearing winds is retarded, rough soil particles are deposited in the form of dunes. Thus, fertile lands are rendered unhealthy for cultivation. In other places, fertile soil is blown away by winds and the subsoil is exposed, as a result the productive capacity of the soil is considerably reduced.

When the intensity of rain is more than 25 mm/ hr, soil erosion can be expected. The classes of erosion could be as follows:

e_1 Sheet erosion

e_2 Sheet and rill

e_3 Sheet, rill and small gullies

e_4 Gullied land

e_5 Very severely gullied

2.3 Land Degradation

Land degradation generally signifies the temporary or permanent decline in the productive capacity of the land (UN/ FAO definition). It refers to a decline in the overall quality of soil, water or vegetation condition commonly caused by human activities. Degradation includes soil erosion, rising water tables, salinity and alkalinity, land slides, stream bank instability and poor quality of water.

Causes of Land Degradation

The current trend of economic and industrial development coupled with the steady growth of human as well as livestock population has been the major reasons behind the incidence of land gradation in India. The factors responsible for land degradation are:

- Soil erosion
- Water logging
- Soil acidity and salinization
- Soil pollution
- Deforestation
- Loss of vegetative cover
- Weed infestation
- Brick making and mining

2.4 Land Improvement

The interventions like soil conservation measures, rehabilitation of waterlogged land, soil amendment to correct acidity and salinisation, afforestation, agro-forestry, cover crops, management of weeds, water management and nutrient management would help improvement of degraded lands for sustainable use.

Chapter -3
Different Models of Land and Water Management

3.1 Description of Four Models

Under OTELP, the soil and water conservation work adopts an integrated intervention, which targets the whole area from the up-stream catchments to downstream command within the same micro-watershed in order to prevent erosion from up-stream slopes and sedimentation in the downstream water bodies. For this purpose, four models, namely: 1) Model A (intervention upstream with slope >20%), 2) Model B (intervention in the middle part of the micro-watershed with slope 10-20%) and 3) Model C (intervention in the downstream command areas within 3-10% slope) and Model D (intervention in downstream command areas with slope less than 3 per cent) may be adopted. For each model, installation structures are classified into three components: i) embankment, ii) gully plugging and iii) catchment conservation. Briefs of four models are described in Table below and depicted in the figure subsequently.

Table 3. 1: Brief Description of Four Models

Model Name	Terrain Conditions	Major Installation Structures
A. Model 1 (intervention of the upstream)	- Narrow valley - Steep slope (more than 20%) - Small catchment less than 5 ha - Water spread area around 2 ha	1) Embankment (if required) - Small earthen check dam 2) Gully plugging - Ave.5 nos.: 3 pallasiding work, 2 brush wood check dam 3) Catchment conservation - Plantation with staggered contour trench for 2 ha - Plantation with half moon terrace for 2 ha - Mulching
B. Model 2 (Intervention for the middle-part of the micro-watershed)	- Narrow valley - Steep to moderate slope (10-20%) - Small catchment less than 10 ha	1) Embankment (short embankment less than 20m, surface water body less than 0.5 ha) - CC Core embankment - Mud core embankment - Submerged spillway - Partially submerged spillway 2) Gully plugging - Ave.5 nos.: 3 pallasiding work, 2 brush wood check dam- every 50m in the stream 3) Catchment conservation - Bench terracing 500m - Plantation with half moon terrace - Staggered contour trenches - Plantation along rivers and stream banks - Mulching
C. Model 3 (Intervention for the downstream command areas)	- Wide valley - Gentle slope (3-10 %) - Small catchment less than 20 ha - Water spread area around 2 ha	1) Embankment (less than 20m, average 40m, surface water body less than 2 ha) - CC core embankment - Mud core embankment - Submerged spillway - Partially submerged spillway 2) Gully plugging

		- Ave.5 nos.: 3 pallasiding work, 2 brush wood check dam 3) Catchment conservation - Check dam - Contour bunding for 1000m - Bench terracing for 3 ha - Plantation around water body and along rivers/stream banks - Mulching
D. Model 4(Intervention for the downstream command areas	- Wide valley - Gentle slope (less than3 %) - Small catchment less than 40 to 50 ha - Water spread area around 3-5 ha	1) Embankment (less than 20m, average 40m, surface water body less than 5 ha) - CC core embankment - Mud core embankment - Submerged spillway - Partially submerged spillway 2) Gully plugging - Ave.5 nos.: 3 pallasiding work, 2 brush wood check dam 3) Catchment conservation - Check dam - Field bunding - Contour bunding for 1000m - Bench terracing for 3 ha - Plantation around water body and along rivers/stream banks - Mulching Integrated farming system

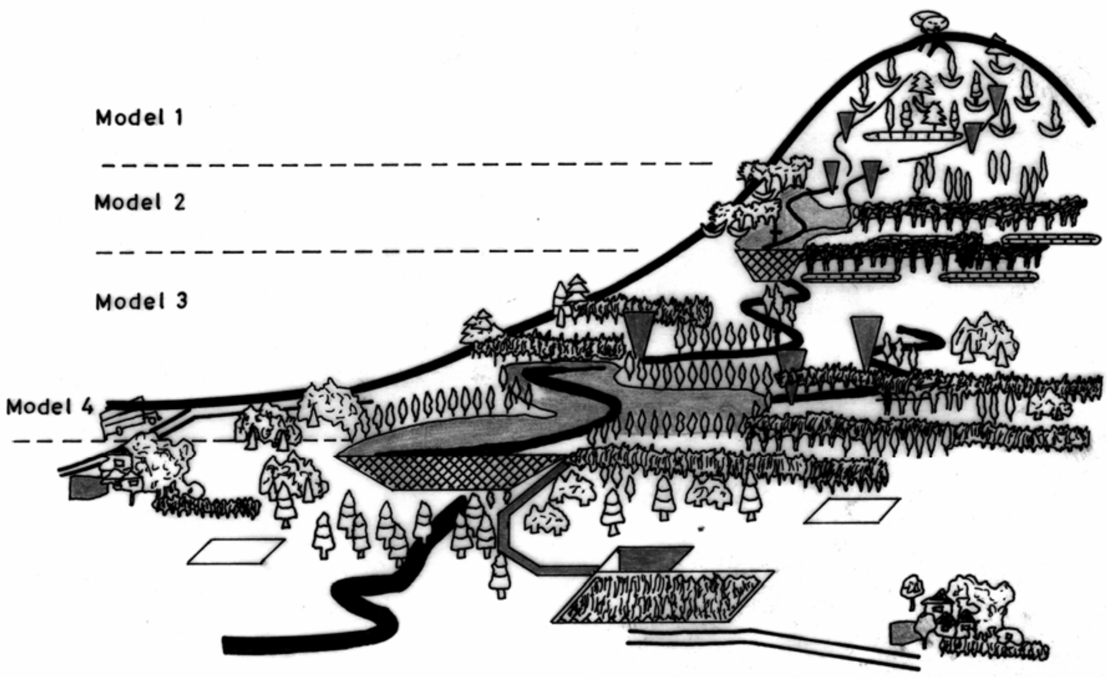


Fig 3.1 Four Models

3.2 Details of Each Measure

Details of each component are described below along with model designs of major works.

(i) Construction of Embankment (Water Harvesting Structure)

Purpose	Check dams are constructed to harvest water and cut peak flows in order to moderate floods, meet critical irrigation needs, provide sediment storage, and store water for live stock use, pisciculture and environmental improvement through on site and off site effects.
Necessary work	Required earthen embankments with spillways and planting around water bodies.
Earthen embankments (Model 2 and 3)	On wide valleys with gentle slopes (<10%), long earthen embankments will be constructed with relatively large water surfaces (< 2.0 ha). On narrow valleys with moderate slopes (10-20 %), small earthen embankments will be constructed with relatively small water bodies (<0.5 ha). Key trenches should be excavated into impervious foundation structures to prevent embankments from collapsing. Impermeable core walls will be introduced to prevent seepage and collapsing of embankments. While concrete-type core walls are sometimes adopted, mud core walls would be considered at sites where suitable soils for impermeable core walls are easily obtained. Types of core wall can be decided from the results of soil surveys at the detailed design stage. Spillways are to be lined with brick mortars to prevent erosion from the slopes. Down-stream side slopes of the embankment are to be covered by grass turfing. Up-stream side slope surfaces of the embankment are to be lined with vegetative materials, such as bamboo net with mud/cement plaster, to reduce seepage and prevent scouring by run-off water. Coconut leaves / banana leaves may be introduced to the bottom of down-stream side slopes of the embankment as water weeping material. Water harvesting structures are to be maintained in the same way as for maintenance / reinforcement of earthen embankments and de-siltation of water bodies. Yearly maintenance is to be conducted from the 2nd year to the 5th year, in which includes earth work on the embankment and slope to tackle the rills, rain cuts. Reinforcement of vegetation viz., grass turfing will be also carried out wherever necessary to prevent the erosion over the soil surface. De-siltation of water bodies are to be carried out in the 5th year in order for water bodies to keep volume of water storage. The cost for the maintenance is to be covered by the project. The maintenance cost after completion of the project should be borne both by the UGs/VLSC and the VDC.
Planting around water bodies (Model 2 and 3)	Around water bodies, bamboo plantations and NTFP plantations are to be established to reduce the amount of soil flowing from the slopes into the water and to prevent sedimentation.
Remarks	Followings should be considered and carried out in the detailed design of earthen embankments, - drawing up of both longitudinal sections of the site at 10 m intervals and cross sections need to design adequate sized embankments, - surveying of the soils at the sites to decide kinds of core walls, - calculation of water discharge and designing of adequate sized and

	designed spillway, - consideration of possibility of seepage of water from the embankment basement and embankment itself, and, - Checking of characteristics of the earth for embankment.

Designs of earthen embankment

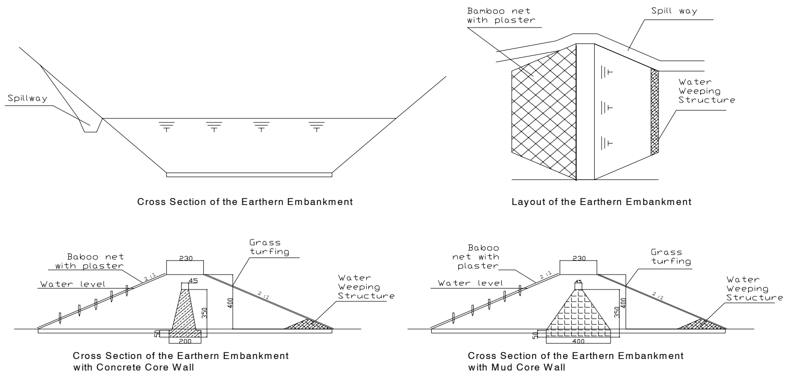
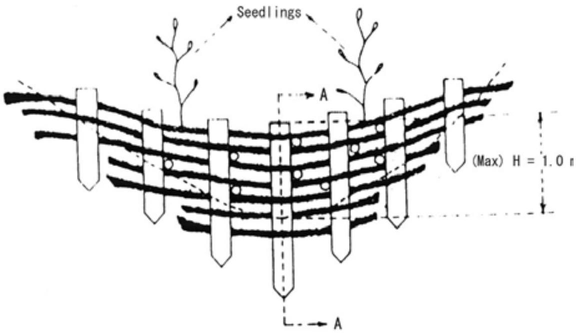


Fig : 3.2 Designs of earthen embankment

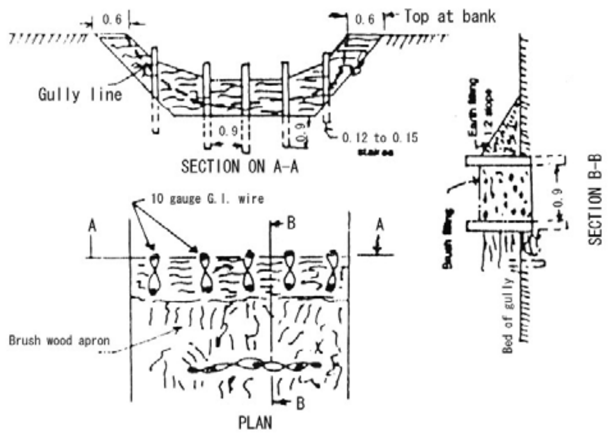
(ii) Gully Plugging Work

Purpose	Gully plugging work is required for reduction of runoff velocities within permissible limits and for controlling gully erosion of micro-watersheds. Appropriate gully plugging works would be selected from brush wood check dams, pallasiding works, gabion structures, sunken pits, etc.
Necessary work	Required gully plugging works include pallasiding work by using bamboos, brushwood check dams and small earthen check dams. Because of difficulties to obtain pebbles / stones, gabion structures will not be installed as gully plugging works.
Pallasiding work (Model 1, 2 and 3)	Pallasiding works are to be constructed by using locally available bamboo posts supported by bamboo/wooden stakes.
Brushwood check dams (Model 2 and 3)	Brushwood check dams are to be constructed by using locally available brushwood supported by wooden stakes. Brushwood check dams can be installed with adequate strength.
Small earthen check dams (Model 1, 2 and 3 and4)	Small earthen check dams will be constructed out of local soil across the stream to check soil erosion and flow of water.
Remarks	Vegetative stabilization of gully banks and both up stream and down stream of structures needs to be ensured with planting of local grass / hill broom / vetiver (Khus grass) and other indigenous species.

Designs of major works in gully plugging



A brushwood check dam



A double row pose brushwood dam

Fig 3.3 Designs of major works in gully plugging

(iii) Catchment Conservation

Purpose	For steep slopes (>20%) runoff is considerably higher than for other slopes. Accumulation of runoff could be used for growing trees in such a way that each tree has its own micro-catchment area. Depending on choice of species (forest / horticulture), various configurations can be given to micro-catchment by appropriate land shaping. Catchment conservation is required to extend the life span of water harvesting structures, such as check dams. Its intent is to minimize the soil erosion around the structures. It also contributes to the regeneration of vegetation around the water bodies.
Necessary work	Catchment conservation requires construction of half-moon terraces, staggered contour trenches, brushwood terraces / bench terraces, contour bunding and/or planting along river / stream banks. This work, except for plantations around water bodies, can be accompanied by bamboo planting, NTFP planting, and other plantation work.
Half-moon terraces (Model 1 and 2)	On moderate slopes (10-20 %) and steeper slopes (>20%), half-moon terraces (60 cm diameter and 30 cm in depth) are to be established for water harvesting purposes at the top side of hills. Economic tree species, NTFP species and other species are to be planted in the basins.
Staggered contour trenches (Model 1 and 2)	On moderate slopes (10-20 %) and steeper slopes (>20%), staggered contour trenches (5-10 m long, 40 cm width at the base and 40 cm deep, with horizontal intervals between rows of 3-5m) are to be established for water harvesting purposes on the lower side of hills. Fuel trees, fodder trees and other trees may be planted just down below the trenches.
Bench terraces (Model 2)	Bench terraces can be constructed on slopes up to 33%. Under field conditions, inward sloping terraces would be more effective on account of high rainfall. Spaces between terraces are determined by the planting distance between trees. Further main tree crops are planted in basins, and vegetative cover, viz. grass, legumes, etc., is planted / sown in the spaces.
Brushwood terraces	Brushwood terraces can be constructed on moderate slopes (10-20 %)

(Model 2)	and steeper slopes (>20%) by using locally available brushwood supported by wooden stakes. Spaces between terraces are determined by the planting distance between trees. Further main tree crops are planted in basins, and vegetative cover, viz. grass, legumes, etc., is planted / sown in the spaces.
Contour bunding and field bunding(Model 3 and 4)	On gentle slopes (< 10%), contour bunding are to be established along the contour. Economic tree species, NTFP species and other species will be planted between the bundings.
Plantations along the river / stream banks (Model 1, 2 and 3 and 4)	Along the river and stream banks, bamboo and NTFP can be planted in order to reduce soil flowing from slopes into rivers and streams.
Remarks	Fuel trees, fodder trees, trees with an economic purpose and other trees should be planted alongside / between catchment conservation works for vegetative reinforcement and stabilisation of catchments.

Designs of major works in catchment conservation work

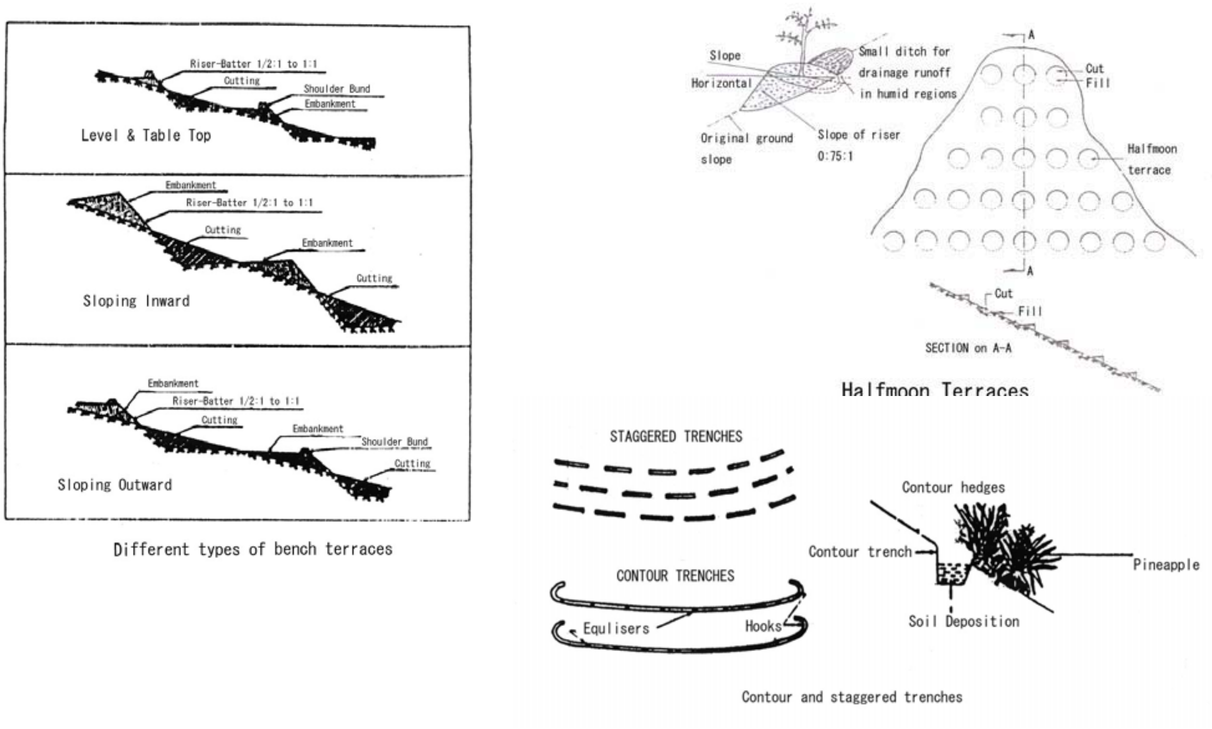


Fig: 3.4 Designs of major works in catchment conservation work

3.3 Construction Procedures and Timeline

The procedure for the installment of soil and moisture control structures can be classified into two stages: A) preparation stage and B) construction stage. These steps may be modified according to the suitability of the ITDA in consultation with FNGO/WDT and VDC.

Table:3.2 Preparation Stage

Steps	Procedures	Responsibility	Timeline
Step 1	. List of potential site is to be prepared by the community in consultation with the FNGO/WDT and SMS of ITDA. . They will jointly visit potential sites and finalize site selection after ensuring feasibility and to be included in VDLP		-
Step 2	Preparation of detailed design. Preparation of plan and estimate to be made by the concerned UG group with the help of FNGO/WDT and ITDA, SMS	UG/FNGO/ITDA	7-21 days
Step 3	Approval of the design and cost estimate. ITDA will approve the detailed design and estimated amount sanctioned.	FNGO/ITDA	7-14 days

*Estimated time is different based on models, scales and terrain conditions.

Table:3.3. Construction Stage

Steps	Procedures	Responsibility	Timeline
Step 4	Selection of Village Volunteer for supervision of construction	VDC	7 days
Step 5	Cleaning of the shrub/jungle	VDC/VLSC	3-14 days
Step 6	Layout of the plan in the site with indelible mark	VLSC/WDT	1-2 days
Step 7	Arrangement of construction equipment and material Material: i.e. cement, brick, sand, aggregate, clay, bamboo, rope, basket Equipment: i.e. phawrah, spade, gainti, concrete mixer	UG	7-30 days
Step 8	Arrangement of labour both skilled and unskilled	UG	7-14 days
Step 9	Construction		20-60 days
	Preparation of muster roll	UG	
	Earthwork measurement	WDT/WDO	
	Check measurement	WDT/WDO	
	Supervising the mixture	VO/WDT/WDO	
	Maintaining a case record of the structure	UG/WDT/VLSC/VDC	
	Final Inspection	WDO/SMS, ITDA	

*Estimated time is different based on model, scale and other conditions.

Table:3.4 Estimated Time for Major Structures

Construction Items	Timeline
1) Embankment	
- Earthwork for concrete core	07 days
- Concrete core	15 days
- Spill way construction	30 days
- Filling of earth and the embankment	30 days
- Grass turfing in down stream side	15 days
- Bamboo net with cement plaster in up stream side	07 days
2) Gully plugging	
- Bamboo cement banana leaf mixing	07 days
- Brush wood check dam	07 days
- Pallasiding work	07 days
- Contour bund	07 days
3) Catchment conservation	
- Staggered trenches	07 days
- Bench terrace	15 days
- Half moon terrace	07 days

3.4 Site Selection

As discussed earlier, site selection procedure consists of two steps; 1) selection of potential sites and 2) final selection. For preliminary area selection ITDA in consultation with FNGO will select priority areas in terms of watershed class or erosion severity. For all the potential sites, FNGO and ITDA/WDT/VLSC will make a joint visit along with UG to investigate the suitability of structure using Site Selection Criteria described below. The final site selection will be done by concerned FNGO, WDT and SMS, ITDA.

Table:3.5 Major Site Selection Criteria

Major criteria for site selection are given below. Selected sites need to meet all these criteria.

1. The structures should be in targeted area	The structures suggested in the different places along the hill from ridge line to valley line should be in targeted area.
2. Soil should be deep	The depth of soil beyond 3m is preferred.
3. The water spread area should be as per the size of dam	There should be around 2 ha water spread area for large dams (i.e.40m length) and 0.5 ha water spread area for small dams (i.e.20m length). The water spread area should not have any displacement or dense forest.
4. Maximum storage with minimum volume of earth fills	The storage area should be 3 times more than earth fill/cut. The length width and depth of water spread area can be measured by tape and in similar way the depth, width and length of the cut can be ascertained. By this the above ratio can be known.
5. Landfill soil should be locally available	Local fill material should be available. Depending on the availability the dam site may be modified.
6. Slope should be within 10-20% for small dam and less than 10% for large dam	The slope of the area can be measured by a simple farm level/Abney level. At different sites the level can be taken and say difference in level between two sites divided by the horizontal distance gives the slope of the area.
7. There should be straight	The rivers /drainage having several curves are to be

section in upstream for 6 to 7 m	avoided, and the at least 6 to 7 m straight section need to be identified.
8. Accessibility of building material should be good	The transport of building material to the site is essential. If in some cases there is no possibility of any kind of road then that site is to be avoided.
9. There should be a clear out fall of 2 - 2.5m	There should be a level difference of at least 2-2.5m between upstream and downstream of the selected site. Level survey for 20to 30m length can be taken at the site before selection.
10. For pallasiding work the bend should be less than 90 degree	The pallasiding work is carried out for stream bank erosion control. Where the stream is curved and there is more possibility of scouring, it should be roughly seen whether curvature is below 90 degree.
11. Willingness of UG/VLSC for utilization of resources and maintenance should be secured	The stakeholders must be willing to use the water and other resources generated by structures for them. They are expected to maintain structures after the project is withdrawn.

Table:3.6 Other Criteria to be Examined

In addition to the Major Site Selection Criteria, some conditions should be examined for final site selection.

1. Rainfall of the area	The total rainfall may not be the same in all the trajectory of the river or drainage line. Hence the quantifiable parameter will be to calculate 24 hours rainfall for 3 days continuously during the monsoon season. Make the average of the season of 3 days Antecedent Moisture Condition i.e. AMC. The site should be in lowest average place.
2. Pick rainfall	The pick rainfall of the area is obtained i.e. highest 24 hours of rainfall for the last 20 years or whatever is available. A probability study can be initiated and the rainfall at 70 percent probability can be taken for designing the check dam at the site.
3. Soil texture	The soil texture can be known by soil analysis in any laboratory. As per soil texture the site is selected. If the site is clayey then earthen core may be better. If the soil is sandy CC Core has to be made. Even for sandy loam also the CC Core is suggested.
4. Soil degradation	If the soil degradation is moderate it is suited for check dam construction. Degree of moderate degradation in KBK district is 50%. In case of strong soil degradation, cost of the structure will be high. Embankment of C.C core is prepared. There is no method to qualify the parameter but on visual observation it can be known
5. Severity of erosion	The sites should be taken where the soil erosion status should is moderate. This can be known from soil erosion / slope map already developed through GIS. This type of situation is in around 26.1% of total geographical area.
6. Land capability criteria	The check dam or embankment site should be in such place where land capability grouping is under III (erosion slope) 2. This kind of land capability group has very deep fine to coarse loamy soils on gently to moderately sloping

	residual hills and undulating plains limited by moderate erosion and fertility status. Ground water level very low crop cultivation restricted proper soils and water conservation measures help growing different crops.
7. Infiltration rate	If the infiltration rate is more than 5 cm per hour then CC Core embankment is preferred. The infiltration can be measured in the field by double ring infiltrometer method.
8. Land use	The land use also influences site selection. If the land use is dense forest it is not possible to construct check dam there. If there is no land for cultivation then also the storage of water has no benefit except soil erosion measure. If for 50 percent water can be used for irrigation then the site is good.
9. Slope	The slope influences the site. Even in 10-20 percent slope the check dam should be in lesser slope nearer to 10 percent. Slope is not generally uniform. The level survey can be made in 10meter interval for purposes of check dam sites. Similar is case for all type of slope.
10. Velocity of flow	Velocity of the stream at different section is important for selecting a site. For measuring velocity, the simplest method is the float method. Measure the length of stream point A to B. Then put a floating material at the centre of the stream at point A and record the time to reach the point B. If the length of AB is X m and time taken by float is Y sec then the flow rate is X/Y m/sec. If the flow rate is more than 10 m /sec than the site is vulnerable for early damage.
11. Depth of flow	Depth of the stream is a verifiable & quantifiable parameter. Lots of check dams depends on the depth. If the depth is more the cost is less. Hence depth of different sites should be measured and least depth at the sites should be 2.5m to 3.5m.
12. Accessibility	This is an important parameter to reduce cost as well as feasibility of the project. Transport of construction material to the site depends on the accessibility. This is a verifiable but not quantifiable parameter
13. Availability of local material	This is also a verifiable but not quantifiable parameter. This also affects the cost of system. Hence while selecting check dam this cost component may be taken into consideration.
14. Sediment load is moderate	To know sediment load at predetermined point, take 1000ml of muddy water from a predetermined point every week. At the end of the week measure the clear water. Let it be Y mm. Then the percentage silt load can be determined by dividing Y with 1000-Y. Repeat the same every week for entire season of flow from the stream as long as it is flowing. Then we can know the sediment load of the stream.

3.5 Execution of Work by concerned UG in VDC/VLSC

3.5.1 Disbursement of the Fund

The total estimated amount will be sanctioned by ITDA, and accordingly the amount will be released to the VDC bank account. VDC on receipt of the funds from ITDA will release funds in favour of concerned VLSC for facilitating execution of the activity by the respective UGs. But the sanction will be given structure/intervention wise.

3.5.2 Responsibility of UG and FNGO

UG and FNGO/WDT will be responsible for the preparation of proposal, construction, utilization and maintenance of the structures. The mobilization of beneficiary for utilization of storage water for irrigation and fishery will be carried out by WDT/FNGO. The WDT/FNGO will organize a Water Users Committee or Fish Farmers Cooperative for the above purpose. As VDC will be using the water body for its economic activities, VDC is responsible for maintaining the water harvesting structure. For the yearly maintenance / reinforcement of earthen embankments and de-siltation of water bodies in the 5th year will be carried out by VDC. Similar procedure will apply for other structures like staggered trench, contour bunding or brush wood dam.

3.5.3 Responsibility of ITDA/FNGO

ITDA/FNGO will have the responsibility of; 1) providing technical guidance for preparation of the detailed design, drawing of the structures and conservation works, 2) approving estimated amount above Rs.50,000/- and check measurement and 3) monitoring the progress of construction. If in the opinion of ITDA/FNGO the construction progress is not satisfactory, ITDA/FNGO shall ask VLSC to expedite or else the authority can make necessary change on the labor and other arrangement.

3.6 Technical Specification

There are different structures required in different models. The model wise structures with technical specifications are given below.

3.6.2 Model 1

A. Embankment (if required)

1. Small earthen check dam	- Length of dam 1.5 to 2.5m - Width of dam 0.75m to 1m - Height of dam 0.75m to 1m - Spillway as per the site with brick lining

B. Gully plugging

2. Pallasiding work	- Branching 3m wide and 1m height - Brush wood 12m length and 1m wide - Packing 3m*1m*1m The curvature of the river bank or stream should be below 90 degree. Three sets of bamboo poles should be given. The diameter of bamboo pole should be nearer to 5 cm. Small earth filling or pebble filling should be there.

C. Catchment Conservation

3. Half moon terrace	- Diameter of terrace 0.25m - Half moon area 0.3925 sq m - Volume 0.355 cu m. - Half terrace volume 0.117
4. Staggered trench	- Cross section area 0.25 sq m - Trench length 5m - Gap 4to 5 m The vertical interval and horizontal interval depending on

	slope of the area where very high slope is there. Generally the common guide lines for the structure is that the length of trenches is around 7 to 15m and 50 cm width at the base and 50 cm deep with horizontal interval between 5 to 7m and the top width of the bund above the trench is 0.2m and bottom width is 0.8m and the depth is 0.15m

3.6.3 Model 2

A. Embankment

1. Embankment with CC Core	- Length 20m - Cleaning of jungle 20 *100*2=4000 sq m - Top width 2.3m and depth 0.5m Earth work - 1st layer 20*2.3*0.5m=23cu.m - 2nd layer 2*8*0.5*31m=248 cu m Concrete core wall - Length 20m - CC(1:3:6)in core wall 0.5*2+(1.5+.45)/2*3.0=3.2925 cu m
2. Embankment with Mud Core	- Length 20m - Cleaning of jungle 20 *100*2=4000 sq m - Top width 2.3m and depth 0.5m Earth work - 1st layer 20*2.3*0.5m=23cu.m - 2nd layer 2*8*0.5*31m=248 cu m Earthen core wall - Length of core 20m - Earth work (2.3+18.3)/2*4.0*20m-78.5=745.5 cu m
3. Spillway	- Length 10m - Top width 1.5m - Bottom width 75m - Depth 75m - Cement plaster (1:4) 20mm Brick lining - Width 0.75+0.84*2=2.43m

B. Gully plugging

4. Brush wood check dam	- Type of wood Awl, Near, Kota, Kari, Ram Della ballahas - Diameter 10cm - Length 12m - Nos. required 2nos - Type of bamboo Barrack bamboo - Diameter 75mm to 100mm - No required 2nos - Length of bamboo 12m Fixation of one layer of champak kampa tarja wall with split bamboo - Split bamboo (tarja)width 75mm - Bamboo button width 40mm - Depth 1.5m The depth will be restricted to 1to 2 m. The length will be

	restricted to 12 to 24m.The wire gage should be 10 gage. The wooden post dia. should be around 10 to 12 cm.
5. Pallasiding work	- Branching 3m wide and 1m height - Brush wood 12m length and 1m wide - Packing 3m*1m*1m The curvature of the river bank or stream should be below 90 degree. Three sets of bamboo poles should be given. The diameter of bamboo pole should be nearer to 5 cm. Small earth filling or pebble filling should be there.

C. Catchment Conservation

6. Bamboo net with cement plaster	- Area 8 sq m - Length 8m - Width 1m - Thickness 20mm - Cement plaster(1:4) 20mm - Bamboo net - Width 1m and length 8m
7. Staggered trench	- Cross section area 0.25 sq m - Trench length 5m - Gap 4to 5 m The vertical interval and horizontal interval depending on slope of the area where very high slope is there. Generally the common guide lines for the structure is that the length of trenches is around 7 to 15m and 50 cm width at the base and 50 cm deep with horizontal interval between 5 to 7m and the top width of the bund above the trench is 0.2m and bottom width is 0.8m and the depth is 0.15m
8. Half moon terrace	- Diameter of terrace 0.25m - Half moon area 0.3925 sq m - Volume 0.355 cu m. - Half terrace volume 0.117
9. Bench Terrace	- Suitable for up to 33 percent slope - Type of terrace: Inward sloping Horizontal interval and vertical interval depends on slope condition. - Slope 30 percent - Depth of cut 0.63m - Width of terrace 4.2m - Vertical interval1. 80m

	- Batter in riser 1:1 - Horizontal Interval 6m - Length of terrace 1666m - Cross section of terrace 0.945sq.m

3.6.4 Model 3

A. Embankment

1. Embankment with CC Core	- Length 40m - Cleaning of jungle 40 *100*2=8000 sq m - Top width 2.3m and depth 0.5m - Earth work - 1st layer 40*2.3*0.5m=46cu.m - 2nd layer 2*8*0.5*41m=328 cu m - Concrete core wall - CC(1:3:6) In core wall 0.5*2+(1.5+.45)/2*3.0=3.2925 cu m The top of the core will be 0.45m and the bottom will be 2m and the top width of embankment will be 2.3 m. The height of core will be 3.5m. The foundation will be 2m for first 0.5m and then for next 0.3m it will be 1.8m and in then tapering as per slope 2:1.Height of the bund is 4m
2. Embankment with Mud Core	- Length 40m - Cleaning of jungle 40 *100*2=8000 sq m - Top width 2.3m and depth 0.5m - Earth work - 1st layer 40*2.3*0.5m=46cu.m - 2nd layer 2*8*0.5*26m=208 cu m - Earthen core wall - Length 40m The top of the core will be 0.45m and the bottom will be 4m and the top width of embankment will be 2.3 m. The height of core will be 3.5m. The foundation will be 4m for first 0.5m and then tapering as per slope 2:1.
3. Spillway	- Length 10m - Top width 1.5m - Bottom width 0.75m - Depth 0.75m - Cement plaster (1:4) 20mm - Brick lining - Width 0.75+0.84*2=2.43m

B. Gully plugging

4. Brushwood Check dam	- Type of wood Awal, Neur, Kota, Ramdella ballhas - Diameter- 10 cm - Length-12 cm - Nos. required-2 - Type of bamboo-Barrack bamboo - Diameter-75-100 mm - No. required-2 - Length of bamboo- 12 m Fixation of one layer of champak kampa taraj wall with

	split bamboo - Split bamboo(taraj) width-75 mm - Bamboo button width-40 mm - Depth- 1.5 m The depth will be restricted to 1-2 m. The length will be restricted to 12-24 m. The wire gauge should be 10 gauge. The dia of wooden post should be around 10-12 cm
5. Pallasiding work	- Branching 3m wide and 1m height - Brush wood 12m length and 1m wide - Packing 3m*1m*1m The curvature of the river bank or stream should be below 90 degree. Three sets of bamboo poles should be given. The diameter of bamboo pole should be nearer to 5 cm. Small earth filling or pebble filling should be there.

C. Catchment Conservation

5. Bamboo net with cement plaster	- Area 8 sq m - Length 8m - Width 1m - Thickness 20mm - Cement plaster (1:4) 20mm - Bamboo net - Width 1m - Length 8m
6. Contour Bunding	- Top width 0.6m - Bottom width 4.2mm - Depth 0.9m - Length 333m - Upstream slope 2:1 - Excess water way every 20m The vertical interval and horizontal interval should be calculated as per slope of the site. The specification of contour bund has been indicated in Chapter 3.

Chapter- 4
Minor Instruments & their use in Watershed

4.1 Instruments

The low cost & user friendly instruments which are successfully used and tested in different watersheds can be assembled/ constructed locally or purchased at low cost and can be used by villagers on proper capacity building.

Most of the watershed treatment works can be accomplished with reasonable accuracy by careful use of the following minor instruments and/ or combined use of the instruments.

Minor Instruments	Uses
• Plumb bob	vertical check
• Carpenter level	vertical & horizontal check
• Ranging rods/ poles	marking stations
• Pegs	Demarcation
• Hydro marker (*or* flexible tube water level)	Elevation difference & contour line
• A- frame	slopes and contour line
• Boning rod	horizontal lines and slopes
• Hand level	contour lines and differences in elevation.

Besides these minor instruments, there are some advanced instruments which are also used in watershed surveying and handled by experts. These are optical square, prismatic compass, Abney's level, Clinometer and Dumpy level etc.

4.1.1. Plumb bob

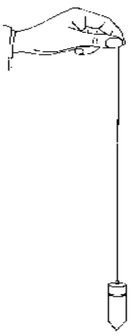


Fig.4.1 Plumb bob

Plumb bob is a heavy metal made up of brass with a pointed end and is attached to a string or cord.

Use

It is used to check if the objects are vertical. When the bob is hanging free within swings the cord remains vertical.

4.1.2 Carpenter level

A carpenter level is used to check if objects are horizontal or vertical. Within a carpenter level there are one or more curved glass tubes, called level tubes.

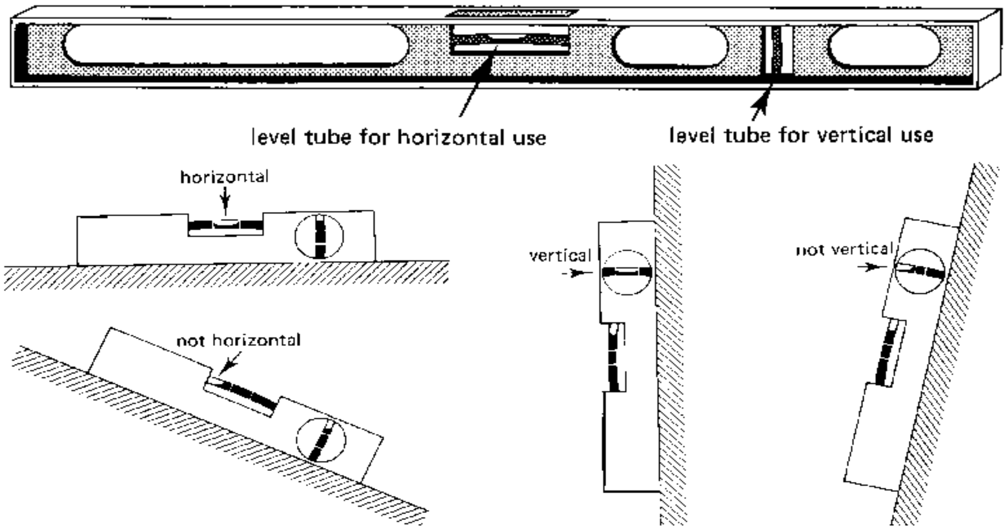


Fig.4.2 Carpenter level

Use

Each tube is sealed and partially filled with a liquid (water, oil or paraffin). The remaining space is air, visible as a bubble. On the glass tube there are two marks. Only when the carpenter level is horizontal (or vertical), the air bubble exactly remains between these two marks.

4.1.3 Ranging rod/ poles

Ranging poles are straight round stalks, 3 to 4 cm thick and about 2 m long. They are made of wood or metal. Ranging poles can also be home made from strong straight bamboo or tree branches.

REMEMBER: Ranging poles shall never be curved.

Ranging poles are usually painted with alternate red-white or black-white bands. If possible, wooden ranging poles are reinforced at the bottom end by metal points.

Use

Ranging poles are used to mark areas and to set out straight lines on the field. They are also used to mark points which must be seen from a distance, in which case a flag may be attached to improve the visibility.

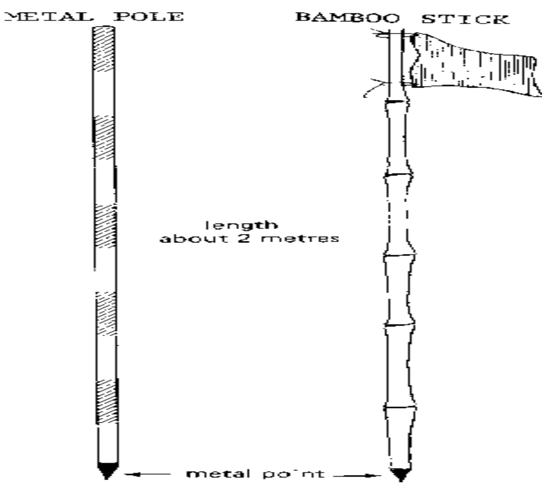


Fig.4.3 Ranging rod/ poles

4.1.4 Pegs

Pegs are generally made of wood; sometimes pieces of tree-branches, properly sharpened, are good enough. The size of the pegs (40 to 60 cm) depends on the type of survey work they are used for and the type of soil they have to be driven in.

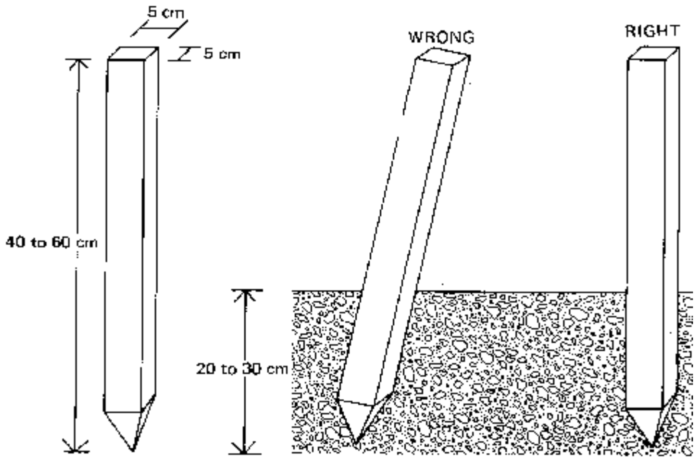


Fig.4.4 Pegs

Use

Pegs are used when certain points on the field require more permanent marking. The pegs should be driven vertically into the soil and the top should be clearly visible.

4.1.5 Flexible tube water level

It consists of two staffs with a length of about 2 m and a transparent flexible tube of about 14 m long. The ends of the tube are firmly fixed to the staffs. Sometimes, a 10 m long rope is fixed to the staffs to limit the distance between the staffs. The rope thus helps to prevent damage to the tube. The tube is filled with colored water so that the water level is about 1 m high in each of the tube ends. Care should be taken so that no air bubbles are trapped in the tube. If so, air bubbles can be removed by tapping the tube with the finger.

Wherever the two staffs are set, the free water surfaces in the tube ends have the same level. This is based on the "communicating vessel" principle.

Use

The flexible tube water level is commonly used for contour lines and measuring differences in elevation in watersheds

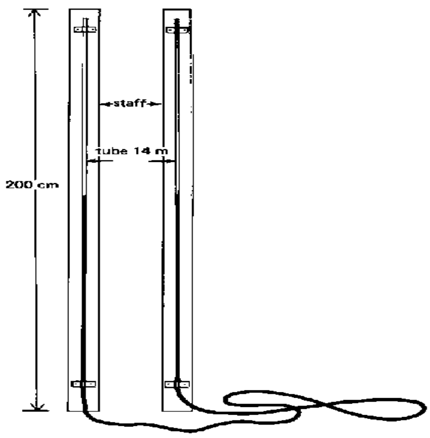


Fig.4.5 Flexible tube water level

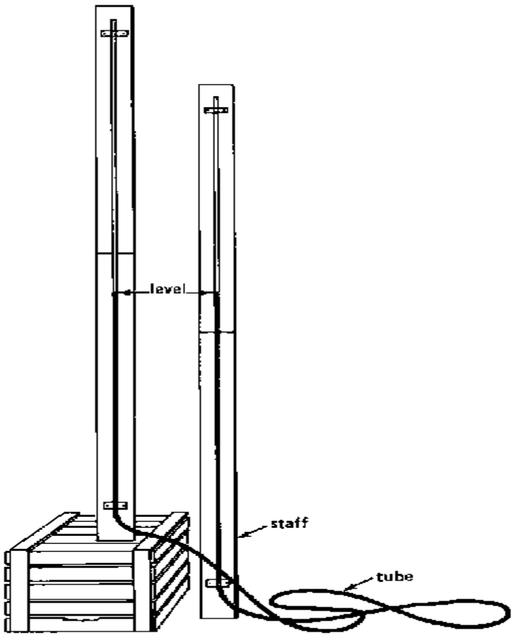


Fig.4.6

4.1.6 A- Frame

Construction:

This is a triangular wooden frame looks like English alphabet **(A)** with a base of 3-4 m and consists of 3 nos. of wooden frames. For practical purpose and to make it convenient for local use, the dimension of main frame is **10ft X 10 ft** as shown in the figure. It can be easily constructed at village level by local carpenters.

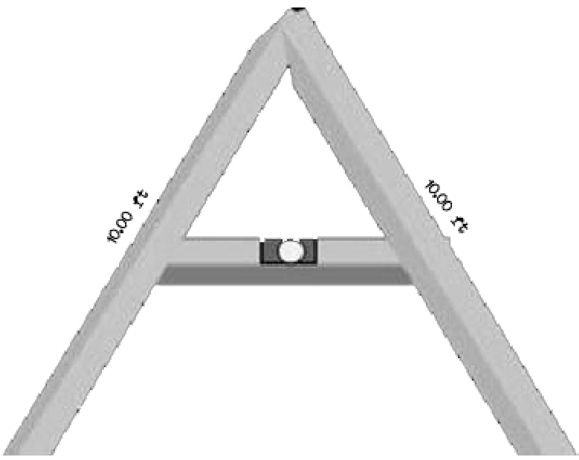


Fig.4.7 A- Frame

- The cross bar/ horizontal frame is fixed half way between the base and tip of the triangle.
- A spirit level/ carpenter level is firmly fixed by metal strips or countersinking it at the middle of the cross bar.
- In stead of fixing the carpenter level, a plumb bob may be fixed at the joint portion of two legs with the bob hanging freely so that it remains always in centre of the cross bar when placed on a level surface.

- Before use, it must be checked for accuracy by placing it on a level surface so that the air bubble of the spirit level is exactly in between the marks. Otherwise it must be adjusted by putting a spacer under one end of the level.

Use

Demarcation of contour line is made by using the A-Frame.

Steps

- Drive a peg at the starting point and place one leg of frame against this peg.
- The other leg is moved up and down till the air bubble rests at the middle. It shows that both the legs are on the same contour line.
- Drive another peg at this point and move the first leg forward keeping the second leg constant.
- Repeat the same procedure so that the bubble of the level comes to centre and remains within the mark. Drive another peg at this point.
- Repeat the same procedure and go on driving pegs.
- The line joining the pegs gives the contour line. The subsequent contour lines are demarcated in similar manner.

4.1.7 Boning Rods

Boning rods are T-shaped and made of wood. Their height is normally 100 cm and the cross-lath is 50 cm x 10 cm. The bottom part may be reinforced with metal sheet. It is important that all boning rods have exactly the same height (100 cm) and while working with the boning rods, the sun should be kept in the back, as it would otherwise be difficult to see them. Usually a total of 3 or 4 boning rods are required.

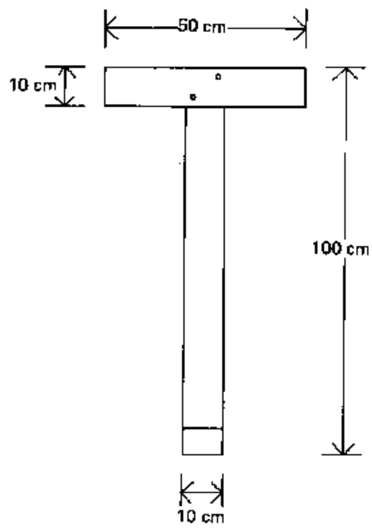


Fig.4.8 Boning Rods

Use

Used for setting out horizontal lines or lines with a constant slope. In particular they are used for setting out canal excavation works, but also for roads and dyke, bund construction. It is also used for setting out horizontal lines or lines with a constant slope, the elevation (or height) of two points on the line (preferably the starting and end points) must be known.

4.1.8 Hand level

The hand level consists of a 10-12 cm long tube with an eye piece at one end and two hair lines (one horizontal and the other vertical) at the other end. A small carpenter level is attached to the tube.

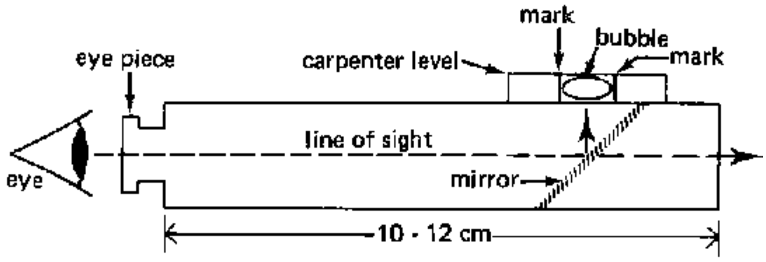


Fig.4.9 Hand level

When the operator looks through the eye-piece, the mirror inside the tube reflects (on the right hand side) the position of the bubble of the carpenter level. The instrument is made in such a way that when the bubble is in sight on the horizontal hair line, the instrument is horizontal and the line of sight is horizontal.

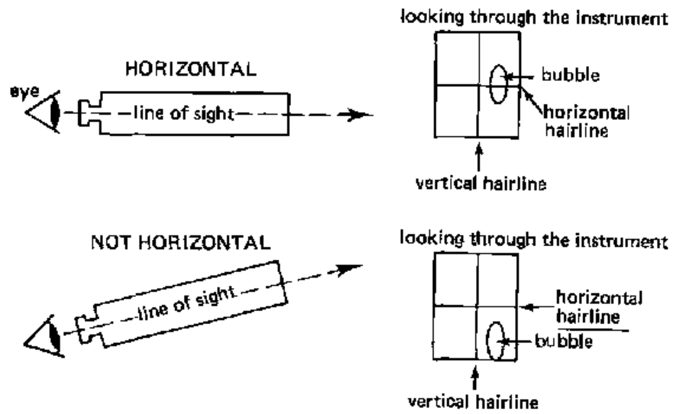


Fig.4.10

For greater stability the instrument can be supported by a forked bush pole, with a metal plate attached to the bottom. This assures that the instrument is always at the same height above the ground surface.

Use

- Used for setting out contour lines and measuring differences in elevation.

4. 2 Simple Surveying Techniques

4.2.1 Introduction

In watershed treatment works, the followings are the most common surveying works.

- Measurement of horizontal distance
- Measurement of vertical interval (i.e. elevation difference between two points)
- Setting out contour lines (of required intervals)

Most common equipment can be home-made and be used by the farmers themselves after little training.

Before going into surveying techniques, minimum understanding on topographic features which are represented in topographic and contour maps is required.

4.2.2 Map orientation

Map is the representation of earth surface on a small scale. Map scale is the fixed proportion which every distance between the locations of the points on the map, bears to the corresponding distances between their positions on the ground. (e.g.: if 1cm. on a map represents 5 m. on ground, the map scale is 1cm. = 5 m. or 500 cm / or 1:500). Plan is the graphical representation of the features on the earth surface or below the earth surface as projected on a horizontal plane. Simply, it is the top view of any object having horizontal dimensions. Topographic maps represent the individual features of earth's surface. Contour is an imaginary line on the ground, joining the points of equal elevation. Contour interval is the vertical distance between any two consecutive contours.

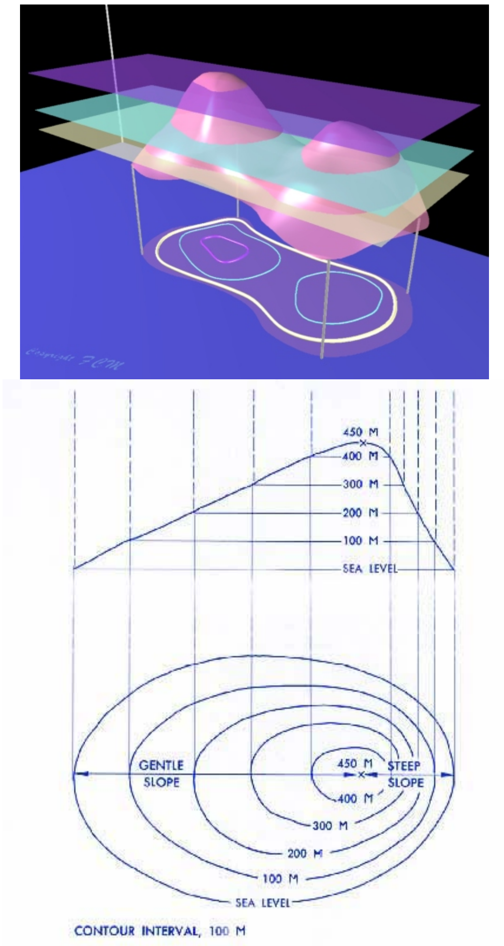


Fig.4.11 Map Orientation

Toposheets

For entire India, topographic maps of different scale have already been developed by Survey of India. In watershed context, toposheets of 1:50,000 or 1: 25,000 scale are generally used. These maps furnish the base information about the geographical condition of the watershed. These maps are also essential for selection, delineation and characterization of watersheds. Horizontal distance on the map is taken along the pan of the paper, but the vertical distance (elevation) is shown by the line joining points of equal elevation called the contours. These lines help to find out the features like hills, ridge valley, depression and plains on the map which are important for location various measures in land & water management.

The legend/ reference, symbols are given in the map to facilitate the location of various landmarks of the ground. Natural and man made features like hills, streams, forests, barren land, villages, roads, bridges etc. can be identified by the symbols. The top of a hill denoted a triangle shape. For maps of 1:50,000 scale, contour lines are drawn at 20 m. interval and every 5th line is made thick or heavier. For maps of 1:25,000 scale, contour lines are drawn at 10 m. interval and every 5th line is made thick or heavier.

Characteristics of a contour line

- All points on a contour line have the same elevation.
- Contour lines close to each other represent steep slope and if far away, represents relatively flatter slope.
- When the slope is uniform, contour lines are spaced uniformly and these lines are straight and parallel to each other.
- Contour lines are perpendicular to the lines of steepest slopes as these are the level lines.

- Contour lines can not end any where, these closes on themselves either within the map or outside the limit of the map.
- A series of close contour line represents a hill if the inside contours are having gradual higher values and the vice versa in the case of depression.
- Contour lines cross ridgelines or valley lines at right angles.

Uses of a contour map

- Collecting information on topography of the area.
- Locating suitable site for engineering structures and preliminary selection of most suitable alignment of road, channels etc.
- Computing capacity of reservoir and calculation of volume of earthwork.
- Measurement of watershed area and estimating runoff for different designs

Setting out straight line

A straight line is the shortest distance between two points on a map or between two points on the field.

A straight line

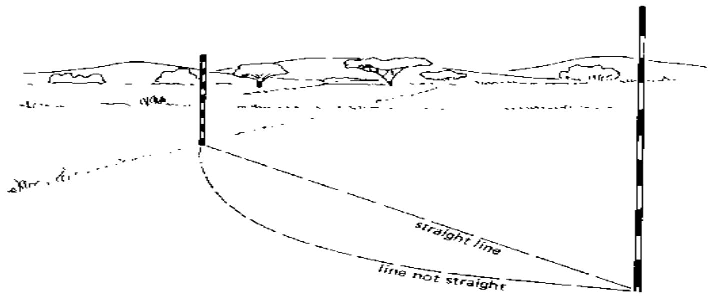


Fig.4.12 Placing of Ranging Poles

Placing of Ranging Poles

The correct way to hold a ranging pole is to keep it loosely between thumb and index finger, about 10 cm above the soil. When the observer indicates that the ranging pole is in the right position, the assistant loosens the pole. The sharp bottom point of the ranging pole leaves a mark on the soil exactly where the pole has to be placed. Once in place, it should be checked if the ranging pole is vertical, e.g. with a plumb bob, or a carpenter level.

Holding a ranging pole

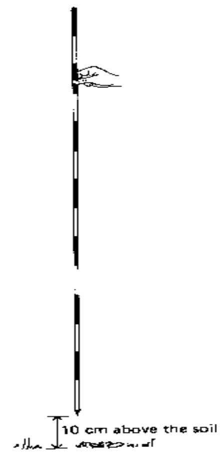


Fig.4.13 Holding a ranging pole

Placing a ranging pole

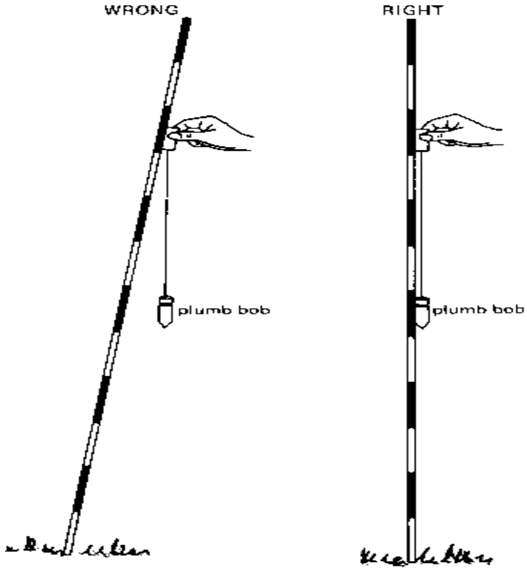


Fig.4.14 Placing a ranging pole

Setting out straight lines over a short distance: Steps

- As shown in Figure, pole (B) is clearly visible for the observer standing close to pole (A). The observer stands 1 or 2 m behind pole (A), closes one eye, places himself in such a position that pole (B) is completely hidden behind pole (A).
- The observer remains in the same position and any pole placed by the assistant in between (A) and (B), which is hidden behind pole (A), is on the straight line connecting (A) and (B).
- The observer remains in the same position and any pole placed behind (B), which is hidden behind poles (A), (B) and (C), is on the extension of the straight line connecting (A) and (B) .

Setting out a straight line over a short distance

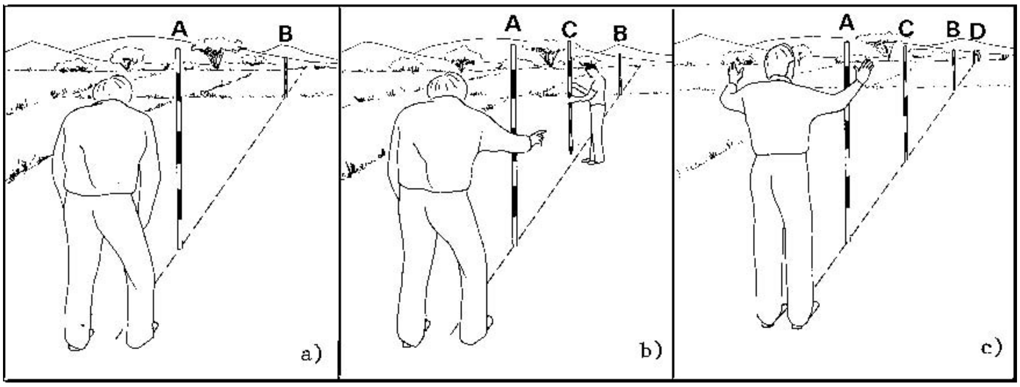


Fig.4.15 Setting out a straight line over a short distance

Setting out straight lines over a long distance

As shown above, ranging pole (B) is at quite a distance from pole (A) and it is hard to see pole (B) clearly. A flag is attached to ranging pole (B) to make it more visible.

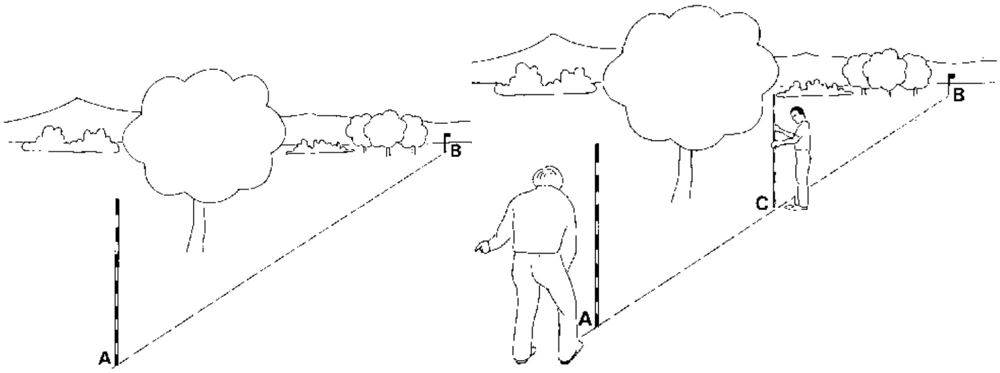


Fig.4.16

Steps

- Pole (C) is approximately set in line with (A) and (B) at about one third of the distance between (A) and (B), closer to (A).
- The observer moves to pole (C) and pole (D) is set in line with (C) and (B) .

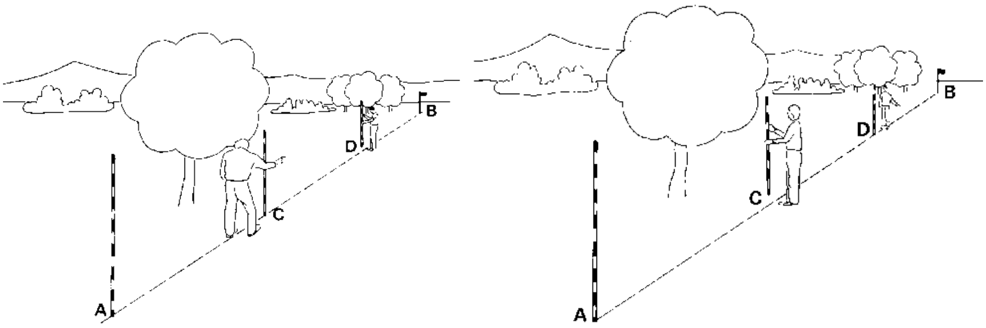


Fig.4.17

The observer moves Co pole (D) and pole (C) is reset in line with (D) and (A) . The observer moves back to pole (C) and pole (D) is reset in line with (C) and (B) .

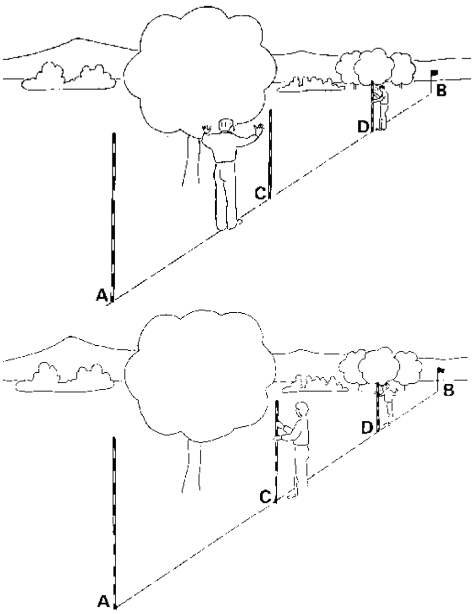


Fig.4.18

Continue until poles (C) and (D) do not require resetting anymore, which means that all poles (A), (B), (C) and (D) are in line. Intermediate poles can now easily be set in line with (A) and (C), (C) and (D), or (D) and (B).

Setting out straight lines over a ridge or a hill

Sometimes, a straight line has to be set out between two points (A and B) which are one on each side of a hill, dyke or any other high obstacle. Standing at point A it is impossible to see point B. A procedure by trial and error is used, which requires two observers and one, or preferably two, assistants.

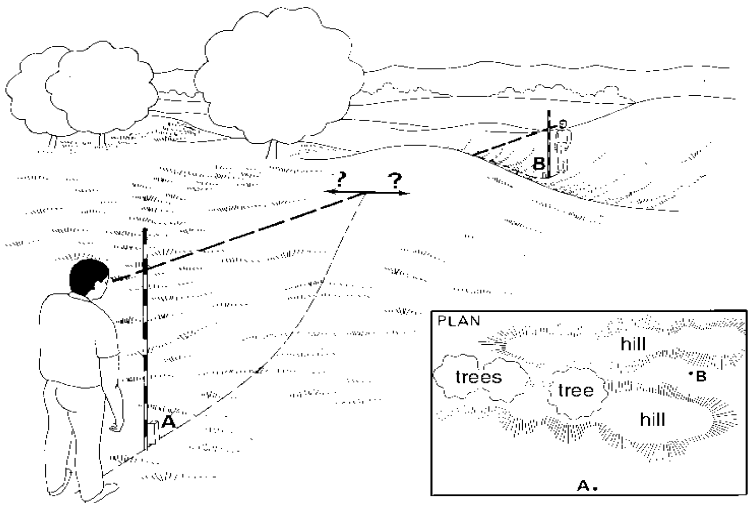


Fig.4.19

Steps

1. First, poles (C) and (D) are placed on top of the hill, as accurately as possible in line with (A) and (B), and in such a way that both (C) and (D) can be seen by the observers standing near pole (A) and pole (B).

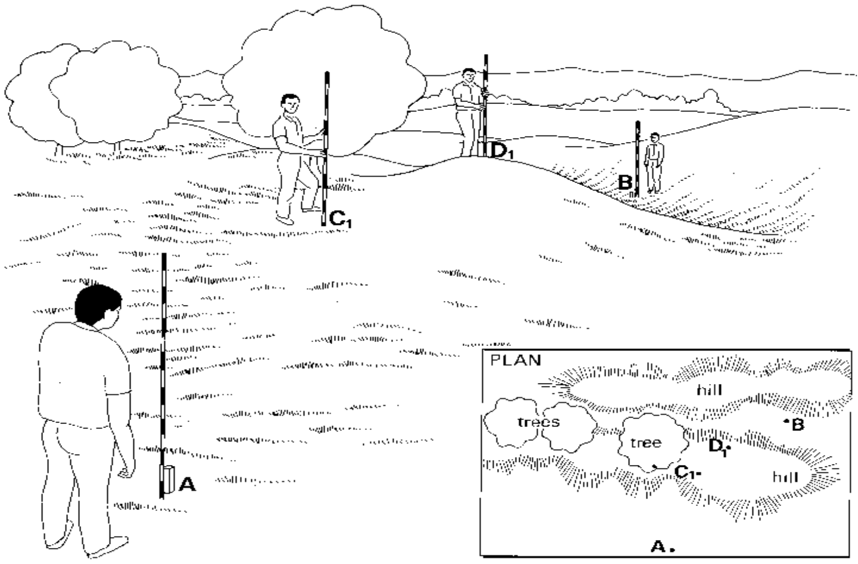


Fig.4.20 (a)

2. At the indication of the observer at pole (A), pole (C) is set in line with (A) and (D); in other words pole (C) is moved from position C, (the original position) to position *C2* .

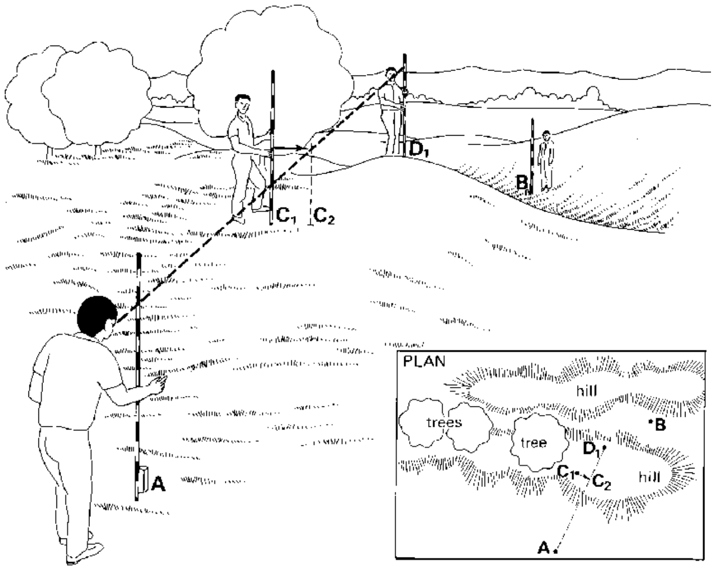


Fig.4.20 (b)

3. At the indication of the observer at pole (B), pole (D) is set in line with (B) and (C); in other words, pole (D) is moved from position D, (the original position) to position D.)
Figure 14 c

4. The procedure is repeated: pole (C) is reset in line with (A) and (D) and pole (D) is reset in line with (B) and (C). Continue until no more correction is required, which means that the four poles (A), (B), (C) and (D) are in line.

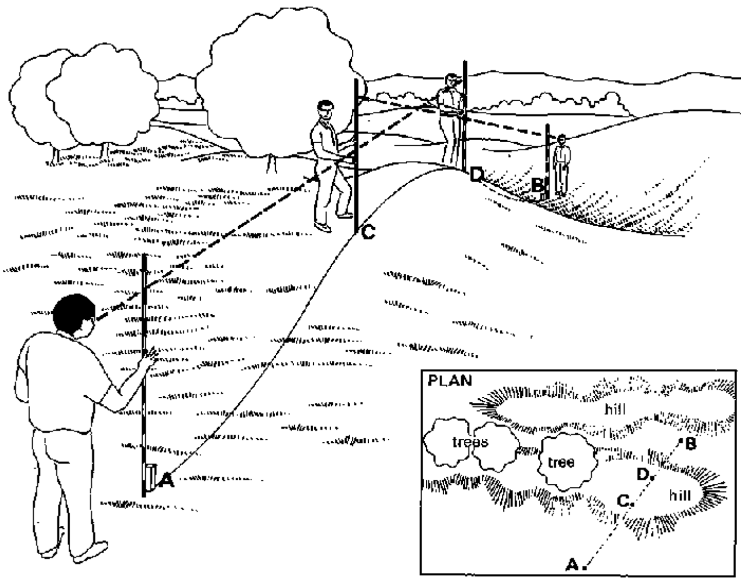


Fig.4.20 (c)

Setting out horizontal line (using boning rod)

Suppose a horizontal line has to be set out between the Bench Marks A and B. Bench marks A and B have the same elevation.

Steps

1. Set out a straight line between A and B and place intermediate pegs at regular intervals .

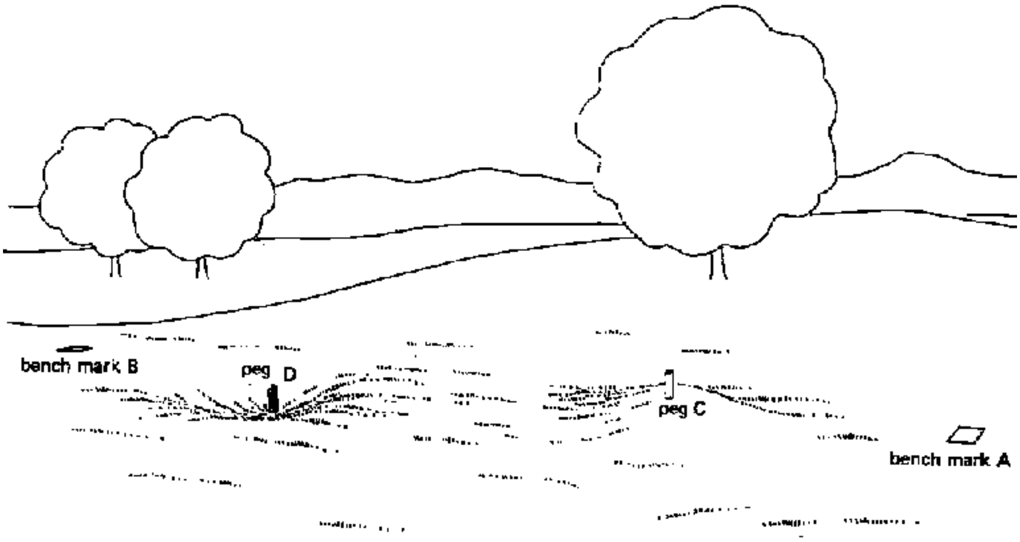


Fig.4.21

2. Place boning rods on top of the two Bench Marks and on top of peg C. The observer, looking just over the top of boning rod A tries to bring the tops of the boning rods A, B and C in line.

As can be seen from Fig.4.22, boning rod C and thus peg C is too high; the tops of the boning rods are not in line.

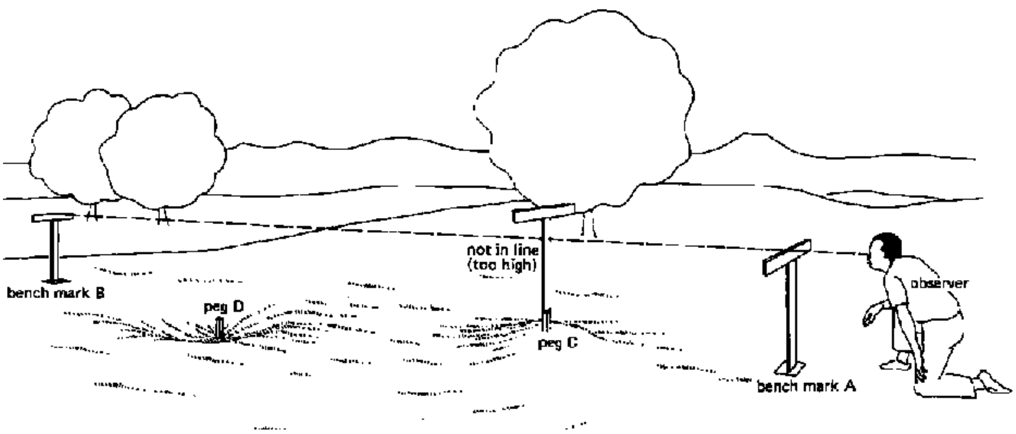


Fig.4.22

3. Hammer peg C further into the soil. It may be necessary to excavate some of the soil surrounding peg C in order to be able to lower peg C sufficiently.

The top of peg C is at the correct elevation when, looking over the top of boning rod A, the tops of the boning rods A, C and B are in line (see Fig.4.23).

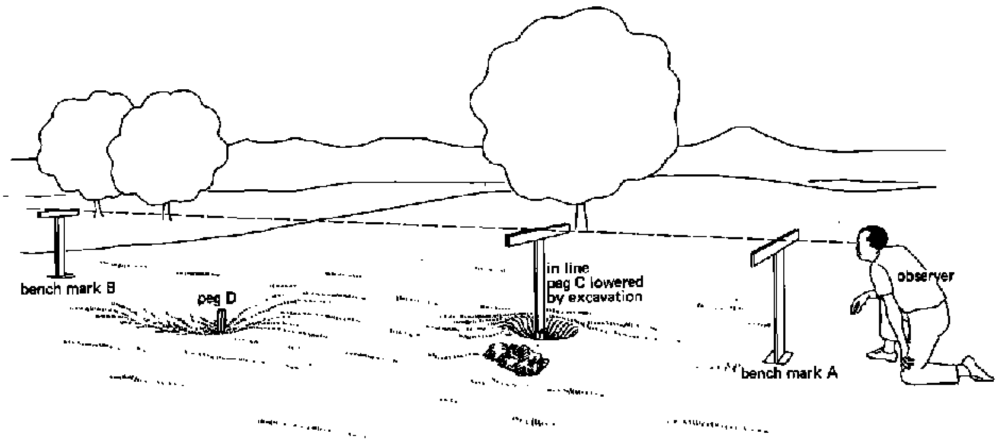


Fig.4.23

4. Place a boning rod on peg D. When looking over the tops of the boning rods A and B it is not possible to see the top of the boning rod on peg D, as peg D is too low (see Fig.4.24).

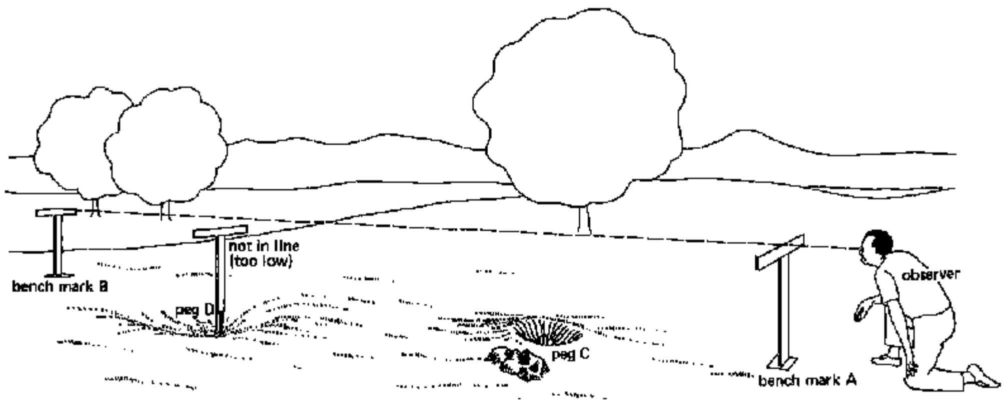


Fig.4.24

5. Replace peg D by a longer peg or pull out peg D and add some soil in the immediate surroundings of D and hammer peg D again into the soil. Repeat this process until the correct elevation of peg D is found (see Fig.4.25).

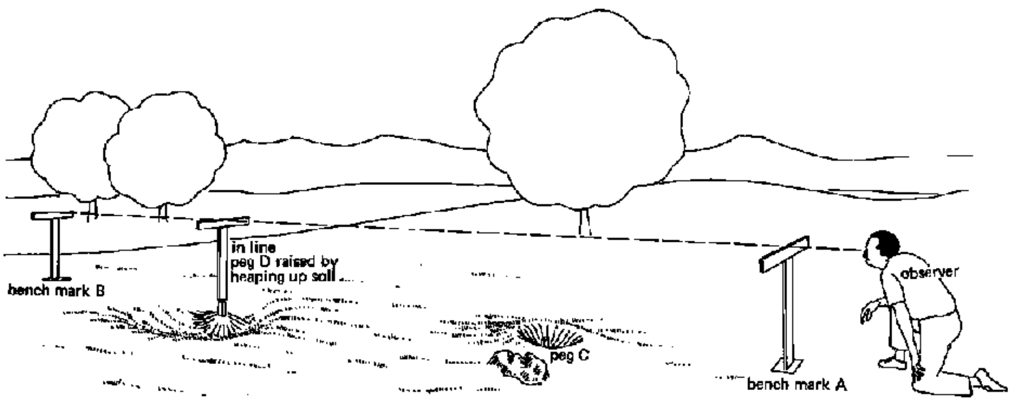


Fig.4.25

6. The two Bench Marks A and B and the pegs C and D all have the same elevation. Line ACDB is horizontal (Fig.4.26).

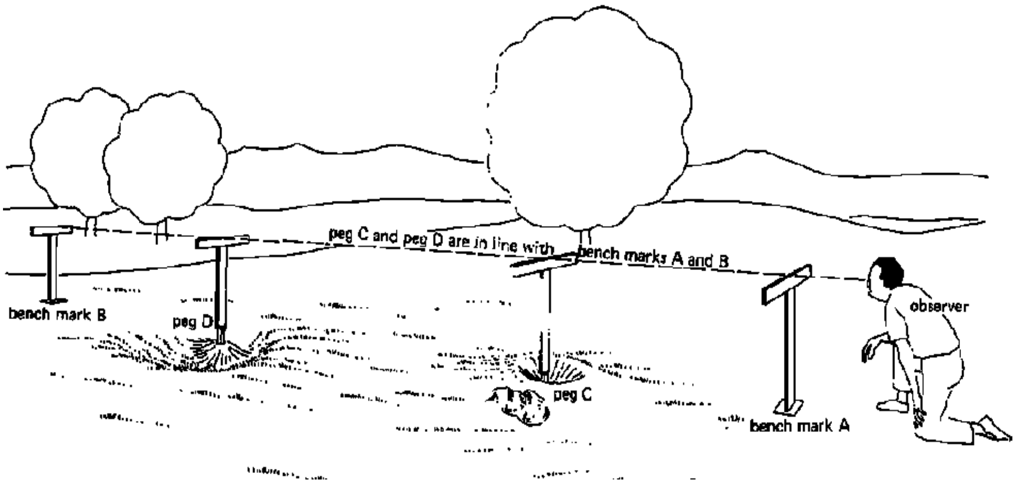


Fig.4.26

4.2.3 Setting out right angle (3-4-5 method)

The 3-4-5 method is used to set out a right angle from a certain point on the base line. The first person holds together, between thumb and finger, the zero mark and the 12 meter mark of the tape. The second person holds between thumb and finger the 3 meter mark of the tape and the third person holds the 8 meter mark.

When all sides of the tape are stretched, a triangle with lengths of 3 m, 4 m and 5 m is formed (see Fig.4.27), and the angle near person 1 is a right angle.

NOTE: Instead of 3 m, 4 m and 5 m a multiple can be chosen: e.g. 6 m, 8 m and 10 m or e.g. 9 m, 12 m and 15 m.

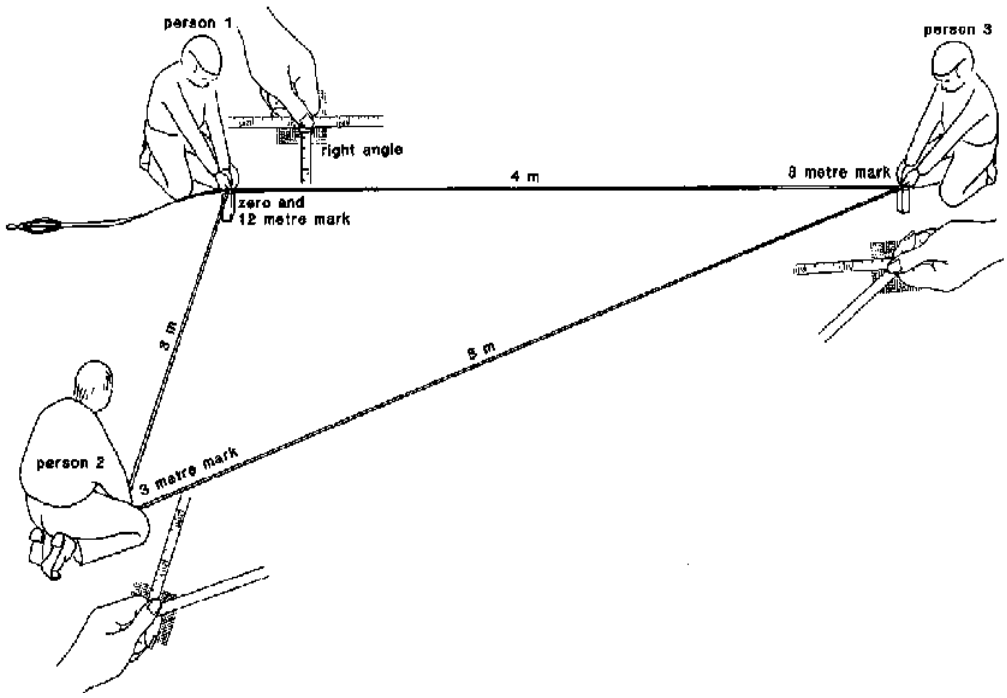


Fig.4.27

Steps:

1. In Fig.4.28, the base line is defined by the poles (A) and (B) and a right angle has to be set out from peg (C). Peg (C) is on the base line.

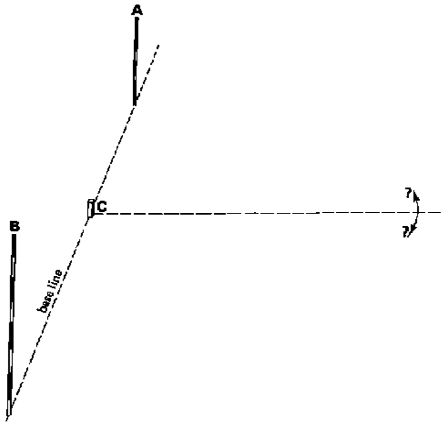


Fig.4.28

2. Three persons hold the tape the way it has been explained above. The first person holds the zero mark of the tape together with the 12 m mark on top of peg (C). The second person holds the 3 m mark in line with pole (A) and peg (C), on the base line. The third person holds the 8 m mark and, after stretching the tape, he places a peg at point (D). The angle between the line connecting peg (C) and peg (D) and the base line is a right angle (see Fig.4.29). Line CD can be extended by sighting ranging poles.

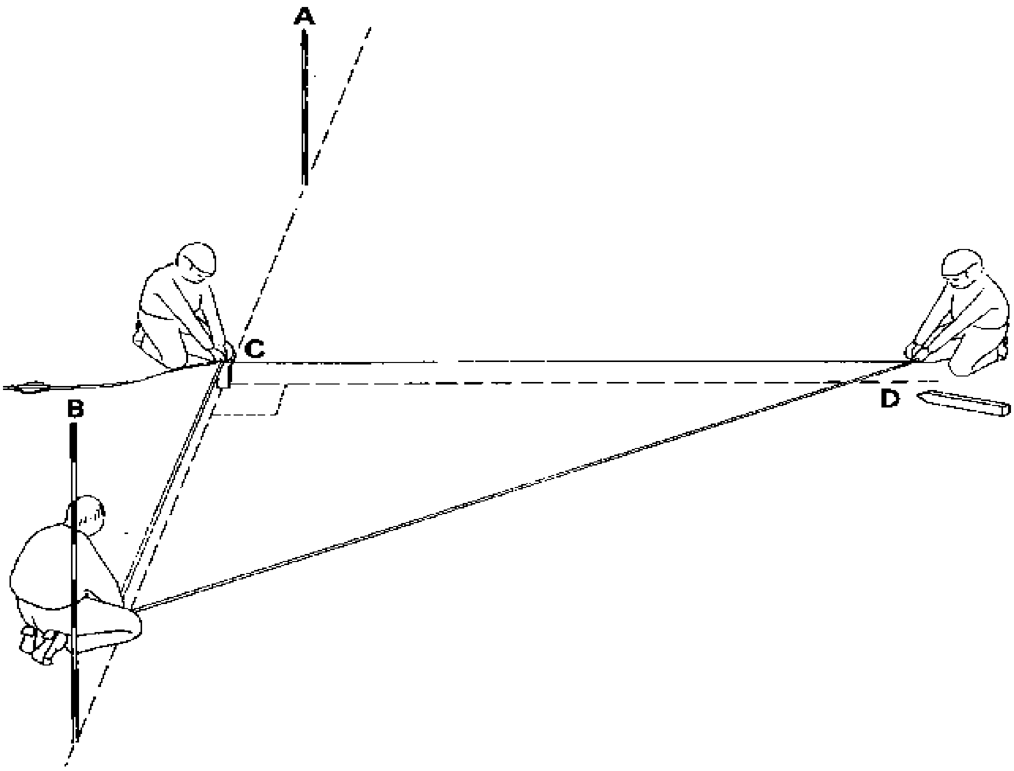


Fig.4.29

Instead of a measuring tape, a 12 m long rope with clear marks at 3 m and 8 m can be used.

Setting out perpendicular line (Rope method)

The rope method is used to set out a line perpendicular to the base line, starting from a point which is not on the base line.

A line has to be set out perpendicular to the base line from peg (A). Peg (A) is not on the base line.

A long rope with a loop at both ends and a measuring tape are used. The rope should be a few meters longer than the distance from peg (A) to the base line.

Steps

1. One loop of the rope is placed around peg (A). Put a peg through the other loop of the rope and make a circle on the ground while keeping the rope straight. This circle crosses the base line twice. (Pegs (B) and (C) are placed where the circle crosses the base line.

2. Peg (D) is placed exactly half way in between pegs (B) and (C). Use a measuring tape to determine the position of peg (D). Pegs (D) and (A) form the line perpendicular to the base line and the angle between the line CD and the base line is a right angle (see Fig.4.30).

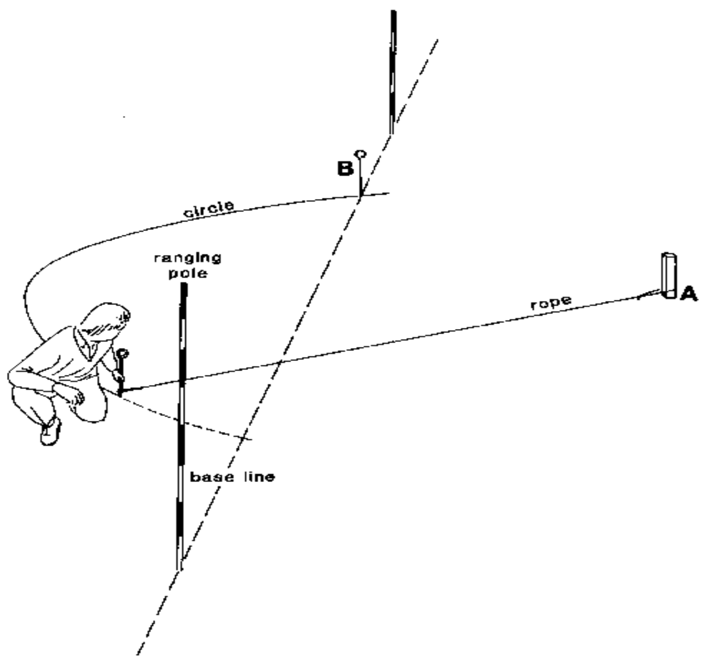


Fig.4.30

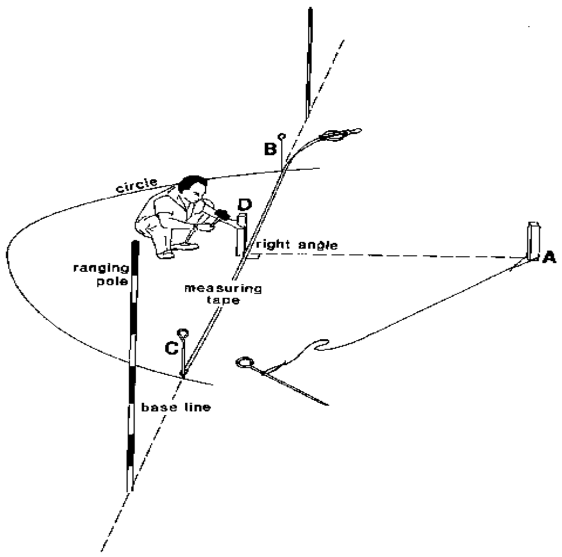


Fig.4.31

4.2.4 Setting out contour line

To set out a contour line in a watershed, flexible tube water level can be used. The followings are the steps for demarcation of a contour line.

1. The two staffs are placed back to back at the starting point marked with peg (A). After the air bubbles have been removed and the water has come to a rest, a mark is made on both staffs, indicating the water level (see Fig.4.32).

2. The lead man takes one staff and drags the tube in what seems to be the direction of the contour line. When the tube is almost stretched, the lead man moves slowly up and down the slope until he obtains a position where the water level coincides with the mark (see Fig.4.33)

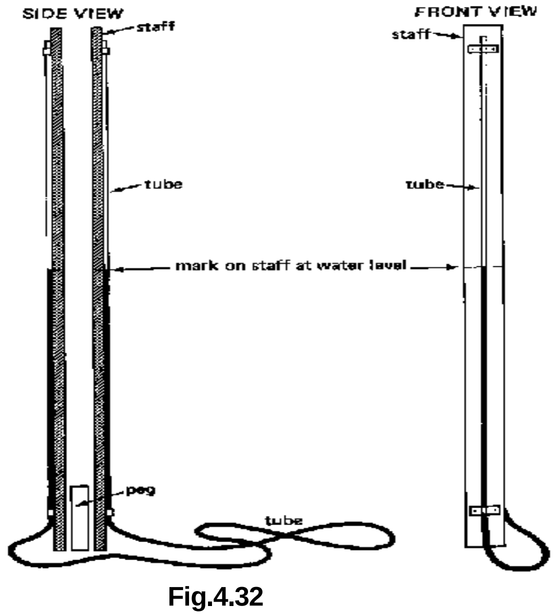


Fig.4.32

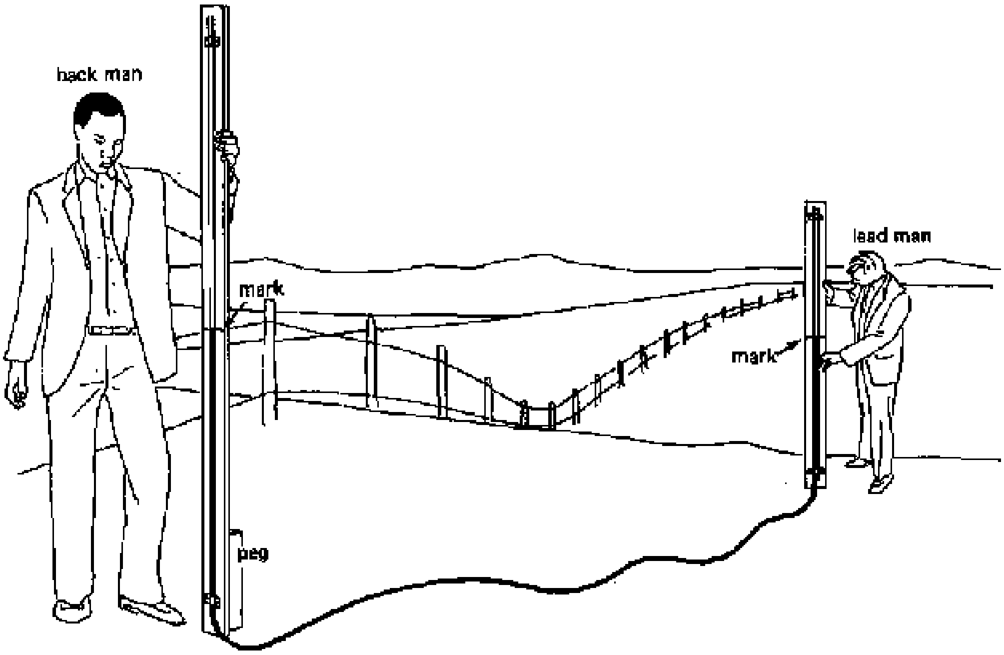


Fig.4.33

The point where the staff is then standing is at the same level as the starting point. A second peg (peg B) is placed at this point.

1. The procedure is repeated, starting from peg (B), to find the third point (peg C) of the contour line.

Care should be taken to avoid spilling water whenever the staffs are moved. For this purpose, the ends of the tube can be closed with plugs during transport.

Note: It is essential to remove the plugs during the measurements, otherwise the communicating vessels principle is not applicable anymore and measurements will be wrong.

4.2.5 Measurement of elevation difference

For the measurement of differences in elevation between two points in the field, the flexible tube water level can be used. Each staff is graduated in centimeters and used as a measuring staff. The zero point usually coincides with the foot of the staff.

A. Measuring the difference in elevation between two close points

Suppose the difference in elevation between two points A and B has to be measured; A and B are less than 10 m apart.

The first staff is set on point A and the second staff on point B (see Fig.4.33). After the water level in both stand tubes comes to a rest, a reading is made on both staffs. The difference in elevation between points A and B is calculated by the formula:

Difference in elevation between A and B = reading on staff A - reading on staff B

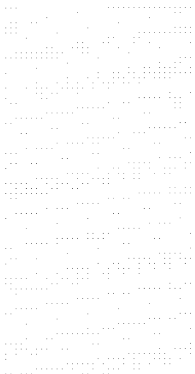


Fig.4.34

In our example (see Fig. above), if

Reading on staff A= 0.50 m and
reading on staff B =1.50 m, then
Difference in elevation between A and B = reading A - reading B = 0.50 - 1.50 = -1.00 m

In this case, the reading on staff B is higher than the reading on staff A; the result of the subtraction is negative which means that point B is below point A.

If the reading on staff B is lower than the reading on staff A, the result of the subtraction is positive which means that point B is above point A.

B. Measuring the difference in elevation between two distant points

Suppose the difference in elevation between two points A and B has to be measured, and A and B are more than 10 meters apart. The flexible tube of the instrument is too short to take only one measurement. Several steps are needed as per the followings.

1. In between points A and B, pegs are placed at intervals slightly less than 10 meters (see pegs C, D and E in Fig.4.35).

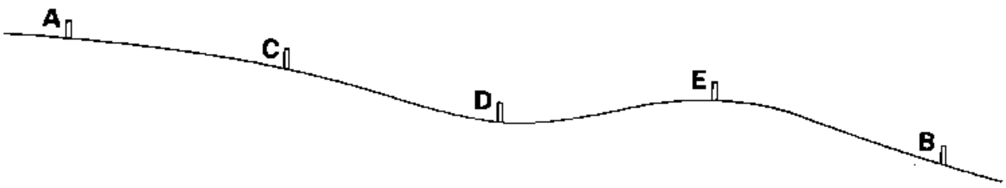


Fig. 4.35

2. The back staff is set near peg A, and the front staff near peg C (see Fig.4.35).

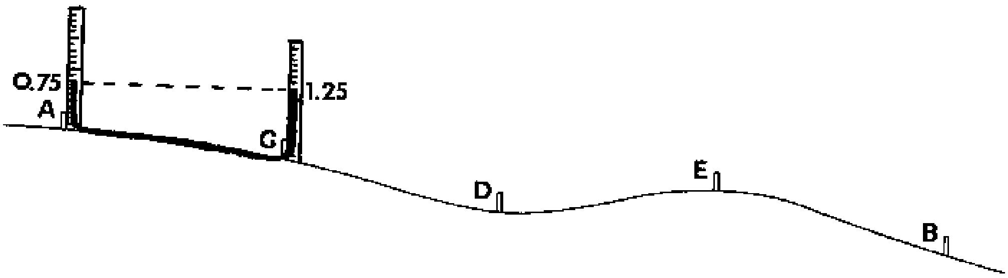


Fig. 4.36

A reading is made on both staffs and the results written down in a book. The back reading in one column, the front reading in another column.

Between pegs	Back Reading (m)	Front Reading (m)
A and C	0.75	1.25

3. Both men move. The back staff is set near peg C and the front staff is set near peg D. Again, readings are made and entered in the book (see Fig. 4.37).

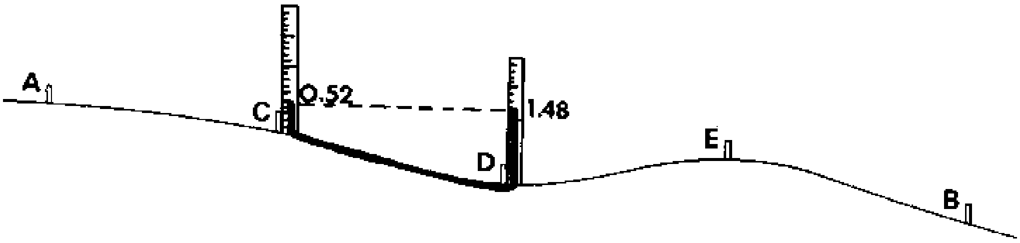


Fig. 4.37

The procedure is repeated until the front staff is set near peg B and the back staff is set near the last intermediate peg (E as in example). The last readings are made and written down in the book.

EXAMPLE:

Between pegs	Back Reading (m)	Front Reading (m)
A and C	0.75	1.25
C and D	0.52	1.48
D and E	1.23	0.77
E and B	0.41	1.59
Total	2.91	5.09

4. The difference in elevation between point A and point B is given by the formula:

Difference in elevation = sum of the back readings - sum of the front readings

In the example,

Measured
sum back readings = 2.91 m
sum front readings = 5.09 m

Answer
difference in elevation between A and B
= 2.91 m - 5.09 m = - 2.18 m

The negative result means that point B is below point A. A positive result would indicate that point B is above point A.

4.2.6 Measurement of horizontal & vertical distance

Measurement of short distance

The following procedure is used when measuring a distance which does not exceed the total length of the chain or the tape.

1. Pegs are placed to mark the beginning and the end of the distance to be measured.

2. The back man holds the zero point of the chain (or tape) at the centre of the starting peg. The front man drags his end of the chain (or tape) in the direction of the second peg. Before measuring, the chain (or tape) is pulled straight (see Fig.4.38).

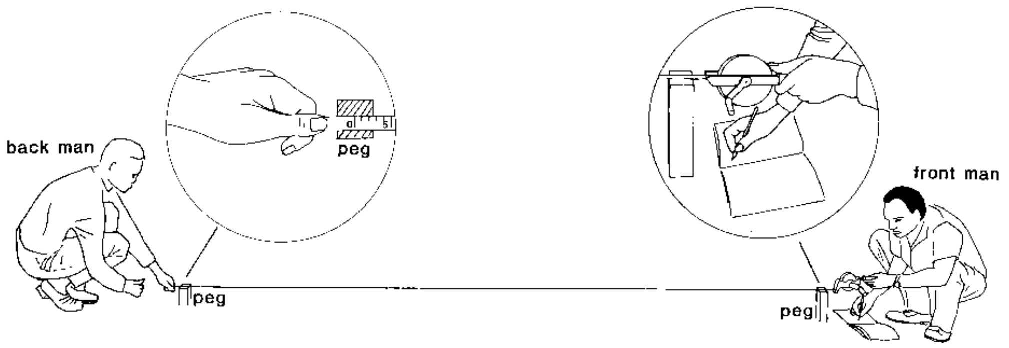


Fig.4.38

Note: Any knots in the tape or entangled links in the chain result in errors in the measurement.

3. When using a measuring tape, the distance between the two pegs can be read directly on the tape by the front man.

When using a chain, the number of links between the two pegs is counted. The total distance is equal to the number of links multiplied by the length of one link (20 cm).

Distance = number of links x length of one link

4.2.7 Measurement of long distance:

Very often, the distance to be measured is longer than the length of the chain or the tape. The front man is then provided with short metal pins, called **arrows**. The arrows are held together by a carrying ring. These arrows are used to mark the position of the end of the chain (or tape) each time it is laid down.

The procedure to follow when measuring long distances is:

1. Pegs are placed (A and B) to mark the beginning and the end of the distance to be measured, and ranging poles are set in line with A and B.

2. The back man holds the zero point at the centre of the starting peg (A). The front mar drags his end of the chain (or tape) in the direction of peg (B). Directed by the back man, he stretches the chain, in line with the ranging poles. Then he plants an arrow to mark the end of the chain (or tape) (see Fig.4.39).

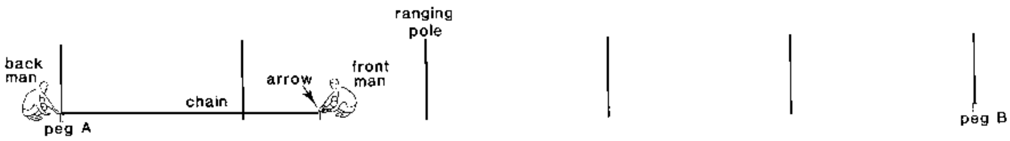


Fig.4.39

3. Both men move forward with the chain (or tape) and the procedure is repeated, the back man starting this time from the arrow the front man has just planted (see Fig.4.40).

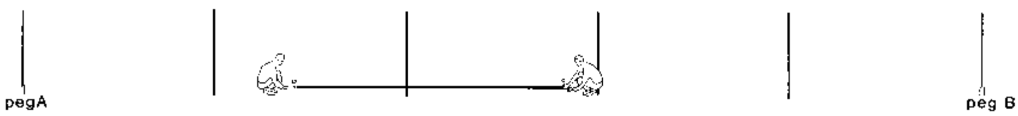


Fig.4.40

4. The procedure is repeated until the remaining distance between the last arrow and the peg (B) is less than one chain length (see Fig.4.41).

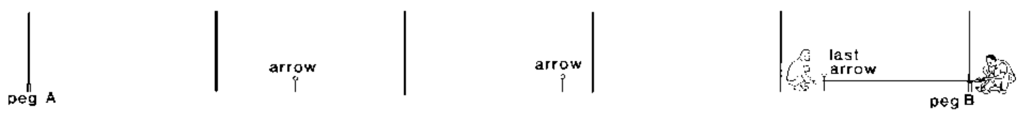


Fig.4.41

5. The remaining distance is measured using the procedure as described earlier.

The number of arrows used during the procedure represents the number of times the full length of the chain (or tape) has been laid out.

The total distance measured is then calculated by the formula:

Total distance	= number of arrows used x length of the chain (or tape)
	+ distance between the last arrow and peg B

EXAMPLE

The distance between two pegs (A) and (B) has been chained. When reaching peg (B), the back man has used 7 arrows. 23 links have been counted between the last arrow and peg (B), What is the total distance between pegs (A) and peg (B)?

Given

number of arrows used by the back man = 7
length of the chain = 20 m
number of links between the last arrow and peg (B) = 23
length of one link = 20 cm = 0.20 m

Answer

Distance between the last arrow and peg (B) = number of links x length of one link = 23 x 0.2 = 4.6 m

Total distance = (number of used arrows x chain length) + (distance between last arrow and peg B) = (7 x 20 m) + 4.6 m = 144.6 m

4.2.8 Measurement of distances in tall vegetations:

Distances may have to be measured in a field where a tall crop or tall grass is cultivated. The measuring tape (a chain would be too heavy) must then be stretched horizontally by the two men above the crop.

When measuring distances it is important to keep the tape horizontal. Push two arrows or two pegs into the soil to mark the distance to be measured (see Fig.4.41). Plumb bobs can be used to check if the measuring tape is indeed horizontal. If horizontal, the free hanging plumb bobs (immediately above the arrows) are perpendicular to the measuring tape. In other words, the measuring tape and the plumb bobs form right angles.

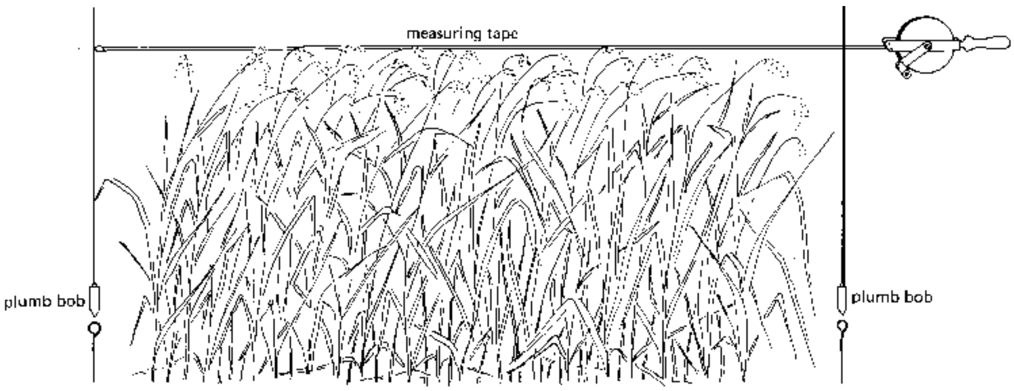


Fig.4.42

4.2.9 Measurement of horizontal & vertical distances in steep slopes:

Case I: When the distance is short

When measuring distances in a field, reference is always made to horizontal distances. In flat areas, these (horizontal) distances can be measured directly. In steep sloping areas, however, it is incorrect to assume that the distance measured over the ground surface is the horizontal distance. Thus the horizontal and vertical distances have to be measured separately.

A measuring rod, a plumb bob and a carpenter level are used to measure short horizontal and vertical distances in steep sloping areas for example between peg 1 and peg 2 of Fig. 1.

The steps followed are:

1. Two pegs (A and B) are driven into the soil in such a way that their tops are at the same height above the ground level (see Fig.4.43).

Fig.4.43

2. The zero point of the rod is placed on top of peg A. A carpenter level is placed on the rod; move the end of the rod up or down until the bubble of the level is between the marks: the measuring rod is horizontal (see Fig.4.44)

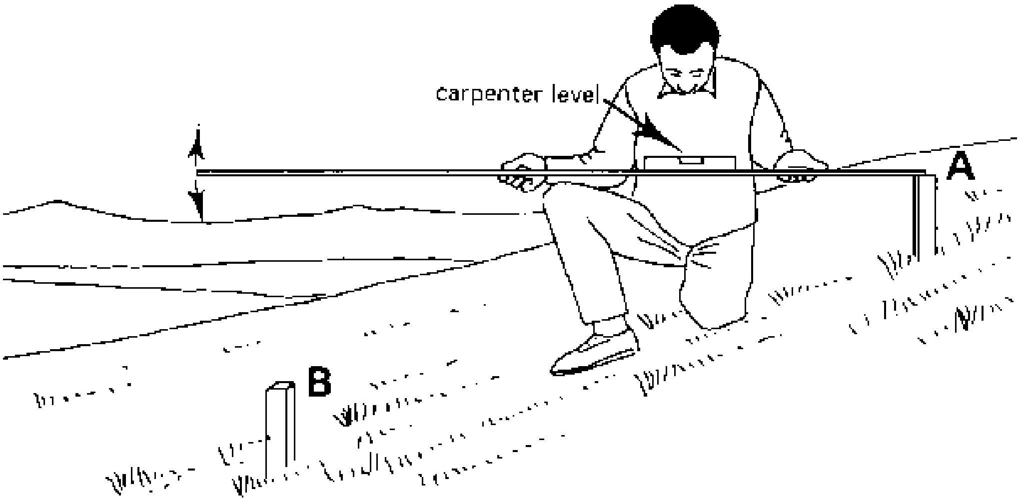


Fig.4.44

3. Hang a plumb bob just above the centre of peg B and read the **horizontal distance** on the measuring rod (see Fig.4.45).

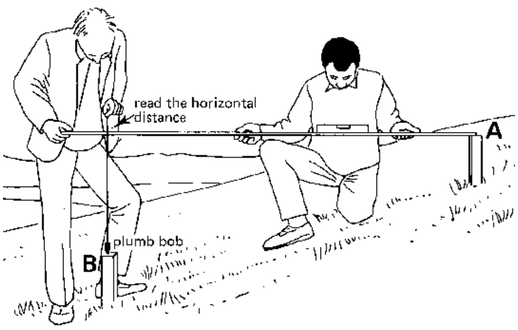


Fig.4.45

4. The measuring rod is maintained horizontal. The vertical distance between peg A and peg B is measured with a ruler or tape along the plumb bob, from the top of peg B to the bottom of the rod (see Fig.4.46).

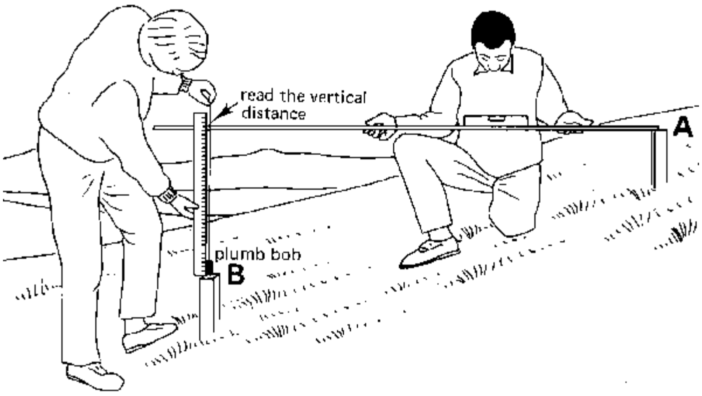


Fig.4.46

Case II: when the distance is long:

Often, however, the distance between the two pegs is longer than the length of the measuring rod. In this case, intermediate pegs are placed in line with A and B, at intervals of not more than one rod length (see Fig.4.47).

To measure the distances between all the intermediate pegs, steps 1 to 4 (see above) are repeated.

Step 1

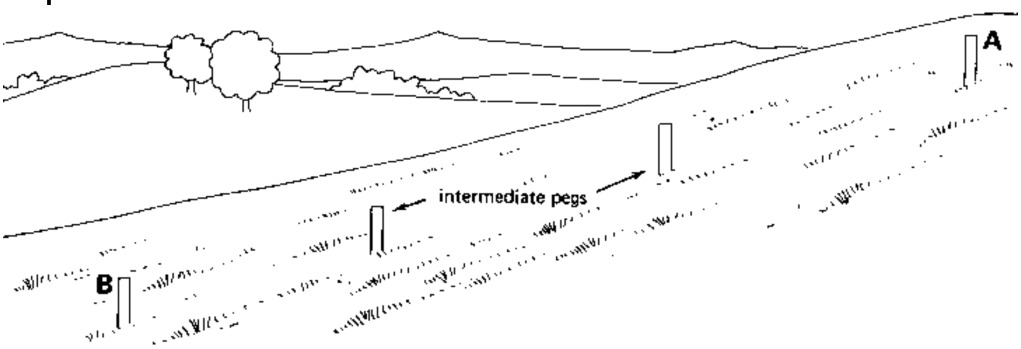


Fig.4.47

Step 2

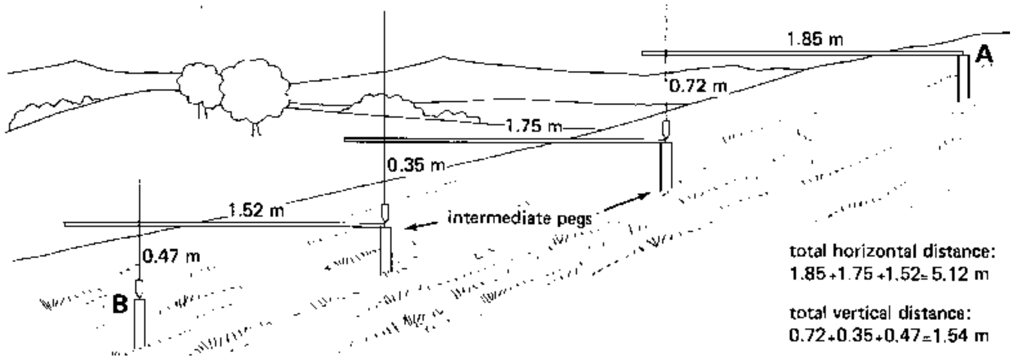


Fig.4.48

The total horizontal (or vertical) distance between pegs A and B is the sum of the horizontal (or vertical) distances measured between all the intermediate pegs (see Fig.4.48).

Total horizontal distance: 1.85 + 1.75 + 1.52 = 5.12 m
Total vertical distance: 0.72 + 0.35 + 0.47 = 1.54 m

Slope between A & B= $\frac{VI}{HI} \times 100 = \frac{1.54}{5.12} \times 100 =$ 30.08 %

Chapter- 5
Soil and Water Conservation Measures

Of the total amount of rainfall arriving at the surface, part infiltrates and the remainder becomes runoff, which concentrates in natural zones of depression. As runoff increases, so does its velocity, volume and its ability to cause erosion. Efficient control of erosion due to rainwater can be achieved by systematic planning and protection of the area from runoff, land preparation, cultivation of crops and soil cover. The measures required for soil and water conservation can be broadly divided into two categories, i.e., mechanical measures and biological measures.

5.1 Mechanical Measures

The structures, among others include bunds, terraces, trenches, grassed waterways, diversion drains and gully control

5.1.1 Bunding

Bunds are more or less like narrow base terraces, and consist of earth embankments built across the slope of the land. They are also constructed along field boundaries and are referred to as peripheral bunds. Based on the functional requirements, they can be divided into two types. They are classified as contour bunds, graded bunds and compartmental of field bunds.

Purpose

To reduce the runoff velocity before attending erosive velocity, check the soil loss and to improve the local soil moisture profile. Bunds control the formation of rills, arrest soil erosion, reduce water velocity and increase soil moisture status.

Location

Unbunded agricultural land with 2-6% slope (maximum 10%), area having low annual rainfall (less than 800mm) and all permeable soils except black cotton soil. They are to be constructed along the field boundaries in upper middle and lower reaches. Such structures should be constructed across the slope for maximum impact

5.1.1.1 Contour Bunding

Contour bunds are narrow based trapezoid bunds on contours to impound rainwater such that it percolates and recharge the root profile on either side of the bund up to 50% of the distance between two such bunds

Purpose

The basic purpose is to intercept the runoff flowing down the slope by an embankment. Contour bunds are constructed following the contour as closely as possible. A series of such bunds divide the area into strips and acts as barriers to the flow of water, thus reducing the amount and velocity of the runoff. Studies have shown that contour bunds result in a saving of soil ranging from 25 to 162 tons/ ha/ annum. In addition to controlling soil erosion and maintaining soil fertility, the construction of bunds helps in better infiltration of water into bunds ultimately replenishing the groundwater.

Location

- It can be adopted in light and medium textured soils.
- It can be laid up to 6% slopes.

Distance between two bunds

- ✓ The greater the rainfall and greater the slope, lesser is the distance.
- ✓ More permeable the soil, greater the distance.

Rule of thumb

- ✓ Vertical interval between two successive contour bunds is fixed at 1m.
- ✓ On higher slopes, bund should be closer, but not closer than 30m.
- ✓ On lower slopes, bund should be far, but not far than 60m.

Design of Contour bund

- ✓ Design involves the selection of vertical and horizontal intervals and determination of bund cross section.
- ✓ The criteria for fixing the vertical interval is same as discussed under graded terrace.
- ✓ The cross section of the bund is determined by fixing the side slopes, base width and top width.
- ✓ The height of the bund should provide sufficient storage behind the bund to handle the expected runoff. But in any case it should not be less than 45 cm.
- ✓ In practice, capacity is provided to take care of runoff from rains expected in 10 yr recurrence interval.
- ✓ The maximum runoff volume is estimated from the maximum amount of rainfall expected during the recurrence interval and infiltration characteristics of the area.
- ✓ The cross section area of storage space required can be computed by the following formula:
- ✓ Cross section Area (m^2) = Runoff (m): bund horizontal spacing (m)
- ✓ The height of bund should be provided with a freeboard of 20% of the design depth.
- ✓ The top width varies from 30 to 90 cm, depending on the height of bund (greater the height, more should be top width).
- ✓ The side slopes depend on the nature of the soil. The following side slopes should be provided.

Recommended side slopes

Type of soil	**Side slope (H:V)**
Clay	1:1
Loam	1.5:1
Sandy	2:1

- The base width depends upon the depth of water and soil type.
- The base should be sufficiently wide so that the seepage line does not go in the middle third.
- The slope of the seepage line can be taken as follows:

Type of soil	**Slope of seepage line (H:V)**
Clay	3:1
Sandy loam to loam	5:1
Sandy	6:1

Planning and design

- ✓ Vertical Interval (m), VI= 0.3*{(S/6) + 2}
- ✓ Horizontal Interval (m), HI= (VI*100)/S
- ✓ Length of bund per ha.= 10000/HI

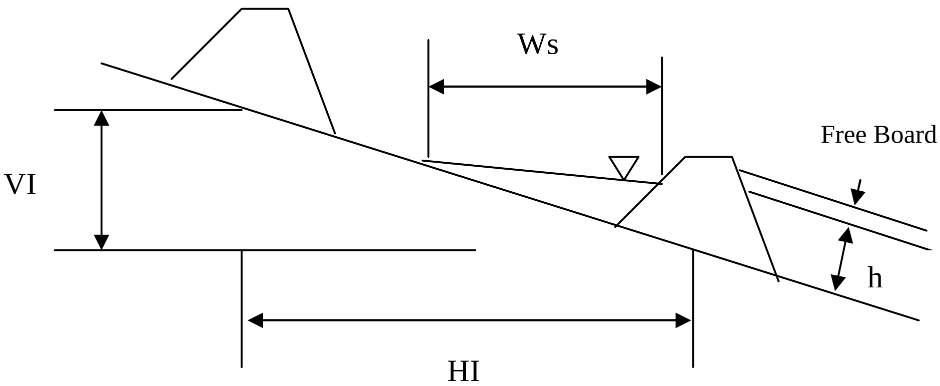


Fig:5.1 Planning and design of slopes

Spacing of contour bund

Standard dimension for contour bund:

- ✓ Top width: 0.45m
- ✓ Height: 0.60m
- ✓ Side Slope: 1.25:1
- ✓ Bottom width: 2m

Contour bund selection including for free board and settlement

Soil type	**Top width(cm)**	**Bottom width (cm)**	**Height (cm)**	**Slope side**	**c/s area (Sq cm)**
Very shallow	45	1.95	75	1:1	0.9
Shallow	45	2.55	82	1.25:1	1.25
Medium	52	3.00	82	1.5:1	1.48
Deep	60	4.20	90	2:1	2.22

Area lost due to contour bunding

The actual area occupied by bunds depends upon the base width of bund, the slope and the vertical interval of the bund. The area occupied by the main bund alone will be as follows:

Let HI = Horizontal interval

VI = Vertical interval, and

S = Prevailing land slope in percent

Length of contour bund per

ha = 10000/HI = 100S/VI

S = 100VI / HI

Area lost (sq m) due to bunding / ha = (100S/VI) x b

Where b = base width of contour bund

% area lost due to bunding (excluding side and lateral bunds) = (S x b) / VI

Assume length of side and lateral bunds to be 30% of length of main contour bund.

Total length of bund/ha = (1.3 x 10000)/HI

Total area lost due to bundig/ha = $1.3 \times \frac{100S}{VI} \times b$ (including side and lateral bund)

Bunds can be used for growing grasses or crops like castor and thus compensate for area lost.

Computation for earthwork for bunding

The earthwork for bunding includes the main contour bund and side and lateral bunds. The area of cross section of side and lateral bunds is taken equal to the main contour bund. The total length of bund per ha:

= $1.3 \times \frac{100S}{VI}$

Area of cross-section of bund:

$$\frac{\text{Top width + Bottom width}}{2} \text{ x Height of bund}$$

Total earthwork/ha = $1.3 \times \frac{100S}{VI}$ x area of cross section of bund

Do's

- ✓ In highly sloping and permeable soil, increase the downstream slope, decrease the distance between bunds, and provide a berm and safe exit to the bund.
- ✓ Use plantation for bund protection.

Don'ts

- ✓ Never excavate continuously as it may cause formation of channel.
- ✓ No cultivation is allowed on the earthen embankments.

Construction steps

- ✓ Layout for construction should be started from top of the catchment.
- ✓ A horizontal line along the slope is marked at one end of the field.
- ✓ Using a pipe level, contour line is demarcated up to the end of the field.
- ✓ Next line for contour bund is demarcated on the line with elevation difference equal to vertical interval.
- ✓ Soil for construction of bunds should be taken from burrow pits of suitable chosen size.
- ✓ Size of burrow pits should be as per required volume of earth required for bund.
- ✓ Normal size of burrow pit is 3 x 3 x 0.3 m or 3 x 3 x 0.45 m.
- ✓ Burrow pit should not be continuous, but interrupted with a gap of 0.6 m.
- ✓ A space of 0.3 m is provided as the gap between the bund and burrow pit which is called as berm.
- ✓ All bunds from the top are constructed to their full sections.
- ✓ All the burrow pits should be uniform in size and the berm gap should be uniform.
- ✓ Ramps are provided for the free passage of cattle, implements etc. on the bund.
- ✓ Suitable vegetation protection must be provided to ensure stability of the bund.

Maintenance

Due to lack of maintenance much of the benefits are lost and in certain cases, degradation may bring even more damage. The neglect in maintenance of even a single contour bund would endanger the whole system in lower reaches. So, before rainfall, following repairs or maintenance works should be attended to:

- ✓ Firm plugging of all breaches.
- ✓ Filling up of all sags in bunds.
- ✓ Restoration of proper height and section.
- ✓ Plugging of all rat holes.
- ✓ Repairs of damaged outlets and bunds.
- ✓ Growing grasses and trees on bunds.

Tentative estimate per ha

Length of bund/ha=500m (say)

CS of bund= (0.45+2.0)/2 m x0.60 m =0.735 cu m

Earthwork for 500 m=0.735x500= 367.50

Details of work	***Unit***	***Rate per unit (Rs)***	***Cost (Rs)***
Survey, demarcation and alignment	*4 MD*	*90*	*360*
Earthwork in ordinary soil with initial lead and lift	*187.8 MD*	*90*	*16902*
Grass turfing the side slope and top of bund with initial lead and lift= (0.98+0.98+0.45)mx500	*36.15 MD*	*90*	*3253*
Planting locally available vetiver sleeves on the U/s of the bund with spacing of 0.23 m	*14.5 MD*	*90*	*1305*
Contingencies etc.			*180*
Total			***22000***

NB: Per running metre Rs 45. Total labour requirement per ha 231 MD. Rate of unskilled manual labour (Mulia) who is engaged for digging, planting, transporting earth and grass turfing etc is Rs 90/day as per minimum wage fixed by GOO for 2009-10.

5.1.1.2 Graded Bund

Graded bunds are narrow-based versions of the channel terraces.

- ✓ They are used for safe disposal of excess runoff in high rainfall areas and regions where the soil is relatively impervious.
- ✓ They may have uniform grade or variable grade.
- ✓ Uniform graded bunds are suitable where the length of bunds and discharge are more.
- ✓ Variable grades are provided in different sections of the bund so that the velocity of flow is within non-erosive limit.
- ✓ Normally bund is constructed along a suitable grade and water is allowed to flow behind the bund.
- ✓ The design of graded bund involves the selection (or determination) of vertical interval, grade and cross section of bund and channel.
- ✓ The criteria for fixing the VI, grade and bund cross-section are discussed earlier (under contour bund and graded terrace).
- ✓ The required capacity of the channel is determined by using the Rational method.
- ✓ The dimensions of the channel can be obtained by applying the Manning’s formula.

Purpose

- ✓ Breaking the length of slope and removing excess water at a non erosive velocity.
- ✓ Checking soil loss.
- ✓ Improving local soil moisture profile.

Location

- ✓ Unbunded agricultural land with 2-6% slope.
- ✓ Where a suitable water course or drainage line is available in nearby area.
- ✓ Area having high annual rainfall (more than 800 mm).
- ✓ Soil having low infiltration rate.

Grade

- ✓ In general a grade of 0.2 to 0.4% is provided depending on soil type and location of drainage line.
- ✓ For permeable soil, grade of 0% at upper end and 0.5% at outlet end.
- ✓ For impermeable soil, grade of 0.2% at upper end and 0.4% at outlet end.

Bund section, VI, HI same as contour bund.

Layout

- ✓ Contour line is marked first in the field as per contour bund using the calculated vertical interval.
- ✓ If a graded bund of 200m is to be provided, different grade can be provided at 50 m interval as per the following example.

  At the end of 50m., grade is 0.1%
  At the end of 100m., grade is 0.2%
  At the end of 150m., grade is 0.3%
  At the end of 200m., grade is 0.4%

Channel cross section

The channel cross section should be such that it is of adequate size to carry the excess runoff at safe velocity and simultaneously permits the farming operation without any obstruction.

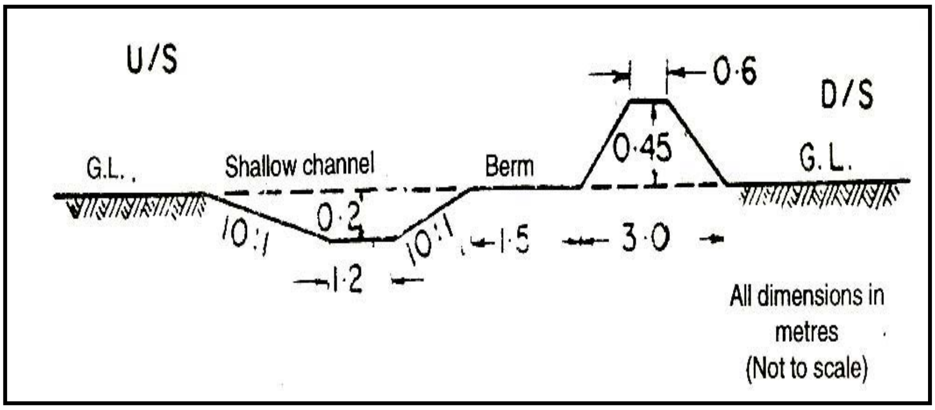


Fig. 5.2 Cross-section of a typical graded bund

Maximum depth of 0.45 m. with a minimum side slope of 5:1 or more flatter. The cross section should be 1.0 sq m minimum.

In general, the channel is not graded or aligned at the field boundaries. The maximum grade provided is 0.1%.

Construction steps

- ✓ The first bund is located at a spacing of 1.5 times the vertical interval from the ridge.
- ✓ Demarcation of contour line for graded bund is as per the demarcation of contour bund.
- ✓ Graded lines are demarcated by lime with suitable grade at different interval.
- ✓ This line is the upstream edge of the bund. Considering the bottom width, the downstream line of the bund is also to be demarcated by lime.
- ✓ The channel of suitable size should be constructed (the width of the channel should be demarcated) at the upstream end leaving a space of minimum 1.0 m. from the upstream side of the bund.
- ✓ The volume of earth work in channel should be approximately equal to the total volume of bund after the settlement.
- ✓ The waterways or channels must be protected with suitable vegetative barriers/ stone check or drops at suitable intervals.
- ✓ Suitable vegetative protection must be provided to ensure stability of the bund.

Maintenance

The graded bund should be inspected after heavy rainfall. The undue settlement in the bund, the places of depression, excessive grade in the channel causing scouring and rill formations and excessive inter bund erosion should be inspected. Leveling, cutting or filling would eliminate the defects. For maintenance, the dead furrow should be always in the centre of the channel and the back furrow at the top of the ridge. Proper farming practices protect the cross-section from being reduced and help in constant build-up and easing the side slopes. Perpendicular crossing of the bund should be avoided. The contour bund may be planted with suitable grasses or vegetation. Proper and timely maintenance of grassed waterways are essential.

Limitations

- ✓ The main limitation of a graded bunding system is the requirement of grassed waterways (for diverting extra water) whose construction and maintenance requires the cooperation of several farmers.
- ✓ The water once removed from a field cannot be brought back easily unless stored in ponds near to the individual fields.
- ✓ If not properly executed, heavy scouring in the channel may take place.
- ✓ Seed and seedlings in the channel, particularly, in the lower reaches, may get washed away if heavy shower occur at that time.
- ✓ Weeds which get collected in the channel portion thrive well under the better moisture regime which if not removed periodically may become a source of propagation into the fields.

5.1.1.3 Compartmental Bunding (Field Bunding)

These bunds control the formation of rills, arrest soil erosion, reduce water velocity and increase soil moisture.

Purpose

- ✓ Breaking the length of slope.
- ✓ Checking the soil loss.
- ✓ Improving local soil moisture profile.

Location

- ✓ In irregular sized and very small land holdings.

- ✓ Where field boundaries/ bunds exists or in unbunded land.
- ✓ Where laying of contour or graded bund is not practically possible, mainly due to resistance of farmers.

Constructed along the field boundaries in upper middle and lower reaches. Such structures should be constructed across the slope for maximum impact

Dimensions

The general dimensions should broadly follow the dimensions of contour bund. Since, the total bund length per hectare is much more than the calculated length of bund per hectare. Due to small land holdings with irregular boundaries, the dimensions of such bund in general are less than the dimensions of contour bund. Generally, cross section is decided keeping the slope, soil and rainfall in view and mostly importantly with the consent of the farmers. The existing side bunds which run along the slope is not constructed/ renovated. Only the existing field bunds across the slope is renovated/ constructed after taking the pre measurement of the length and section. Provision of series of suitable outlets for each bunding is a must considering the total runoff to be handled/ cumulative runoff from the catchment.

Fig. 5.3 Compartmental Bunding

Estimation for field bunding/graded bunding/contour bunding

For 1 ha land (100m x100m field size)
Total length of bund =300m (bund will be on three sides, no bund on up stream side)
Area of cross section = 0.3375m^2
Volume of earthwork= 0.3375 x 300=101.25m^3
Cost of excavation and formation of bund @Rs. 46/ m^3=101.25 x 46=Rs. 4657.50
Assuming cost of brick masonry broad-crested rectangular weir/ prefabricated cement concrete drop structure= Rs. 662/-
Total cost of construction= Rs.5320/ha

5.1.1.4 Semi-Circular Bunds

Semi-circular bunds are earth bunds in the shape of a semi-circle with the tip of the bunds on the contour.

Purpose: The bunds are constructed to increase soil moisture and reduce erosion.

Location: Semi-circular bunds are suitable on gentle slopes (normally below 2%) in areas with annual rainfall of 200-750 mm. The soils should not be too shallow or saline. These bunds are easily constructed on uneven terrains.

Design: The size of the bunds varies, from small structures with a radius of 2 m to very large structures with a radius of 30 m. They are often used to harvest water for fruit trees and are especially useful for seedlings. Large structures are used for rangeland rehabilitation and fodder production. The entire enclosed area is planted. When used for tree growing, the runoff water is collected in an infiltration pit, at the lowest point of the bund, where the tree seedlings can also be planted. The bunds are laid out in a staggered arrangement so that the water which spills round the ends of the upper hill will be caught by those lower down.

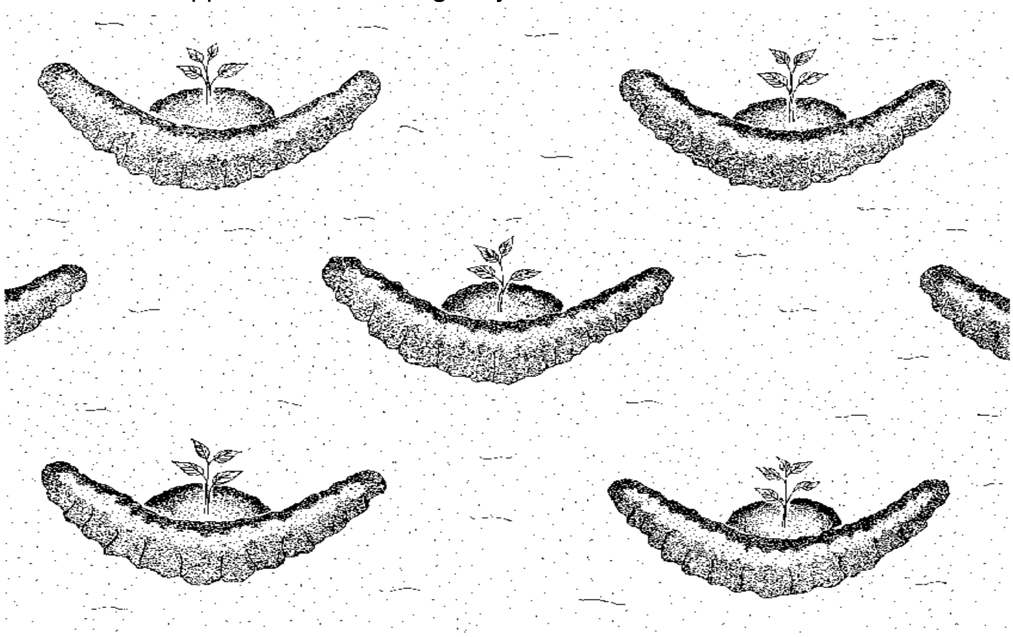


Fig.5.4 Semi-circular bunds for fruit production

5.1.2 TRENCHING

Trenches are dug around the hill slope at a given contour especially used for treating non-arable area of hill slopes. Continuous contour trench is recommended in the upper reaches of watershed. Trenches that are dug on contour lines is called as counter trench, whereas the trenches constructed continuously are called as continuous contour trenches.

Purpose

Trenches are suitable for erosion control in hills. These trenches intercept the runoff which enters into soil and increases soil moisture status. They hold water in upper reaches leading to increased percolation and soil moisture and recharge of ground water and to reduce erosion.

Location

Cultivable barren hillocks and common fallow lands with steep slopes in the upper reaches, usually in degraded forest lands, revenue lands and common lands.

- Adopted for hill slopes >20%
- Normal size: 1000 cm^2 to 2500 cm^2
- Continuous or interrupted
- Stone terraces and walls can be constructed whether stones are available

5.1.2.1 Contour Trenching

Contour trenching is excavating trenches along a uniform level across the slope of the land in the top portion of catchment. Bunds are formed downstream along the trenches with material taken out of them.

Purpose

The purpose is to hold water in upper reaches leading to increased percolation and to recharge ground water. The main idea is to create more favourable moisture conditions and thus to accelerate the vegetative growth.

Location

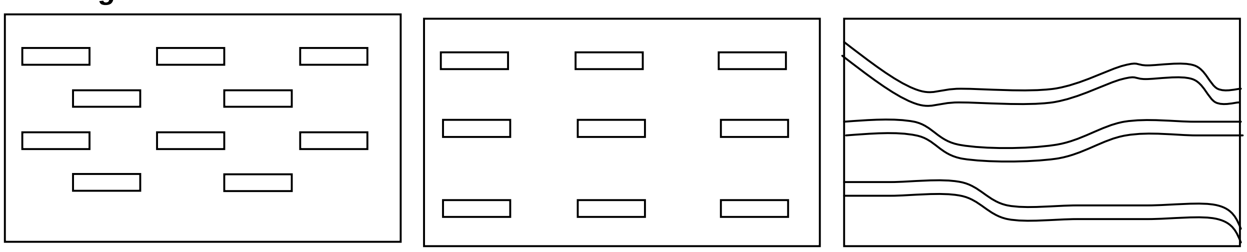
Contour trenches are suitable for barren hillocks and common fallow lands with steep slopes in the upper reaches, usually degraded lands, revenue lands and common lands.

Design

Plants are put on the trench side of the bunds along the berms. If not continuous, trenches are not more than 15 m long and are generally staggered. In the cross section they rarely exceed 0.3m x 0.3m. The side slopes of the trenches are 1:1 or 0.5:1, according to the nature of the soil.

- ✓ Vertical interval between two successive contour trenches is fixed at 1m.
- ✓ Trench should be closer, but not closer than 10m on higher slopes.
- ✓ Trench should be far, but not farther than 30m on lower slopes.
- ✓ Depth: 30 -50 cm, width: 30-50cm.
- ✓ Practically adoptable size 45 cm x45 cm

Drawings:



Staggered In line Continuous

Fig.5.5 Types of Trenches

(6) **In-line Contour Trenching**

Dimensions

For continuous trenches/ staggered trenches with the in between gap equal to length of trench, the runoff from the contributing area is estimated for 2 year frequency and the following formula is used to workout the dimensions.

$$Q = \frac{W \times D}{100HI}$$

Where,

Q = depth of runoff from area in cm

W = width of trench in cm

D = depth of trench in cm

HI = horizontal interval in metres

Staggered trenches with gap not equal to length of trench:

$$Q = \frac{W \times D}{100HI(1 + X / L)}$$

X = gap between trenches in m

L = length of the trench in m

For convenience of layout and construction, shorter lengths of 3.5 or 7m are generally adopted. In pasture lands longer lengths up to 200m can also be made.

Construction Steps

- ✓ Measure the slope in one section of the ridge area.
- ✓ Join the highest point and lowest point along the slope by a straight line with a rope and lime (wet).
- ✓ Calculate the interval between successive lines of trench.
- ✓ On the straight line, mark points at the calculated interval.
- ✓ Demarcate the contour line starting from each of the mark points (using A- frame, pipe level)
- ✓ Excavate trenches along the demarcated contour line starting from the mark so that when the trench is filled with rain water, water remains at the level of the marked contour line or below.
- ✓ Always start excavation from the highest contour line.
- ✓ Pile the excavated earth at least 20cm. away from the trench in the downstream side.
- ✓ Deposit stones, gravels found during excavation/ or collect freely available material nearby area in a layer of 1.0 ft/ or put soil binder grass in the upper edges of the trench.
- ✓ Suitable plantation works must be undertaken in the lower edge of the trench.

Suitable time

- ✓ Trenching is preferably to be carried out during winter and spring so that sowing and planting can be done during first monsoon.

Do's and Don'ts

Do's

- ✓ Boulders and gravels from excavation should be stalked on the lower side of the bund / spoil bank to serve as the toe of the bund.
- ✓ Top soil should be kept towards the trench as it can be used for refilling if necessary.
- ✓ Trench area should be protected from animal and human interference.

Don'ts

- ✓ Do not go for trenches when slope is more than 25% or less than 10%. Vegetative measures to be adopted in slopes more than 25% and contour bunding to be adopted in slopes less than 10%.
- ✓ Do not excavate trench across drainage line.
- ✓ Do not excavate trench when roots are encountered or in the area of thick vegetation.
- ✓ Do not go for plantation inside the trench.
- ✓ Do not go for trench in excessive hard/ stony earth and where loose stones are plentily available, instead go for stone bunding/ stone wall terrace.
- ✓ Do not go for CCT in high rainfall areas; instead go for staggered trench in combination of 2 to 3 nos.

(b) Continuous Contour Trench (CCT)

Trenches dug on contour lines are called as contour trenches. Where these trenches are continuous then called as continuous contour trenches.

Purpose

To hold water in upper reaches leading to increased percolation and soil moisture and recharge of ground water and to reduce erosion

- Reducing the runoff velocity.
- Checking soil loss.
- Improving local soil moisture profile

Location

Continuous contour trench is recommended in the upper reaches of watershed. It is also recommended for cultivable barren hillocks and common fallow lands with steep slopes in the upper reaches, usually in degraded forest lands, revenue lands and common lands.

Design

- Slope= 10-25% (max-33%)
- Soil depth= minimum 7.5cm (3.0 in
- Vertical interval between two successive contour trenches is fixed at 1.00 m (3ft)
- On higher slopes, trench should be closer, but not closer than 10m. (30ft)
- On lower slopes, trench should be far, but not farther than 30m. (100ft)

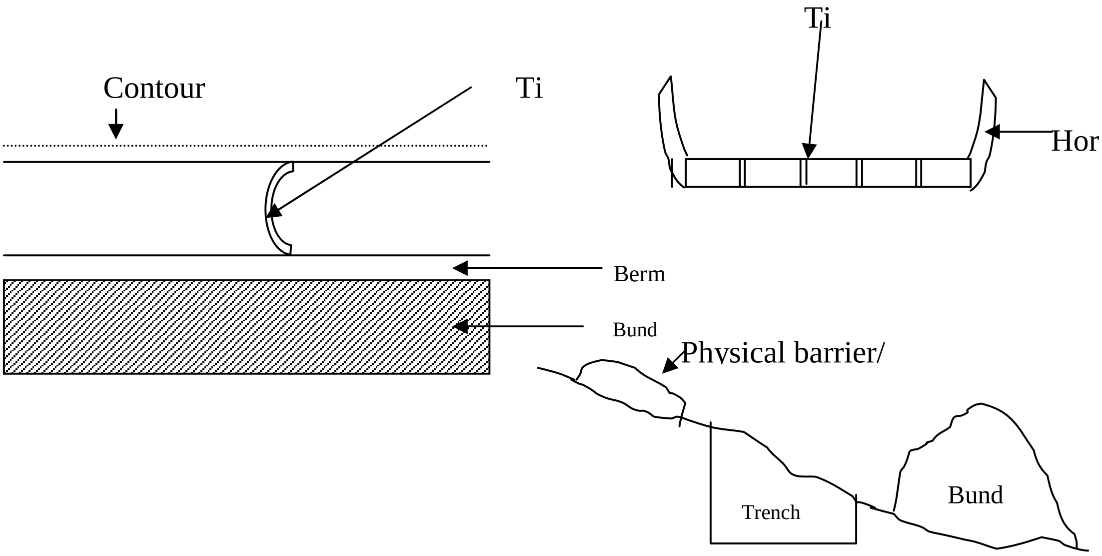


Fig.5.6 Continuous Contour Trench (CCT)

Design Details of CCT

Dimension	:	
Width	:	0.6m
Depth of	:	0.3M
Cross section	:	0.18 sq m
Total running meter per ha	:	1116.07 m/ha.
Total No. of lines of 100 m length	:	11.16 no
Slope of land	:	8%

$$VI = \frac{Slope}{No.\ of\ lines} = \frac{8}{11.16} = 0.72\ m$$

$$HI = \frac{100xVI}{S} = \frac{100x0.72}{8} = 9\ m$$

The following table can also be used as a ready reckoner for estimating horizontal interval.

Table:5.1 Estimation of horizontal interval

AV Annual Rain fall mm	No of Rainy days Days	Rainfall per day mm	Runoff volume cum/ha	Add 25% Vol. Cum/ha	Running Meter ha	Horizontal interval meter
900	40	22.50	225.00	281.25	1562.50	6.60
900	45	20.00	200.00	250.00	1388.89	7.20
900	50	18.00	180.00	225.00	1250.00	8.00
900	55	16.36	163.64	204.55	1136.36	8.80
1000	45	22.22	222.22	277.78	1543.21	6.48
1000	50	20.00	200.00	250.00	1388.89	7.20
1000	55	18.18	181.82	227.27	1262.63	7.92
1000	60	16.67	166.67	208.33	1157.41	8.64
1100	45	24.44	244.44	305.56	1697.53	5.89
1100	50	22.00	220.00	275.00	1527.78	6.55
1100	55	20.00	200.00	250.00	1388.89	7.20
1100	60	18.33	183.33	229.17	1273.15	7.85
1200	45	26.67	266.67	333.33	1851.85	5.40
1200	50	24.00	240.00	300.00	1666.67	6.00
1200	55	21.82	218.18	272.73	1515.15	6.60
1200	60	20.00	200.00	250.00	1388.89	7.20
1300	45	28.89	288.89	361.11	2006.17	4.98
1300	50	26.00	260.00	325.00	1805.56	5.54
1300	55	23.64	236.36	295.45	1641.41	6.09
1300	60	21.67	216.67	270.83	1504.63	6.65
1400	45	31.11	311.11	388.89	2160.49	4.63
1400	50	28.00	280.00	350.00	1944.44	5.14
1400	55	25.45	254.55	318.18	1767.68	5.66
1400	60	23.33	233.33	291.67	1620.37	6.17
1500	50	30.00	300.00	375.00	2083.33	4.80
1500	55	27.27	272.73	340.91	1893.94	5.28
1500	60	25.00	250.00	312.50	1736.11	5.76
1500	75	20.00	250.00	250.00	1388.89	7.20
1600	50	32.00	320.00	400.00	2222.22	4.50
1600	55	29.09	290.91	363.64	2020.20	4.95
1600	60	26.67	266.67	333.33	1851.85	5.40
1600	75	21.33	213.33	266.67	1481.48	6.75
1700	55	30.91	309.09	386.36	2146.46	4.66
1700	60	28.33	283.33	354.17	1967.59	5.08
1700	75	22.67	226.67	283.33	1574.07	6.35
1700	80	21.25	212.50	265.63	1475.69	6.78
1800	55	32.73	327.27	409.09	2272.73	4.40
1800	60	30.00	300.00	375.00	2083.33	4.80
1800	75	24.00	240.00	300.00	1666.67	6.00
1800	80	22.50	225.00	281.25	1562.50	6.40

1900	60	31.67	316.67	395.83	2199.07	4.55
1900	75	25.33	253.33	316.67	1759.26	5.68
1900	80	23.75	237.50	296.88	1649.31	6.06
1900	85	22.35	223.53	279.41	1552.29	6.44
2000	60	33.33	333.33	416.67	2314.81	4.32
2000	75	26.67	266.67	333.33	1851.85	5.40
2000	80	25.00	250.00	312.50	1736.11	5.76
2000	85	23.53	235.29	294.12	1633.99	6.12

Tentative Estimate

Total running metre per ha is 1116.07 m and total number of lines of 100 m length is 11.16.

Item	Number of MD	Rate in Rs	Total amount
Survey, demarcation and alignment	1	90	90.00
Earth work in ordinary soil with initial lead and lift	9.2 MD	90	828.00
Contingency			45.00
Total			963.00

Abstract:

(i) Labour required 10.2 MD
(ii) Cost per m Rs 9.63
(iii) Cost per ha Rs.10747.oo

Construction steps

- Measure the slope in one section of the ridge area
- Join the highest & lowest point along the slope by a straight line with a rope and lime (wet).
- Calculate the interval between successive lines of trench
- On the straight line, mark points at the calculated interval
- Demarcate the contour line starting from each of the mark points (using A-frame, pipe level)
- Excavate trenches along the demarcated contour line starting from the mark so that when the trench is filled with rain water, water remains at the level of marked contour line or below.
- Always start excavation from the highest contour line
- Pile the excavated earth at least 20 cm. away from the trench in the downstream side
- Deposit stones, gravels found during excavation/ or collect freely available material in nearby area in a layer of 1.0 ft/ or put soil binder grass in the upper edges of the trench
- Suitable plantation works must be undertaken in the lower edge of the trench

Don'ts

- ☒ Do not go for trenches when slope is more than 25% or less than 10%. Vegetative measures to be adopted in slopes more than 25% and contour bunding to be adopted in slopes less than 10%.
- ☒ Do not excavate trench across drainage line
- ☒ Do not excavate trench when roots are encountered or in the areas of thick vegetation.
- ☒ Do not go for plantation inside the trench
- ☒ Do not go for trench in excessive hard/ stony earth and where loose stones are plentily available, in stead go for stone bunding/ stone wall terrace.
- ☒ Do not go for CCT in high rainfall areas, in stead go for STAGGERED TRENCH in combination of 2 to 3 nos. of Water Absorption Trench.

(c) Staggered Contour Trench (SCT)

Fig. 5.7 Staggered Contour Trenches

Important to note

- Most suitable in steep & irregular sloping lands and high rainfall areas.
- In highly undulating land align trench in the direction of flow of water (as shown in fig-4)
- Boulders & gravels from excavation should be stalked on the lower side of the bund/spoil bank to serve as the toe of the bund.
- Top soil should be kept towards the trench as it can be used for refilling if necessary.
- Trenching is preferably carried out during winter and spring so that sowing and planting can be done during the first monsoon.

Protection of trench area from animal and human interference is a must till it is fully covered by vegetation until achievement of the desired results.

Construction Steps

- Excavate a trench of 4m long on a contour line
- Provide a gap of 4m and dig another trench along the same line and so on.
- On the next contour line, dig the trench of 4m in the gap portion of the trench of previous contour line and provide a gap of 4m and so on.
- The gap portion of this contour comes directly below the trench portion of the higher contour line.
- In this way chains of staggered trenches should be constructed along successive contours so that water left by one line of trenches are caught hold up by the immediate lower line.

  At the both end of each individual trench provide horn.

Tbale:5.2 Tentative estimate for staggered trench per ha

Details of work	Unit	MD	Unit cost (Rs)	Amount (Rs)
Earthwork	Area 0.16 sq m and gap of 2-4m	136.3 MD	90	12267
Earthwork for 200m length	320 cu m	13 MD	90	1170
Vegetative reinforcement	2000 m length	5 MD	90	450
Skilled				
Earthwork	Area 0.16 sq m and gap of 2-4m	7.5 MD	116	870

Earthwork for 200m length	320cum	2.2 MD	116	255
Vegetative reinforcement	2000 m length	1 MD	116	116
Total				**15128**

NB: Rs 90 for unskilled labourer as explained earlier

Rs 116.00 for skilled labourer (masons, stone fixer and artisans, grass turfing etc) as explained in Standard Scheduled of Rated fixed by GOO for 2009-10

5.1.2.2 Water Absorption Trench (WAT)

A WAT is nothing but a CCT of larger dimension excavated along the contour line.

Fig. 5.8 Water Absorption Trench

Purpose

- Reducing the runoff velocity.
- Checking soil loss.
- Storing excess rain water and recharge ground water
- Providing protection to the lower treated area from heavy rain.

Location

- Slope= 10-25% (max-33%)
- Barren hills and degraded wastelands having poor soil depth
- Areas where rainfall is medium to high

Size and spacing in general

- Width of trench= 100 cm (3.0ft.)
- Depth of trench= 100 cm (3.0ft)
- Max. Length of trench= 200 -400m. per ha

Important to note

- 3 WATs are generally excavated- one at top, one at middle and one at end of the hill slope.
- Combination of WAT and staggered trench is always better when rainfall intensity is high.

The soil bank or mound must be of uniform height and stabilized by planting grass/ bush species.

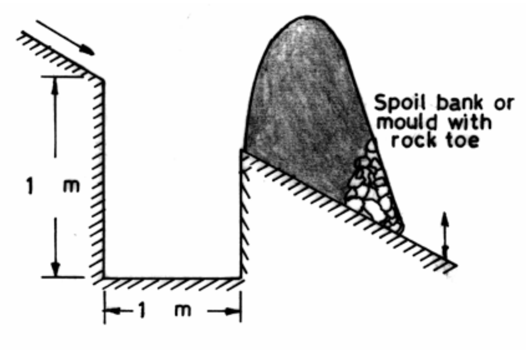


Fig. 5.9 Cross Section of WAT

Fig.5.10 Combination of WAT & Staggered Trench

5.1.3 TERRACING

It consists of construction of step like fields along contours by half cutting and half filling. Original slope is converted into level fields. The vertical and horizontal intervals are decided on land slope.

5.1.3.1 Bench terrace

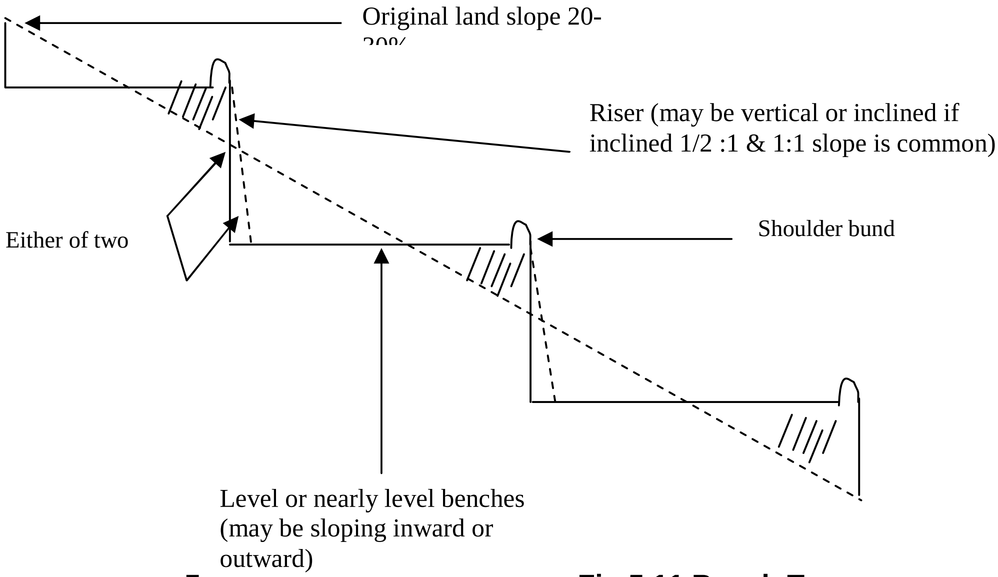
The original bench terrace system consists of a series of flat shelf like areas that converts a steep slope of 20 to 30 percent to a series of level or nearly level benches. They are costly to construct. It consists of an earthen embankment and a very broad nearly flat channel that resembles a level bench. The sloping area above this bench and extending upslope to the next terrace ridge is the runoff contributing area to the benched area

Purpose

To level the fields beyond 6% slope for practicing hill agriculture. It helps to bring sloping land into different leveled strips to enable cultivation.

Location

Bench terraces are adaptable to slopes up to 6-8%. These are suitable for semi arid regions where maximum moisture conservation is needed.



F **Fig 5.11 Bench Terrace**

The condition of soil, depth, slope, rainfall, farming practices etc., all have direct bearing on terrace design. The design of bench terraces consists of the following:

- ✓ Terrace spacing
- ✓ Terrace grade length
- ✓ Terrace cross section

Terrace spacing:

- ✓ Find out the maximum depth of productive soil range (D).
- ✓ Find out the maximum admissible cutting (d), for the desired land slope (S) and the crops to be grown.
- ✓ Compute the width of terrace (W) = 200d/S, where, W and d are in metres and S in percent.
- ✓ The vertical interval (V.I.) can be computed as hereunder:

  V.I. = WS/(100-S),

  For riser with side slope 1:1 and

  V.I. = 2WS/(200-S),

  For risers with side slope 0.5:1

Terrace gradient:

For quick disposal of excess water, a suitable gradient has to be provided.

- ✓ Estimate the peak rate of runoff(cumec)

  Q = CIA/360 (i) Rational formula
- ✓ The area drained,

  A (ha) = L x W/100

  Where,

  L = length of terrace (m)

  W = average width of terrace (m)
- ✓ Compute the grade of the terrace using Manning's formula.

  $$V = \frac{1}{n} R^{2/3} S^{1/2}$$

  Where,

  V = permissible velocity

  R = hydraulic radius (m)

  n = roughness coefficient

  S=Slope of the channel

  (ii) Curve no. technique

  $$Q = \frac{(P - Ia)^2}{P - Ia + S}$$

  Where, S= maximum storage in cm

  Ia = Initial abstraction

  P= Total amount of rainfall

  Q= Total amount of runoff

Terrace cross-section:

To construct a bench terrace the earthwork is excavated from the upper half is deposited over the lower half. The deposited portion forms an embankment. Care should be taken to secure this well on the slope by providing suitable key trenches and cleaning the surface of all vegetation. The height of the embankment should be raised sufficiently keeping in view the shrinkage of soils, so that the ultimate slope, after consolidation, conforms to the specification. Shoulder bunds are usually 0.3 m high with bottom width of 0.75 m and side slopes of 1:1, sometimes 0.5:1. Protection of the risers of the terraces is done either by establishing grasses or by providing stone pitching or revetment.

The width of the bench terraces should be as per the requirement for which the terraces are to be put after construction. Once the width of the terrace is decided, the depth of cut required can be calculated.

(1) When the terrace cut are vertical.

D = WS/100

S is the slope in percent; D/2 is the depth of cut and W is the width of terrace.

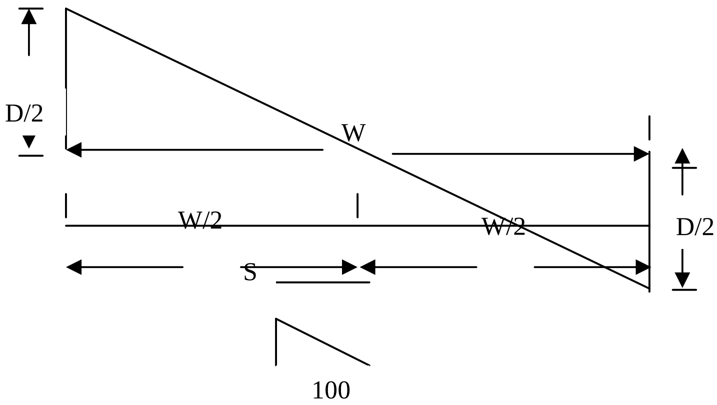


Fig: 5.12 Terrace cross section

(2) When the batter slope is 1:1.

0.5*D/ (0.5W + 0.5D) = S/100

Or D = WS / (100 - S)

(3) When batter slope is ½:1.

0.5D / (0.5W + 0.25D) = S/100

Or D = 2WS / (200 - S)

After deciding the width required, the depth of cut can be calculated from one of the above formulae. An adjustment has to be made between the width and the depth depending upon the land slope and soil conditions.

The inward slope of the terrace may be between 1 in 50 (2 per cent) to 1 in 10 (10 per cent) depending upon soil conditions. In case of these terraces a drainage channel is to be provided at the inner edge of the terrace to dispose the runoff.

Terrace grades

- ✓ Grades usually range from 0.1 to 0.6%, depending on soil and climatic factors. Generally, the steeper grades are recommended for impervious soils and short terraces.
- ✓ ASAE (1972) recommended maximum velocities of 0.46 m/ sec for most erosive soils and 0.61 m/ sec for other soils, if n = 0.03.
- ✓ The variable graded terrace is more effective because the capacity increases towards the outlet with a corresponding increase in runoff.
- ✓ The grade varies from a maximum at the outlet end.

- ✓ The resulting reduced velocity in the upper portion provides for greater absorption of runoff. However, sediment is likely to be deposited in the upper portion (disadvantages).

Table:5.3 Channel grades for variable grade terrace

Length of terrace (m)	Grade in %			
	Lower ¼	Second ¼	Third ¼	Upper ¼
30-120	0.3	0.3	0.2	0.2
150-240	0.4	0.3	0.2	0.2
270-360	0.5	0.4	0.3	0.2
400-above	0.5	0.4	0.3	0.2

Terrace length

- ✓ The maximum length for graded terrace ranges from approximately 300-500 m, depending on shape and size of field, runoff rate, channel capacity, outlet possibility etc.
- ✓ On permeable soils longer terraces may be constructed than on impervious soil.
- ✓ In the case of level terrace, there is no limit to maximum length provided blocks or dams are placed in the channel about every 150 m.

Maintenance

Maintenance of the bench terraces is important. The shoulder bund should be planted with permanent vegetation and ploughing of the toe of bund should be avoided. The batter slope of the terraces should be stabilized and protected by establishing deep rooted and soil binding and spreading type of grasses.

Table:5.4 Tentative estimate for bench terrace in 1 ha

Item of work	Unit	MD	Rate/MD	Amount (Rs)
Earthwork	1574.37cum	472.2	90	42498
Grass turfing	1666m	266.4	90	23976
Skilled labour	1574.37 cu m	18.9	116	2192.4
Grass turfing	1666m	10.0	116	1160
LA				1777
			Total	**71603**

5.1.3.2 Stone Terracing

Stone terracing, also known as stone wall terraces are small embankment constructed with stones across the hill slopes. These can be adopted in any slope where stones are available in plenty at the spot.

Specifications

The spacing adopted for stone terraces need not be rigid and suitable spacing can be adopted depending upon local conditions. Spacing from 10 m to 30 m can be adopted depending upon slope. Stone terraces should be as far as possible straight. Local depression should be crossed straight in the alignment and whenever required a neat curve may be adopted. Deviation from the contour is allowed provided that the bunds are strengthened at the depressions by additional stone work to bring the height of bund at the depression to the same level as the rest of it. The last stone terrace should coincide with the field boundary. For the construction of the terraces, a shallow trench has to be dug and the stone collected and packed directly into the foundation and in the super structure to form the terrace. The stone are now arranged to form the shape of the bund. The stone should be properly interlocked.

The soil excavated to form the foundation for the terrace is used for forming a small bund on the upstream side of the terrace. In order to stabilize this bund and the terrace suitable vegetative cover may be provide on this bund.

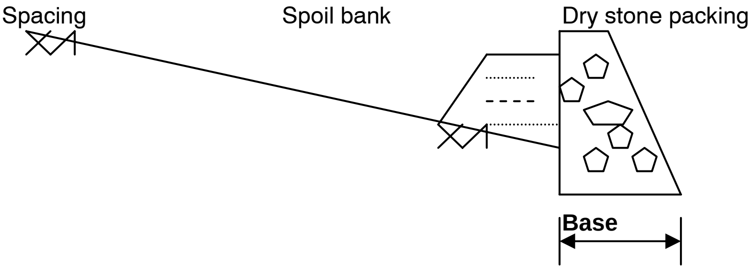


Fig. 5.13 Stone Terracing

Stone wall construction

- Mark the contour line using pipe level.
- Excavate the trench up to 30 cm depth and width up to 90 cm as per the suitability along the contour and deposit the excavated material on the upstream side of the trench.
- Arrange stones in layers with bigger stones at the bottom and downstream side with proper locking of smaller stones in the gap of bigger stones.
- Ensure proper interlocking between stones of different layers.

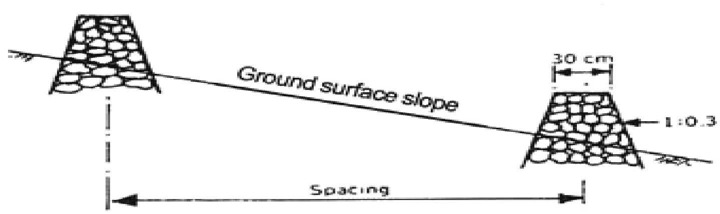


Fig.5.14 Stone Bund

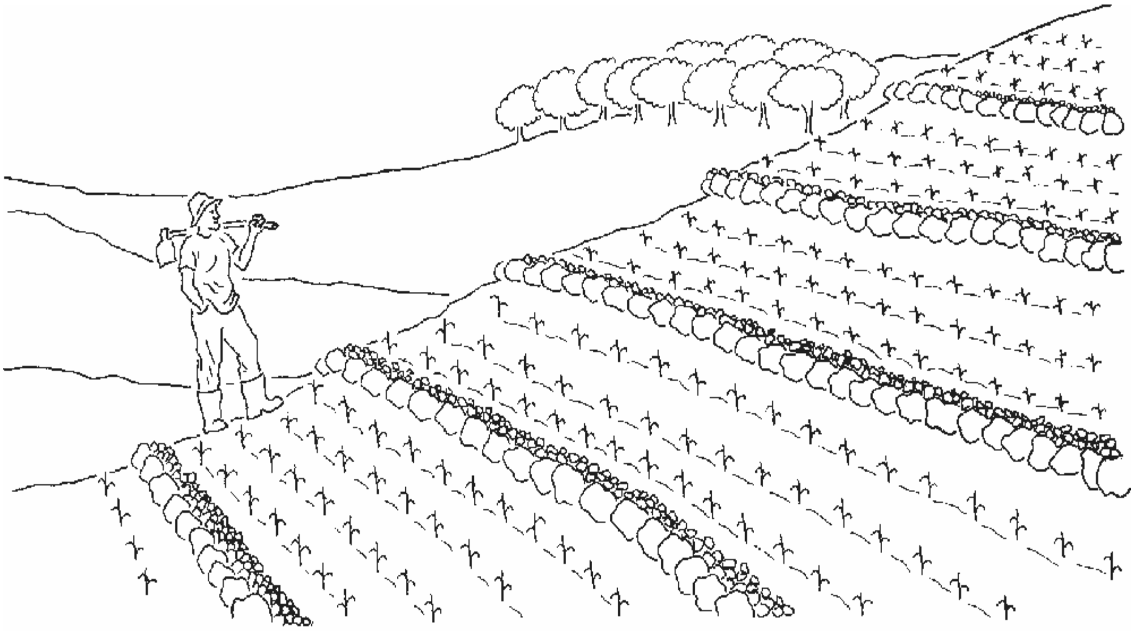
Stone Lining

Description: Stone lining along the contour are popular technology in dry stony areas. Stones are placed along contour lines to serve as a barrier to surface runoff.

Purpose: Since the runoff water can pass through the stone lines slowly the water gets filtered and spread over the field. Thus enhancing water infiltration and reduces soil erosion.

Location: Stone lines are suitable on gentle slopes in areas with annual rainfall of 200-750 mm and areas where plenty of stones are available. They are often used to rehabilitate eroded and abandoned land.

Design: The lines are constructed by making a shallow foundation trench along the contour. Larger stones are then put on the down slope side of the trench. Smaller stones are used to build the rest of the bund. The stone lines can be reinforced with earth, or crop residues to make them more stable. When it rains, soil will start to build up on the upslope side of the stone-line, and over time a natural terrace is formed. The stone lines are spaced 15-30 m apart. In steeper slopes length of stone lines are kept short.



Stone lines along the contour

Fig :5.15 stone lining along with the contour

5.1.4 Loose Boulder Structure (LBS)

These are the structures made up of loose stones and boulders in upper reach gullies.

Purpose

It reduces velocity of runoff water and traps silt and soil which promotes vegetation in the upstream side.

Location

Gully size of 1.2 to 1.5 m. depth with contributory runoff area less than 2.00 ha and areas where plenty of stone and boulders are available are suitable for construction of LBS. The specific requirements are:

- ✓ Constructed in series on a drainage line.
- ✓ Independent catchment of LBS should not be more than 1 ha.
- ✓ Should not be constructed where bed slope is more than 20%.
- ✓ Locate the structure where the upstream slope is flatter to store more water and more recharge
- ✓ Height of gully = max depth of flow in stream + design height of structure in central portion of gully.

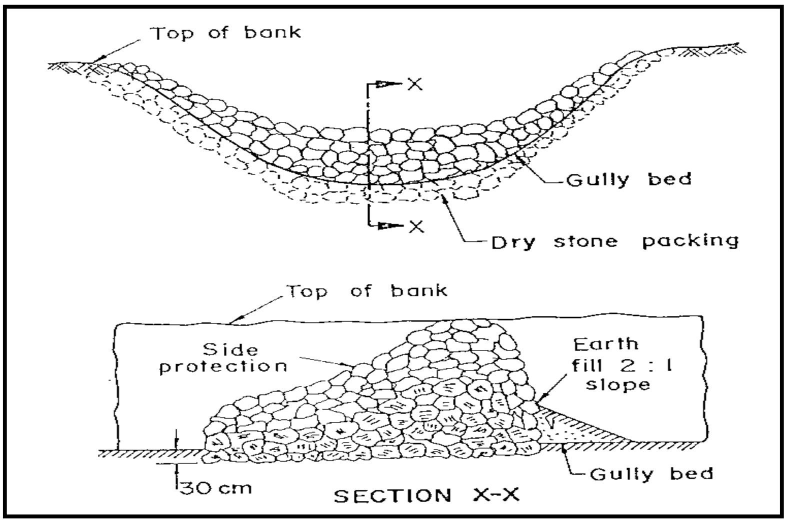


Fig. 5.16 Loose Boulder Structure

Material of construction

- ✓ Smaller angular stones (not less than 15cm preferably 20-25 cm or 1 kg) can be used to fill up the interior portion.
- ✓ Angular stone is preferred for greater stability.
- ✓ Shale, lime stone or any loose rock should not be used as these disintegrate when comes in contact with water.
- ✓ The large boulders must be placed at the lowermost edge of the d/s side of the LBS and preferably be anchored to ground.

Planning

- ✓ Identify the drainage line and start from the top, fix the topmost location of LBS.
- ✓ Walk 5m downstream, this is the d/s bottom edge of the LBS.
- ✓ Measure the slope of nala/ gully bed over 10m. Stretch starting from the bottom edge of 1st LBS.
- ✓ If S>10%, HI= 10m. / S<10%, HI> 10m. (but in no case it should be beyond 50m.)
- ✓ And go on marking up to the end of the drainage line.

Design

- ✓ Maximum height= 1.0m (at the deepest section of gully / nalla).
- ✓ Top width= 0.4m
- ✓ U/S slope = 1:1 to 1:2, D/S slope = 1:2 to 1:4
- ✓ Provide a dip in the middle to avoid erosion at sides by directing max flow at the middle.
- ✓ Height of LBS at both side = height of embankment or 1.5m. which ever is lower.
- ✓ LBS should be embedded 0.5m into both the embankments to prevent erosion where the LBS join the embankment.
- ✓ If nalla / gully bed is hard and rocky, no base stripping is required, otherwise excavate max. 0.25m.

Layout

- ✓ Minimum V.I. between two LBS= height of the structure.
- ✓ Height of structure= height of gully – max. depth of flow in the stream.

- ✓ H.I. depends on bed slope of the gully (e.g. If VI= 1.0m, for 5% bed slope HI= 20m and for 10% bed slope HI= 10m.)
- ✓ HI= VI / S (in %)

Distance between two LBS

Thumb rule

- ✓ On higher slopes, LBS should be closer, but not closer than 10m.
- ✓ On lower slopes, LBS should be far, but not farther than 50m.

Construction steps

- ✓ Start construction from ridge to valley.
- ✓ After finalizing the location, the site must be cleared by removing boulders and debris.
- ✓ Mark the bottom width and length of structure with lime and excavate trench with uniform depth of 45 cm (maximum) across the gully. Normal depth is 30.0 cm..
- ✓ Draw a line running through the centre of the proposed site for LBS till it reaches on either side which are 1.5m above the bed of nalla, if embankment is less than 1.5m the line will reach up to the embankment only.
- ✓ Form this line, draw two parallel lines at 20cm. at both the u/s and d/s end up to the embankment (these two lines are the boundaries of crest, if top width is 40 cm.)
- ✓ Suppose u/s slope is 1:1 and d/s slope is 1:3. (a) Mark at 1.0m perpendicular to u/s crest line (b) mark at 3.0m distance perpendicular to down stream crest line. (these points are upstream end and down stream end of the LBS respectively and draw lines at both the sides)
- ✓ The LBS should be raised in horizontal layers.
- ✓ Using larger size stones laying in layer with proper interlocking fill up trench. Care should be taken so that last layer of the stone (in trench) is half inside the trench and half above the ground level.
- ✓ Use smaller stones to fill up the gaps within layers and use hammer or boulder to fix small stones for better stability of the structure.
- ✓ The upper portion is completed in the similar manner keeping the side slope in view.
- ✓ Care should be taken so that one layer of stone is interlocked with another layer of stone.
- ✓ The structure must keyed (extended) minimum of 1.5ft into both side of the gully bank
- ✓ Larger boulder must be placed outer sides (especially in downstream side).
- ✓ Care is to be taken for maintaining both the slopes during raising of layers.
- ✓ Provide dip at middle, allow safe exit of excess runoff.

Dimensions	**Maximum**	**Usual**
Total Height	1.5m.	1.0m. or 3/4th of gully depth
Top Width	0.6m.	0.45m
Upstream side slope (H:V)	1 : 1.25	1 : 1
Downstream side slope (H:V)	1 : 2	1 : 1.25 (1 : 2)

Important

- ✓ If it is not practically possible to follow the above method due to non-availability of sufficient boulders and highly undulating hilly topography, just locate the site as per people's choice keeping the technical point in mind.

Do's

- ✓ Locate the LBS only where the height of the stream embankment is greater than or equal to the sum of the peak depth of flow in the *nalla* and decide the height of the structure.
- ✓ The top of the LBS should be lowest in the middle of the stream and highest at both of the embankment.
- ✓ The height of the LBS in the middle of the stream should be 1.0m above the ground level.
- ✓ Upstream slope of the LBS should be 1:1 while the down stream slope can vary from 1:2 to 1: 4.
- ✓ The bed of the stream at the base of the LBS should be cleared of mud/ sand up to 0.25m depth.
- ✓ The top of the LBS should be extended into either embankment by cutting a trench and filling it with boulders.
- ✓ Large boulders should be placed on the outer portion of the LBS.
- ✓ Use of angular boulder is preferred.

Don'ts

- ✓ Do not use boulders dug up from neighborhood as it increases soil erosion from that area.
- ✓ Do not use boulders less than 0.15m diameter.

Tentative estimate

Loose Boulder Check dam/ Structure is a medium sized mechanical structure provided in middle reached of the gullies having width from1 m to 3 m and depth from 0.5 m to 1.2 m. Rough stones of size 0.15 m to 0.3 cm are required for the construction of these structures. Earthen bund should be provided in both the sides of the structure. Potted vetiver sleeves must be provided at the D/S toe of the structure. The rough stone will be transported at an average distance of 1 km.

(Gully with 1.3 m width, 0.6 m bottom width and depth 0.6 m)

Sl. No	Details of work	MD	Rate	Amount in Rs.
1	Survey, alignment, demarcation	1	90	90
2	Earth work excavation in stony earth mixed with gravel within initial lead and lift i) Edging out of gully 2x0.5x0.85x2.25x0.6 = 1.15 ii) Foundation for stone packing1x2.3x1.8x0.3 = 1.24 iii) D/S guard wall 1x1.3x0.5x0.6 = 0.39 iv) Side wall 2x2.13x0.5x0.3 =0.64 Total = 3.42	1.74	90	157.30
3	a. Dry stone packing in the foundation of structure b. U/S dumping (deflected by 45 deg.)			

	1x{(1.3+2.2)/2}x 0.45x0.3 = 0.24 Head wall and D/S dumping 1x1.3x0.9x0.3 = 0.35 Apron 1x1.3x0.9x0.3 = 0.35 Side walls 2x3.95x0.5x0.33=1.19 D/S guard wall 1x1.3x0.5x0.6 = 0.39			
	c. Dry stone packing in super structure U/S dumping 1x{(3.2+2.3)/2x0.45 (0.45+0)/2=0.27 D/S dumping 1x2.3x0.45x(0.45+0.2)/2 = 0.33 Head wall 1x2.3x0.45x0.45 = 0.47 Apron 1x0.9x1.3x0.15 =0.18 Side walls 2x3.95x0.5x0.3 =1.30 Total (a+b) = 5.07	2.6 MD Material 2 tractor load	90 600	234.00 1200.00
4	Earth work in hard soil for side bund of 10m length in both side of structure 2x10x {(1.05+ 0.45) /2}x0.3 =4.5-3.42 = 1.08 i.e excavated earth in the foundation will be adjusted for the side bund	0.6 MD	90	54.00
5	Fine dressing and turfing locally available grass within initial lead and lift both side slopes 2x10x0.42 = 8.40 Top 1x10x0.45 = 4.50 For 2 no. bunds 2x12.90 = 25.80 sq m	0.8 MD	90	72.00
6	Vetiver plantation with locally collected vetiver sleeves in D/S of the structure with Spacing (0.23x 0.23) sq m over 1.3 mt span and 1.0mt width of 3 rows including foliar spraying with Urea. No. of sleeves required = (2.3/0.23)x3 =30 nos.	0.2 MD	90	18.00
7	Contingencies and unforeseen charges			76.10
	Total			**1900.00**

Abstract

Labour (unskilled) 6.94 @ Rs 90.00= Rs 624.60

Material cost Rs 1200.00

Contingency Rs 76.10

Total Rs 1900.00

5.1.5 Diversion Drains

Diversion drains are constructed on the top of the arable area to intercept the uncontrolled flow of runoff water from the non-arable area and to safely divert the excess rain water to the natural/improvised water courses.

Purpose

The purpose is to divert the water flowing down from the upper reaches towards the natural water course, thus preventing from eroding of cultivable lands. It also effectively protects bottomland from hillside runoff and diverts water from uncontrolled areas

Location

Upper reaches mostly.

Design

A diversion channel is constructed around the slope with a slight gradient for easy flow of water to the desired outlet. The capacity of the diversion drains should be based upon estimates of peak runoff for the 10 year return period if it is to empty into vegetative waterways. The design procedure is same as vegetated waterways.

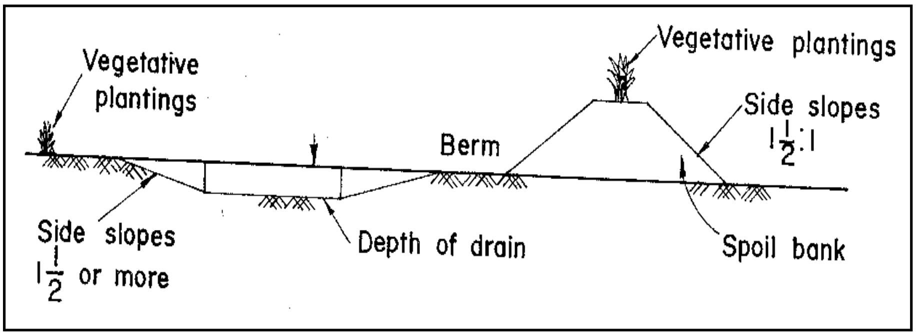


Fig 5.17 Diversion Drain

5.1.6 Gully Plugging

Gully plugs (also called check dams) protect the gully beds by reducing the velocity of the flow, redistributing it, increasing its infiltration, encouraging silting and improving the soil moisture regime for establishing grasses and other vegetative cover.

Purpose

To check further widening and deepening of these gullies and to arrest soil erosion, collect silt and level the fields.

Location

On undulated private lands in middle reaches.

Temporary Structure

As far as possible such structures should have low heights, proper provision for dissipating kinetic energy, and be spaced closely enough.

Such structures may usefully be combined with vegetative measures to help stabilization. Various types of gully plugs or temporary structures are made of locally available materials like hedges or sod checks, woven wire, earth, sand bags, loose rock dams, and others. All types of gully plugs are effective either in retaining or retarding the runoff.

Earth is the cheapest and usually the most readily available material and it is, therefore, easier and economical to construct earthen gully plugs where possible, but they require stabilization and vegetative cover. Loose rock dams are effective and long lasting, but are economical only if the material is available on site. For smaller amount of runoff to be handled, hedges or sod strip checks can also be effective.

Design criteria

The check dams should be extended far enough into the bottom and side of the gully to prevent washouts underneath or around the ends. Sufficient spillway capacity must be provided in the structure. The overall height of a temporary gully plug should not ordinarily be more than 75cm. An average effective height of about 30cm is usually considered suitable.

Spacing

Check dams theoretically should be spaced so that the crest elevation of one will be the same as the bottom elevation of the adjacent check upstream. However in practice a small grade is usually allowed in the gully bed to reduce the number of checks. A grade of 1% is usually allowed in fine sand and silt loam soils; and about 0.5% in silt and clay soil.

Permanent structure

Permanent masonry structures are very costly structures and, therefore, justifiable only in case of extreme erosion. Drop spillways, chute spillways, and drop inlet spillways are the basic permanent structures. These should be constructed only after considering the essential design parameters to avoid failures. Critical design is highly technical, and the relevant references must be consulted.

Table: 5.5 Specification for materials and location of gully plugs.

Slope of gully bed (%)	Width of the gully bed (m)	Location	Type of gully plug	Vertical interval between two gully plugs (m)
0 - 5	Up to 4.5	Gully bed	Brush wood	Up to 3
	4.5 to 10.5	Gully bed with side branch	Earthen	Between 2.25 and 3
	7.5 to 15	At the confluence of 2 gullies	Sandbag	-
	7.5 to 15	At the confluence of all branches of a compound gully	Brick masonry	-
5 - 10	Up to 4.5	Gully bed	Brush wood	Up to 3
	4.5 to 6	Gully bed and side branch	Earthen	Between 1.5 to 3

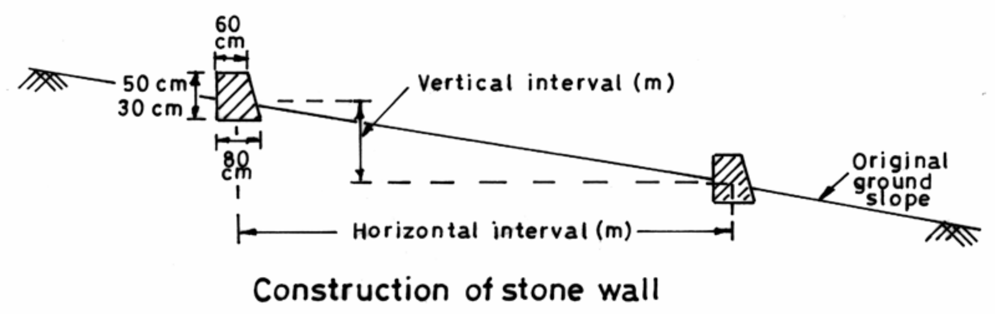


Fig. 5.18 Interval of structures

5.1.7 Surplus weirs

Outlets are provided for each bund at suitable locations mostly in depression points for safe disposal of excess water from one field to other. For design of each outlet, the cumulative catchment contributing runoff is calculated. The standard size of length of clear overfall stone weir for different catchment area is mentioned in the table.

Cumulative catchment area in Ha.	Length of the crest wall (m)	Height (m)
5	1.2	0.3
6	1.5	0.3
7	1.8	0.3

8	2.1	0.3
9.5	2.4	0.3
11	2.7	0.3
12	3.0	0.3
14	3.3	0.3
15.50	3.6	0.3
17.50	3.9	0.3
19.50	4.2	0.3
21.50	4.5	0.3
23	4.8	0.3
25	5.1	0.3
27.5	5.4	0.3
30	5.7	0.3
32	6.0	0.3
34	6.3	0.3
37	6.6	0.3
38.50	6.9	0.3
40	7.2	0.3

Different types of outlet

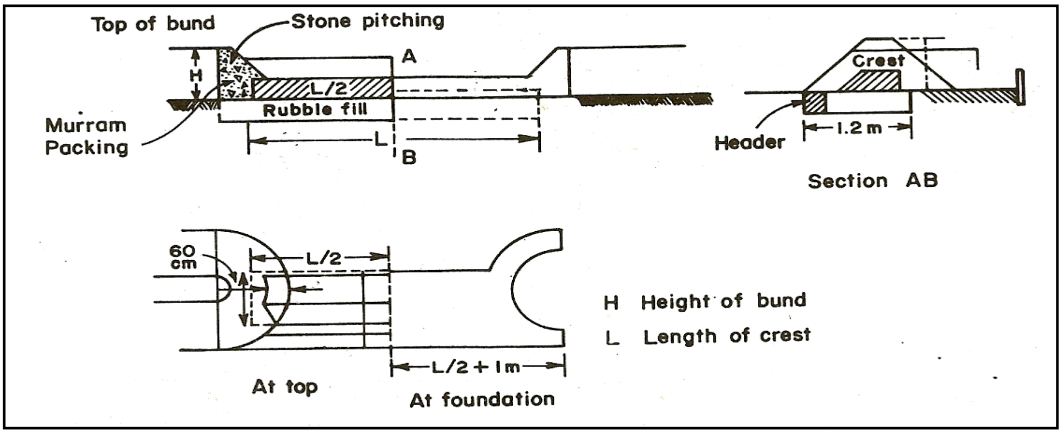


Fig. 5.19 ***Clear over fall stone weir***

It comprises of a masonry wall of a designed length constructed at a suitable place in bund and the two ends of the bunds are stone pitched. A clear over fall weir should be provided along the contour bund with its crest 0.30m above the contour.

Channel weir

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

Cut outlet

It is a channel weir and is cut as an ordinary channel about 1.75m away from the end of the bund with its fill kept 0.03m above the contour level. It has an approach and a tail channel to give runoff water proper entry and exit from the weir. Such outlets are suitable when the soil is very hard.

Ramp-cum-waste weir or grassed outlet

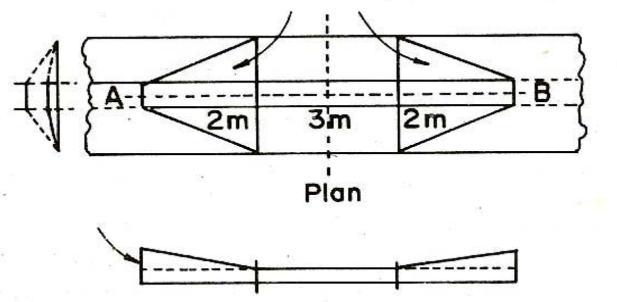


Fig.5.20 Grassed Outlet

Ramp-cum waste weir

During the period of construction of bund or other structures, it is not possible to construct weir immediately. Therefore, ramp-cum-waste weirs are constructed which are temporary in nature. It consists of an earthen bund with its top 22.5cm above the contour level and having a slope 1: 10 like a ramp both on the upstream and on the down stream side of the bund. When permanent waste weirs are to be constructed, they will be located at the side of these ramp-cum-waste weirs and should be pitched with grass wherever conditions of rainfall are favourable.

Pipe outlet

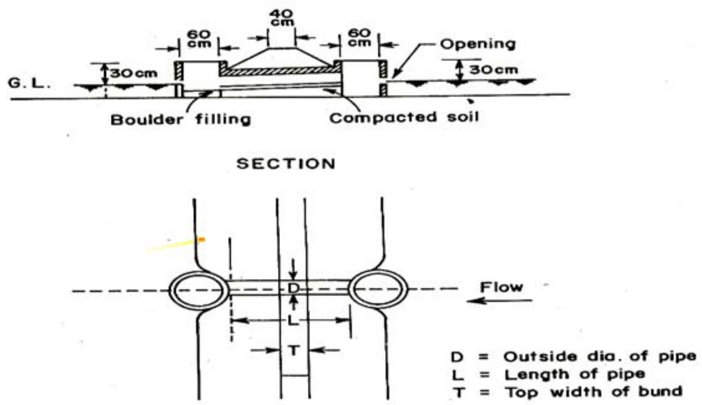


Fig.5.21 Pipe outlet

A pipe outlet comprises of a pipe discharging surplus water. The design consists of a hume pipe of required diameter with one well at the upstream side. A 15cm. diameter pipe is suitable for 4.0 ha catchment. The well consists of 0.4m diameter and 30 cm outlet. The top of the well is kept 0.30m above the contour level.

5.1.8 Groundwater & wells

Part of the rainfall accumulating on the land surface is lost to atmosphere through evaporation and transpiration and some of it is retained in an unsaturated state by the upper layers of the subsoil. The remaining water moves down and accumulates over the impervious stratum. Seepage from surface water sources such as rivers, streams, reservoirs, canals etc., also accumulate in the subsurface layer of the earth. The saturated portion over the impervious stratum is known as the zone of saturation and is referred to as groundwater. It is this water that is available to be tapped by means of wells.

Subsurface distribution of water

The occurrence of water below the land surface may be divided into two zones, the zone of saturation and the zone of aeration. In the zone of saturation all the pores are completely filled or saturated with water. The saturated zone is bound at the bottom by impermeable strata. The upper surface of the zone of saturation (when there are no overlaying impermeable strata) is known as the water table and water occurring in the zone of saturation is commonly referred to as ground water.

The zone of aeration occurring above the zone of saturation consists of pores occupied partially by water and partially by air. This zone may be subdivided into three belts (1) The belt of the soil water, (2) The intermediate belt, (3) The capillary fringe.

All geological formations, even though containing water may not yield sufficient water for the purpose of putting wells. Those geological formations or materials which will yield significant quantities of water are defined as aquifers. Groundwater aquifers may be classified as unconfined, confined and semi-confined aquifers.

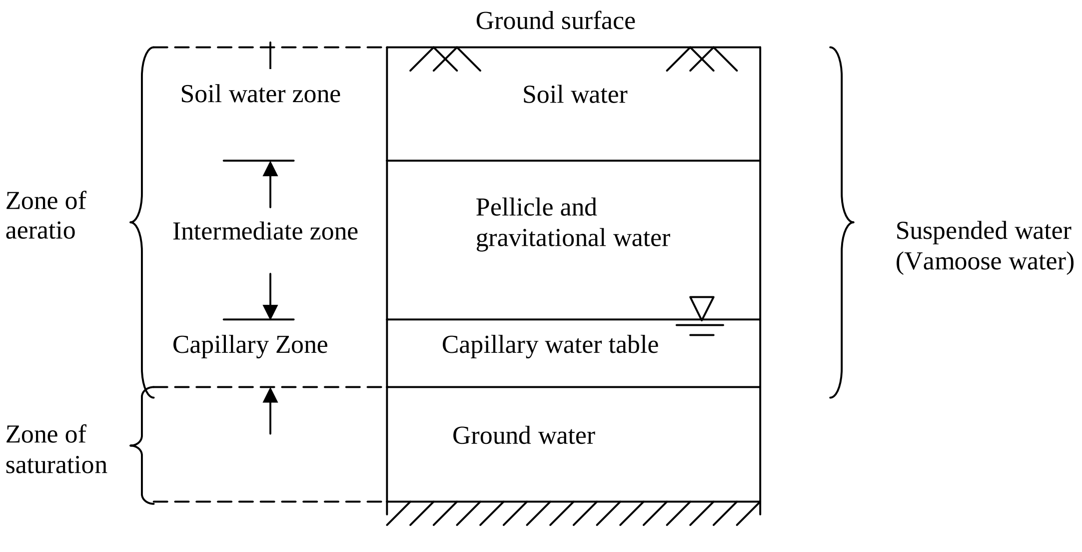


Fig 5.22 Classification of subsurface water

Types of well

Depending upon the type of the aquifer supplying water to the well, the wells are classified as

- ✓ Water table wells
- ✓ Artesian wells

Depending upon methods of construction, wells are classified as:

- ✓ Dug wells or open wells
- ✓ Driven wells

- ✓ Jetted wells
- ✓ Bore wells
- ✓ Drilled wells or tube wells

Dug wells or open wells are comparatively of large diameter, small depth and excavated manually. The depth of the well is below the water table and thus taps the water from the first aquifer only. The open wells are again grouped under four types depending upon their lining. These are:

- ✓ Unlined wells
- ✓ Masonry wells
- ✓ Well with pervious lining
- ✓ Wells in rocky substrata

Unlined wells are generally constructed for temporary use and are dug in harder soils which can stand vertically without lining. A wider pit up to the water table is dug. Sometimes the narrow pit is lined with a woven fabric or matting to allow the water to ooze through into the pit. The masonry wells have a masonry lining constructed either with stone or brick. Water enters these wells from the pervious bottom. Wells with pervious lining are constructed in areas where good water bearing strata is not available within a reasonable depth from the ground surface. These wells consist of pervious lining which may be made of dry brick or stone masonry and even sometimes of brushwood.

Open wells are constructed even in rocky substrata provided such substrata have water. In such strata, water usually comes from joints, cracks and fissures. The wells are constructed in large size as masonry. The open wells are also classified as shallow wells or deep wells depending upon whether the well draws water from first sandy stratum or the well penetrates the impervious stratum and draws water from below.

Construction of open wells

Construction of open wells is done either as dug wells or as sunken wells. The selection of method depends upon the nature of the subsoil formation. *Dug wells* are adopted when the subsoil formations are hard and stable during excavation. During excavation the diameter is kept about 1m more than the proposed diameter of the well and dug up to a depth below the ground table. After digging the well to the required depth, lining of the well may be done either with brick masonry or stone masonry. The lining is raised about 1m above the ground level with a parapet. The space between the lining and the dug portion can be filled either with brickbats in mortar or compacted clayey soil.

Sunken wells are constructed in soft formations where the sides are likely to collapse if dug wells are tried. In the constructions of the sunken wells, certain height of the lining is first constructed above the ground level and then it is sunk in the subsoil formation by putting load on the lining. The procedure is continued till the required depth of the well is attained.

Excavation is done about 1m larger than the required diameter of the well and about 1m deep. At this depth well curb is laid. The well curb is a circular structure made of either wood, reinforced cement concrete or mild steel plates. The well curb is useful in sinking of the well and ultimately it remains at the bottom of the lining and serves as the foundation. The inner diameter of the well curb should be the same as the inner diameter of the finished well. After laying the well curb, masonry wall is constructed on the same till the wall comes about 10 to 20 cm above the ground surface. A temporary platform is constructed on top of the lining and it is loaded either with sand filled gunny bags or other locally available material. On this platform sufficient opening is kept and through this opening the soil is removed. As the removal of the soil progresses, due to the weight placed, the lining sinks. When the lining sinks up to the point the loaded platform comes down to the ground level, the load is removed and additional height of the platform is constructed. The process of loading and sinking

Again the loading and sinking is done. The process is repeated till the required depth is reached. The space between the lining and the soil is filled with compacted clayey soil. In order to keep the sinking vertical, it is necessary to suspend four plumb bobs from four sides of the well. Unequal sinking of the well can be corrected by suitably adjusting the load on the loading platform.

Estimate for open well

Inside dia of well=5m
Thickness of well wall=30cm
Depth of well=8m
Cost of digging=Rs.18,000
Cost of material=23,000
Total cost=41,000
Mandays required
Skilled=20mandays
Unskilled=200

5.1.9 Land leveling and grading

Land leveling or grading is the process of preparing or modifying the land surface to a planned grade to provide a suitable surface. Land leveling usually requires cutting of high areas and raising of low spots, in order to remove the surface irregularities and unevenness to make a plane surface. It prepares a suitable field surface to control the flow of water, to check soil erosion and provide better surface drainage.

Factors governing land leveling:

- ✓ Soil characteristics
- ✓ Topography
- ✓ Cropping pattern
- ✓ Method of irrigation
- ✓ Rainfall characteristics

Preparatory steps:

- ✓ Clearing of land (removal of thrash and vegetation)
- ✓ Land development programme must be planned so that the location of field boundaries, irrigation water supply system, drains and farm roads are fixed.
- ✓ A topographic survey may be made by any of the conventional methods. Generally grid survey is adopted for land leveling design.

Layout:

Laying out fields into workable size compartments is very important. The fields are laid out as nearly rectangular as possible. Sharp turn in the field boundaries should be avoided as far as possible. The division of an area into plots according to its contour and soils is an important step in layout. Subdivision of fields depends on ownership boundaries too.

The length of plots depends on the maximum allowable length of run for the irrigation method selected. Alternatively, the field length may be limited by ownership boundaries.

Soil type	**Length of run for border Strip/furrow**
Sandy and sandy loam soils	60 to 120
Medium loam soils	100 to 180
Clay loam and clay soils	150 to 300

Land leveling design:

The design of land leveling or grading involves the determination of level at each grid corner, up to which the land surface is to be raised or lowered. There are four basic methods of land leveling:

- ✓ The plane method
- ✓ The profile method
- ✓ The plan-inspection method
- ✓ The contour adjustment method

Each of these has some advantages and disadvantages, but when properly used, all will provide satisfactory results.

Contour adjustment method:

In this method, using the levels, a contour map of the area is drawn. The ground surface expected after grading is shown on the same map with the help of new contour lines as in figure above. The new contour lines are so drawn that a uniform desired slope is obtained. The cuts and fills are estimated at the grid points by interpolating between contour lines and by taking the difference in elevation between the original and the new surface.

Earthwork volumes:

After cut and fill at each grid point are estimated, using this information, the total earthwork required in the entire field need to be calculated. While there are several methods for earthwork calculations, the commonly used methods are:

- ✓ Four point method
- ✓ Summation method

Four point method: The four point method is based on the formulae:

$$V_c = \frac{L^2}{4}\left(\frac{H_c^2}{H_c + H_f}\right) \quad \text{and} \quad V_f = \frac{L^2}{4}\left(\frac{H_f^2}{H_c + H_f}\right)$$

Where,

V_c = volume of cut (m^3)

V_f = volume of fill (m^3)

L = grid spacing (m)

H_c = sum of cut on four corners of the grid square (m)

H_f = sum of fills on four corners of the grid square (m)

Using the above formula, volume of cut and fill in each grid square can be calculated and the totals for the field is obtained.

Construction procedures:

- ✓ To bring the ground surface to a planned grade, desired cut and fill is marked on the grid stakes and are driven to the ground.
- ✓ Job planning should be done by taking time, skill of operator, and haul distance into consideration.
- ✓ Keep haul distance to a minimum, it is important to construct the fills from the nearest excavation available.
- ✓ Do not disturb grid stakes.
- ✓ Work slight diagonally so that the area between stakes can be almost completely worked out until there remains only small islands around each grid stake.

- ✓ In some soil conditions it may be necessary to stockpile the topsoil from an area, over excavate the cuts and replace the top soil for preservation of top soil.
- ✓ Final check must be made before the grid stakes are removed. The grade between stakes must be uniform.
- ✓ After the earth-moving work is completed, the land surface is smoothened with a float or land plane to remove minor irregularities.

Maintenance

A leveled field requires regular maintenance to preserve its surface. Soil erosion and improper use of tillage implements may render a smooth field into an uneven one. Although annual scraping is not usually required, irrigated fields should be smoothened with a float or a plane prior to seeding as a regular land preparation practice.

5.1.10 Conservation Ditches

This is basically construction of trenches along the contour in agricultural field where black soil is predominant. As black soil is having the typical characteristics of low infiltration rate, swelling and shrinking properties, construction of contour bund is not suitable because of frequent breaching. Graded bund is also not advisable because it disposes maximum water from the field. Hillside ditches consist of a series of shallow ditches built along the contour lines at appropriate intervals. Hillside ditches not only break long slopes into shorter segments to intercept surface runoff and serve as path way to facilitate farm operations and transportation. These are found to be suitable for slopes with a gradient of less than 40%.

Purpose

Conservation ditch is basically an inverted form of a contour bund (sunken into the ground) or a trench with flatter side slopes. Flatter side slope is provided for safety against scouring by incoming runoff. Along with the runoff, most of the eroded soil is stored in the ditch.

Location

- ✓ Agricultural field with black soil or hillside slopes.

Dimensions

- ✓ Spacing between ditches: 75 m.
- ✓ Maximum length of the ditch: 30 m.
- ✓ General cross section: 1.583 sq m.
- ✓ Average depth: 0.61 m.
- ✓ Minimum spacing between two bunds is 10 m.

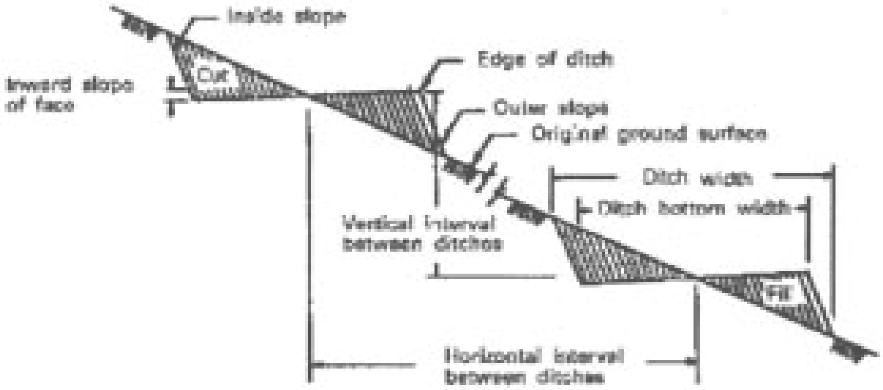


Fig.5.23 Hillside ditches

5.1.11 Check Dams

Check dams are the structures, generally constructed on a small river or nalla in order to break the flow of water during the monsoons, and allow it to seep into the soil. Check dams range in size, shape and cost. It is possible to build them out of easily available materials and even at a very little cost. Decision of building such a dam depends on its location. Essentially a check dam has an earthen dam and masonry spillway.

Purpose

- It cuts the velocity and reduces erosive activity
- The stored water improves soil moisture of the adjoining area and allows percolation to recharge the aquifers
- Spacing between the check dams should be such that water spread of one should be beyond the water spread of the other
- Height depends on the bank height, varies from 1 metre to 3 metre and length varies from less than 3m to 10m

Location

- A low weir normally constructed across the gullies
- Constructed on small streams and long gullies formed by erosive activity of flood water

Advantages of Check Dams

The advantages of check dams are that they store surface water for use both during and after the monsoon. They help in ground water recharge of the area, which in turn helps in raising the water table in the area. Availability of water ensures the increase of agricultural yield by multi-cropping. Check dams can also be used for pisciculture. The cost of building a check dam for irrigation of one hectare of land normally varies between Rs 5000 to 8000. A large dam or canal network would cost over Rs 2 lakhs for the same purpose. Before building a check dam the following points have to be kept in mind regarding site selection:

- Check dams can be of various sizes and built with a variety of materials including stone, clay and cement.
- Individual farmers can build small check dams of clay.
- Masonry and cement concrete structures require some degree of construction skills and high investment.
- The structure should be able to store a high volume of rain-water over a long duration of time. It should provide a long length of stored water.

- There should be large cropped area on either side of the length of stored water.
- Minimizes risk of submergence of cropped lands during flash floods. It should have a high cost-benefit ratio.

Design

Catchment area = 50 ha.
Intensity of rainfall at 10 year frequency for the region= 60 mm/hr
Runoff coefficient = 0.35
Peak discharge = $\frac{0.35\times 60\times 50}{360}$ = 2.92 cumecs
The discharge in the weir is given by the relation $Q = 1.66\ L\ h^{3/2}$
On solving the equation we get a number of L and h values. We select a suitable L and h value. In this case a value of L= 3m and h= 0.7 m is selected. The ratio of L/h should always be equal to or greater than 2 for all rectangular channels. Adding freeboard, the h value is selected as 1m.
The h/F ratio should be kept lower than 0.50 with an absolute maximum of 0.75. A value of 0.75 is considered here as the depth of *Nala* will not allow a bigger F value.
h/F = 0.75 ⇒ F= h/0.75 = 0.75/0.75 = 0.93 m.
Length of headwall extension E = (3+0.6) or 1.5 F whichever is greater = 3.6m
Length of basin L_B = F (2.28 h/F+0.52) = 2 m
Height of wing wall and sidewall at the junction J = 2h = 1.4m
M = 2 (F+1.33h-J) = 0.92 m
L = (L_B+0.1)-M = 3.22 m
Height of longitudinal sill $s_{h=}$ 1/4 = 0.25 m
Height of transverse sill $s_{t=}$ 1/3 = 0.34 m
Thickness of apron for different values of overall F are given below

Overfall, F(m)	0.5-0.75m	1.0-1.75 m	2.0-3.0 m
Apron thickness (cm)	20 cm	25 cm	30 cm

So, a thickness of 25 cm is selected here
<u>Wall thickness</u>- top widths and minimum base widths of headwall, sidewall, wing wall and headwall extensions for different wall heights for masonry construction are given below.

Description	**Head wall**	**Side wall**	**Wing wall and head wall extension**
Minimum top Width (m)	0.45	0.30	0.30
Height (m)	Recommended base widths		
0.5	0.45	0.30	0.30
1.0	0.67	0.55	0.40
1.5	1.0	0.82	0.60
2.0	1.33	1.10	0.80
2.5	1.67	1.37	1.00
3.0	2.0	1.65	1.20
3.5	-	-	1.40
4.0	-	-	1.60
4.5	-	-	1.80

Using the above table following dimensions have finalized in the present case.
Headwall – Top width 0.45 m and bottom width 1.15 m
Sidewall- Top width 0.30 m and bottom width 0.95 m
Wing wall and headwall extension – Top width 0.30 m and bottom width 0.70 m.

The design has been done for extreme cases which very rarely occur. So, by taking a little worthwhile risk, the dimensions and thereby price can be reduced.

Work particulars	Quantity	Mandays	Rate / Unit (Rs)	Amount (Rs)
Cleaning	8000 sq m (40 x 200m)	174	90	15660.00
Earthwork	1800 cum (40m x 10m x 4.5)	682	90	61380.00
C.C(1:3:6)	3.925 cum	200	90	18000.00
Spillway Brick work	8.44 cum	64	90	5760.00
Brick laying	23.8 sq m	56	90	5040.00
With Cement Plaster	23.8 sq m	16	90	1440.00
Turfing	449.6 sq m	14	90	1260.00
Bamboo net	320 sq m	8	90	720.00
With Cement Plaster	0.160 cum	8	90	720.00
Total		**1222**		**109980.00**

Table 5.6 Tentative Estimate of Earthen Check dam with 40 m concrete core wall

Mason / Carpenter / Bamboo netter / Supervisor (Skilled Work)

Work particulars	Quantity	Mandays	Rate / unit (Rs)	Amount (Rs)
C.C(1:3:6)	3.925 cum	14	116	1624.00
Brick laying	23.8 sq m	16	116	1856.00
Cement Plaster	23.8 sq m	16	116	1856.00
Turfing	449.6 sq m	2	116	232.00
Bamboo net	320 sq m	2	116	232.00
With Cement Plaster	0.16 cum	2	116	232.00
Total		**52**		**6032.00**

Material Cost

Material	Unit	Unit Cost	Amount
Cement	1030 bag	@ 270/-	278100
Brick	8300	@ 5000 / 1000	41500
Sand	60 truck	@ 200/-	12000
Aggregate (40 mm)	20 truck	@ 4000/-	80000
Bamboo	200 nos.	@ 50/-	10000
Total			**421600**

Total Cost **=** Ordinary Labour + Mason / Carpenter / Bamboo netter / Supervisor + Material Cost

= 109980 + 6032 + 421600 **= Rs 537612.00**

Earthen Check dam, 20 m with Concrete Core wall

Labour cost			
Ordinary Labour	620 mandays	@90/-	55800.00
Skilled Labour (Mason etc.)	30 mandays	@116/-	3480.00
Total			**59280.00**
Material Cost			
Cement	500 bags	@270/-	135000.00
Sand	30 truck	@200/-	6000.00
Brick	4500 Nos.	@ 5000 / 1000	22500.00
Aggregate (40 mm)	10 truck	@ 4000/-	40000.00
Bamboo	130 nos.	@ 50/-	6500.00
Total			**210000.00**

Total Cost = 59280 + 210000 **= Rs.269280**

Earthen Check dam, 10 m with Concrete Core wall

Labour cost			
Ordinary Labour	310 mandays	@90 /-	27900.00
Skilled Labour (Mason etc.)	15 mandays	@116 /-	1740.00
Total			**29640.00**
Material Cost			
Cement	230 bags	@270 /-	62100.00
Sand	15 truck	@200 /-	3000.00
Brick	2500 Nos.	@ 5000 / 1000	12500.00
Aggregate (40 mm)	5 truck	@ 4000/-	20000.00
Bamboo	60 nos.	@ 50/-	3000.00
Total			**100600.00**

Total Cost = 29640 + 100600 **= Rs.130240.00**

Brushwood Check Dam

Brushwood check dams made of posts and brush are placed across the gully. They are temporary structures and should not be used to treat ongoing problems such as concentrated run-off from roads or cultivated fields. There are many types of brushwood check dams. The type suitable for a particular site depends on the amount and kind of brush available. Whatever sort is used, the spillway crest of the dam must be kept lower than the ends, allowing water to flow over the dam rather than around it.

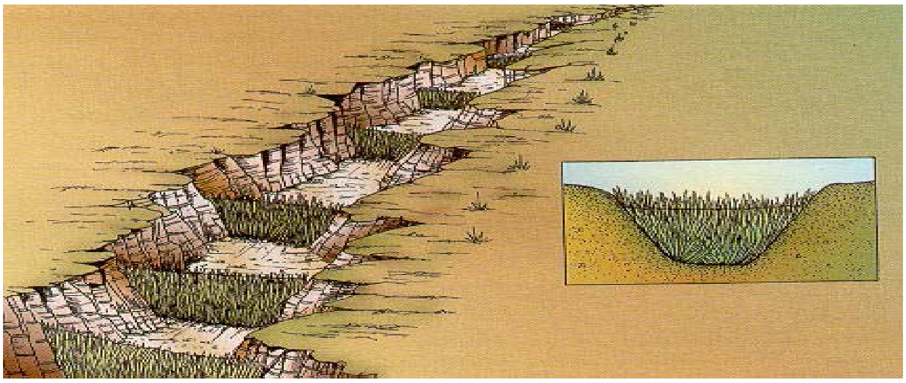


Fig.5.24 Brushwood Check dam

Purpose

The main purpose of brushwood check dams is to hold fine material carried by flowing water in the gully. Small gully heads, no deeper than one meter, can also be stabilized by brushwood check dams. They can be employed in connection with land use changes such as reforestation or improved range management until vegetative and slope treatment measures become effective.

Location

If soil in the gully is deep enough, brushwood check dams can be used in all regions. The gradient of the gully channel may vary from 5 to 12 percent, but the length of the gully channel, beginning from the gully head, should not be more than 100 meters. The gully catchment area should be one ha or less.

Construction

The maximum height of the dam should be one meter from the ground (effective height). Both the upstream and downstream face inclination should be 30 per cent backwards. The spillway form is either concave or rectangular.

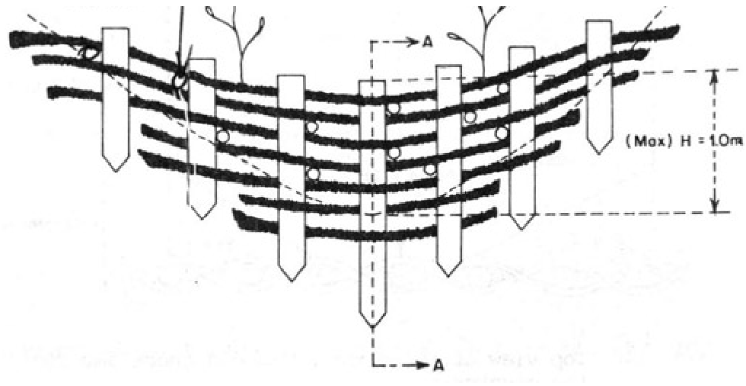
- Posts are set in trenches (0.3 by 0.2 m in size) across the gully to a depth of about 1/3 to 1/2 of the post length, and about 0.3 to 0.4 m apart. -The length of the posts is kept at 1.0 to 1.5 m and their top-end diameter is kept at 3 to 12 cm.
- Any tree or shrub species, such as alnus, pine, bamboo, salix, poplar, etc., can be used as posts.
- The flexible branches of trees (Salix, Poplar, Gliricidia, Cassia, etc.), flexible stems of shrubs (Tithoniarg andis, Tamarix, Arundinaria Intermedia, etc.), and the strips made of bamboo stems may be used as interlink material. These materials are woven between wooden posts driven into the ground.
- The ends of interlink materials should enter at least 30 cm into the sides of the gully.
- The space behind the brushwood check dams must be filled with soil to the spillway.
- If sprouting species (Salix, Poplar, Tithonia grandis, etc.) are selected as posts and interlink materials, brushwood check dams should be constructed when the soil in the gully is saturated or during the early rainy season.
- If non-sprouting species (pine and alnus as posts, bamboo strips as interlink materials) are used, brushwood check dams can be constructed during any season.

Materials

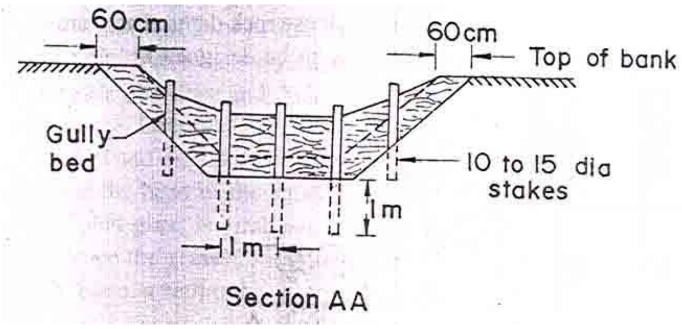
The primary materials used are brushwood, posts, or pegs and the filling materials are soils and stones. This can be used on small gully heads for stabilization. Posts or pegs to be used could be sprout-producing tree species available in the area.

Design

First, a foundation extending into the banks is dug. The brushwood is then placed between two rows of pegs driven in 40 cm apart across the gully bed. The distance between the rows is from 80-100 cm for gullies with about 5 m in width. The brushwood is then packed firmly and the two rows of pegs are tied together with wire. A notch or spillway of about half of the span and the top of the dam are then spared. On the lower side of the dam; brushwood is placed lengthwise to provide an apron that will prevent scouring by overflow. It is very important that these temporary structures are supplemented by cuttings and seedlings, which will replace the brushwood when decayed.



Single row brushwood check dam



Double row brushwood check dam

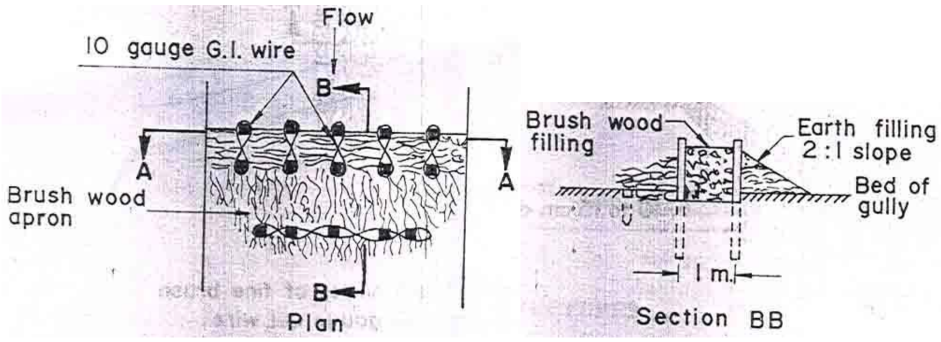


Fig: 5.25 Brushwood Check Dam

Table:5.7 Tentative Estimate

Item of work	**Unit**	**MD**	**Rate (Rs)**	**Amount (Rs)**
Unskilled(providing and fixing wood ballies)	24m	15.6	90	1404
Providing and fixing barack bamboo	24m	16.8	90	1512
Providing and fixing one layer champatarja wall	36 sqm	21.6	90	1944
Collection of grass and vegetation wood		5.0	90	450
Skilled				
Providing and fixing wood ballies	24m	2.4	116	278
Providing and fixing barrack bamboo	24m	2.4	116	278
Providing and fixing one layer champatarja wall	36 sqm	3.6	116	418
Collection of grass and vegetation wood		2	116	232
		Total		**6516**

Abstract

Labour cost			
Ordinary Labour	59 mandays	@90 /-	5310.00
Skilled Labour (Carpenter etc.)	10.4 mandays	@116 /-	1206.00
Total			**6516.00**

5.1.12 Gabion structure

. A gabion is a rectangular shaped cage made of galvanized wire, which is filled with locally found rocks or stones. To facilitate easy transport, gabions are kept flat and are folded to desired shape at the construction site. If abundant stones are available, but their shape makes them unsuitable for loose stone construction, or if the expected water velocity is very high, gabions can be used

Purpose

Gabion structures reduce the velocity of water flowing through the drainage line. These structures are built to cushion the impact of water, preventing it from eroding the banks. On high slopes surrounding roads or railway lines, such structures are built along contour lines to prevent landslides.

Location

The minimum independent catchment area for a gabion structure is 5 ha. For a catchment area smaller than this even a loose boulder check may suffice. On stream embankments, these should be located in stretches prone to severe erosion. The length of the embankment to be strengthened has to be determined. Along this length the rectangular boxes have to be placed as a straight wall with a vertical face.

Construction

The gabion check dam is made by connecting several gabions horizontally as well as vertically. Usually gabions are 1 m wide and 1 or 0.5 m high; their length can vary between 2 – 6 m.

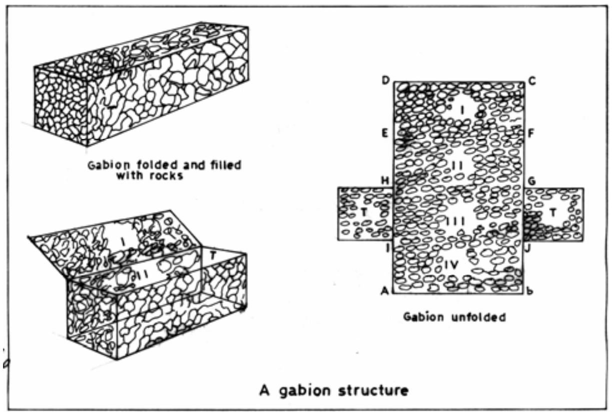


Fig.5.26 A gabion structure

An important advantage of a gabion structure is its flexibility; it will shape itself according to the stream bed even when this changes due to erosion, without loosing its stability.

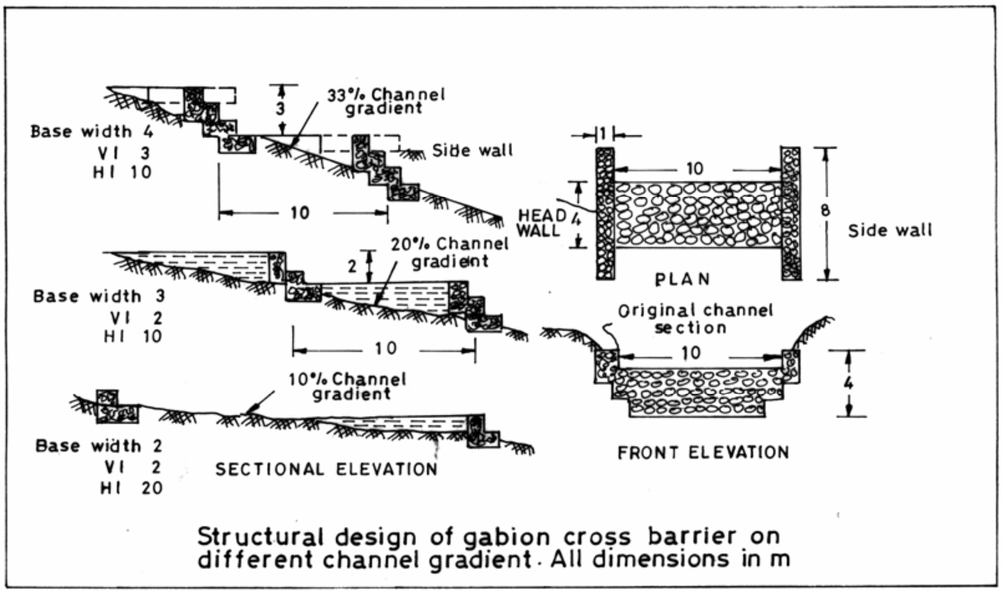


Fig.5.27 Structural design of gabion cross barrier on different channel gradient. All dimensions in m.

Gabions are permeable, but they slow down the water velocity considerably, causing sedimentation and finally complete filling up behind the gabion check dam is achieved.

Table:5.8 Tentative estimate

Description	Quantity	Rate (Rs)	Cost (Rs)
Excavation of hard morum for both bank of nala including lead up to 15 m and lift 4.00 m etc	15.60 cu m	46.00	717.60
Construction of stone bund including lead up to 15 m and lift 4 m	20.30 cu m	64.00	1299.20
Transportation of boulder of size 22 cm from 2 km	20.30 cu m	106	2151.80
Providing and laying galvanized mesh of size	84 sq m	105	8820.00

15x15 cm dia along the periphery and total length including transportation etc			
Contingency and inflation charges			111.40
Total			**13100.00**

Abstract

Labour cost			
Ordinary Labour	8 mandays	@90 /-	720.00
Mason / Stone worker	13 mandays	@116 /-	1508.00
Boulder	2 tractor load	@1025	2050.00
Galvanized iron mesh (15 cm x 15 cm)	84 sq m	105	8820.00
Total			**13098.00**

5.1.13 Masonry drop structure

The drop structure is one of the most commonly used gully control structures. It is mainly used to act as a control point along the gully bed. But at times, the drop structure is also used at the gully head.

Components

The components of the drop structure are given below with description.

Head wall and Head wall extension: Permits stable fill and prevents piping (due to seepage) around the structure.

Side wall: Guides the water and protects the fill against erosion, Wing wall: Provides stability to fill and gives protection to gully banks and surface.

Cutoff wall: Prevents piping under the structure besides reducing uplift and preventing sliding,

Toe wall: Prevents under-cutting of apron.

Apron: Dissipates the kinetic energy of waterfall.

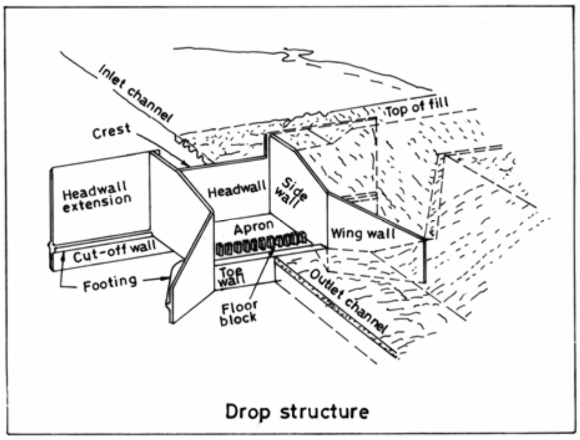


Fig.5.28 Drop Structure

Water enters the drop structure through the weir or stream, falls on the apron and then leaves the structure. Sedimentation gradually occurs on the upstream side. The apron, longitudinal and end sills help in the energy dissipation of the falling water.

Functions

- ✓ To control gradient in either natural or constructed channel.
- ✓ To control tail water at the outlet of a spillway or conduit.
- ✓ To serve as reservoir spillway where the total drop is low.
- ✓ To serve as inlet/ outlet structure of tile drainage system.

Material

Rock masonry, concrete, reinforced concrete most widely used for long life and low annual cost.

Advantages

- ✓ Very stable and likelihood of serious structural damage is remote.
- ✓ Non-clogging of weir rectangular weir so no clogging.
- ✓ Low maintenance cost.
- ✓ Ease and economy of construction
- ✓ Standardization: May be standardized resulting in saving in engineering cost.

Disadvantages/ Limitations

1. Use is limited to a maximum drop of 3 m. Use for more than 3 m drop, may be costlier than other structures.
2. Where temporary spillway storage is desired, this structure is not suitable.

Design of the Drop Structures

The design of a drop spillway proceeds from the hydraulic design of the capacity of spillway

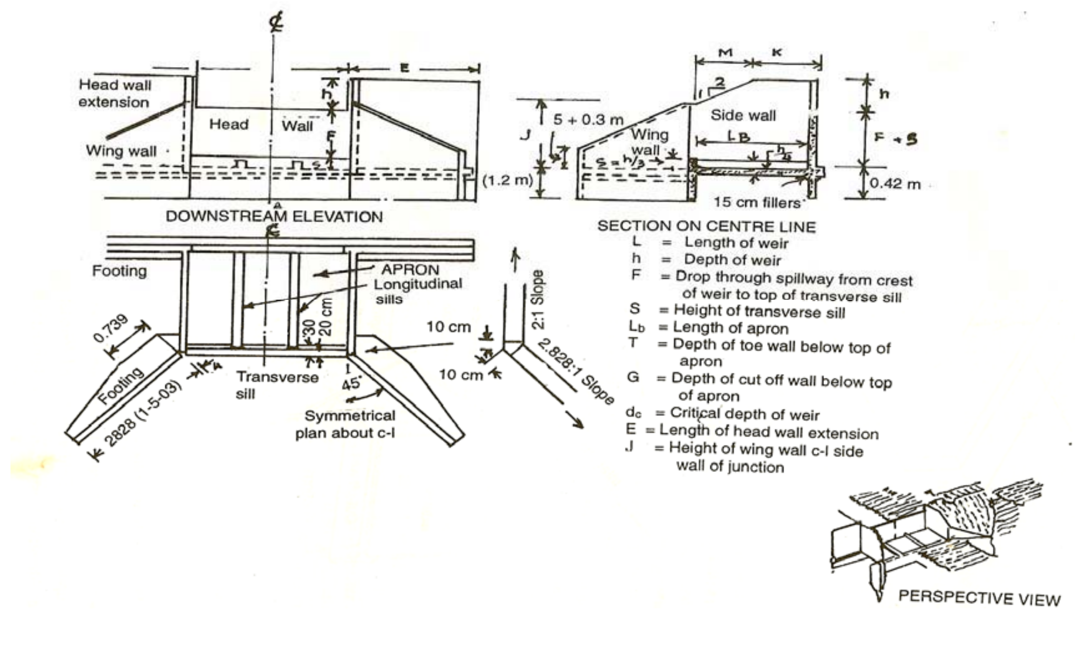


Fig : 5.29 Drop Structures Design

opening (weir), which should be more than design discharge. It is convenient and logical to consider free board in terms of increased weir discharge capacity. The capacity requirement is modified to take care of free board in the equation:

$Q = 1.66\, L\, h^{3/2}$ for flow through rectangular weir. It is modified to

$$Q = \frac{1.66\, L\, h^{3/2}}{1.1 + 0.01F}$$

Where,

Q = maximum discharge capacity of the weir (with provision of free board) (cumec)

L = Length of weir (m)

h = total depth of water (including free board) above weir crest (m)

F = net drop from top of transverse sill to crest (m).

Detailed estimate for construction of Masonry Drop Structure for 4 m width Nalla

Work particulars	Quantity	Rate/Unit (Rs)	Amount (Rs)
Clearing of grass and removal of rubbish up to a distance of 50 m outside of the periphery of area cleared	360 sq m	135.65 / 100 sq m	488.00
Excavation of foundation trenches with initial lift of 1.5m including getting out the excavated soil and disposal of excavated soil as directed within an initial lead of 50 m	55.13 cum	90 / cum	4961.70
Laying of 10 cm thick PCC of 1:3:6 (1 cement: 2 coarse sand: 6 graded stone aggregate 40 mm nominal size) in foundations	10.81 cum	1913.05 / cum	20680.07
Laying of DPC of 25mm thick of 1:2:4 (1 cement: 2 coarse sand: 4 graded stone aggregate 20 mm nominal size) on the top of the walls	0.387 cum	3257.45 / cum	1261.00
Reinforced cement concrete work with 1:1.5:3 (1 cement: 1.5 coarse sand: 3 graded stone aggregate 20 mm nominal size) Total volume of RCC	36.41 cum	2117.15 / cum	77085.43
Brick work with modular brick of class designation 75 with cement mortar 1:4 (1 cement: 4 coarse sand)	35.6 cum	1400.25 / cum	49849.00
Applying cement plaster of 1:4 (1 cement: 4 fine sand) of 20 mm thickness to exposed surfaces of walls and head wall	53.72 sq m	110.45 / sq m	5933.00
Providing stone pitching of 30 cm thickness	16.5 cum	450 / cum	7425.00
Total cost			**167683.20**

Abstract

Item	Unit	Unit cost	Amount in Rs
Labour	400 MD	90	36000
Labour –skilled	49	116	5684
Total			41684.00
Material Cost			
Stone	8 truck	3000	24000
Brick	2000	5	10000
Cement	200 bag	270	54000

Sand	10 truck	200	2000
Aggregate	9 truck	4000	36000
Total			126000

Total cost = 41684+126000= 167684.00

5.1.14 Chute Spillway

A chute spillway is an open channel with a steep slope, in which flow is carried at supercritical velocities. It usually consists of an inlet, vertical curve section, steep-sloped channel and outlet. Flow passes through the inlet and down the paved channel to the floor of the outlet.

Material

Reinforced concrete is the most widely used and safest material for large chutes. Plain concrete and masonry, though not as suitable as reinforced concrete, can also be used.

Functional use

- ✓ To control the gradient in either natural or constructed channel.
- ✓ To serve as a spillway for flood prevention, water conservation, and sediment collection structures.

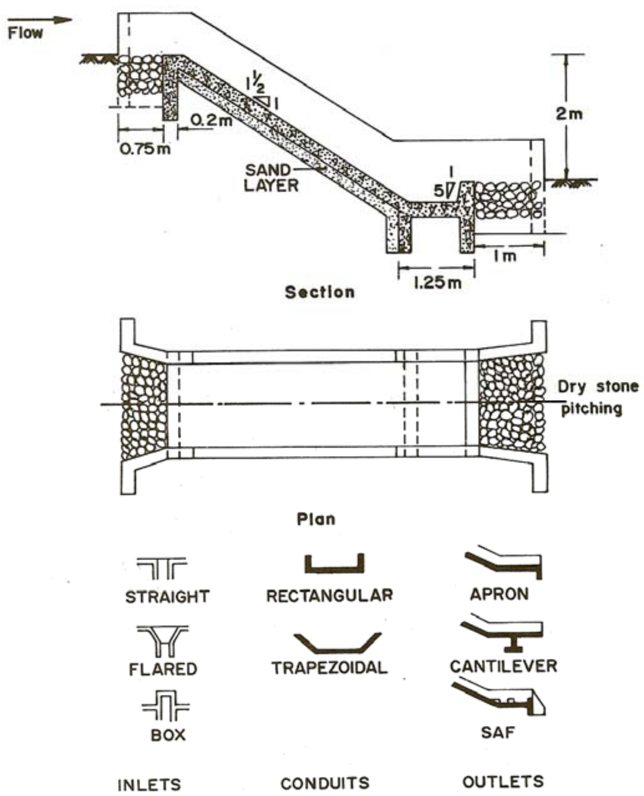


Fig.5.30 A typical chute spillway

Adaptability

The chute, specifically concrete chute, is particularly adapted to high overfall. It may also be used with detention dams, taking advantage of the temporary storage to reduce the required capacity and the cost of the chute.

Advantage

It is more economical than a drop-inlet structure, when large capacities are required.

Limitations

There is a suitable danger of undermining of the structure by rodents. In poor drainage locations, seepage may weaken the foundation. It must be placed on compacted fill or on undistributed soil in an abutment.

Design

The hydrologic design of the structure relies in estimating the peak rate of runoff as in the case of drop structure.

In the hydraulic design the length of the crest is calculated using the weir formula as in the case of drop structure.

For practical purpose, h_f is assumed a fraction of H say 10%. Once the velocity at the toe is known, the depth of flow (d1) is calculated from the relation.

$Q = A_1V_1$

$= b \times d_1 \times V_1$ (for rectangular conduit)

The sidewall of the basin may be parallel (rectangular basin) or may diverge (trapezoidal basin). The later is preferred for higher flows. The side slope is recommended is 1 in 10 depending upon the site condition.

Referring to the figure, the different recommended dimensions for the SAF stilling basin are as follows:

Length of the stilling basin $L_B = 4.5d_2/F^{0.38}$ $(3 < F < 300)$

The height of the chute blocks and floor blocks = d_1

The width and spacing of the chute blocks and floor blocks = $3d_1/4$

The distance of the floor blocks from the upstream end of the stilling basin = $L_B/3$

The height of the end sill $c = 0.07\ d_2$

While d_2 gives theoretical tail water depth, the actual tail water depth d2 is given by

$d_2 = 1.4\ F^{0.45}\ d_1$

The freeboard of the side wall above the tail water depth is given by

$z = d_2 / 3$

Wing wall should be equal in height to the stilling basin sidewalls. The top of the wing walls are give a slope 1:1.

Length of the wing walls = $z + d_2$

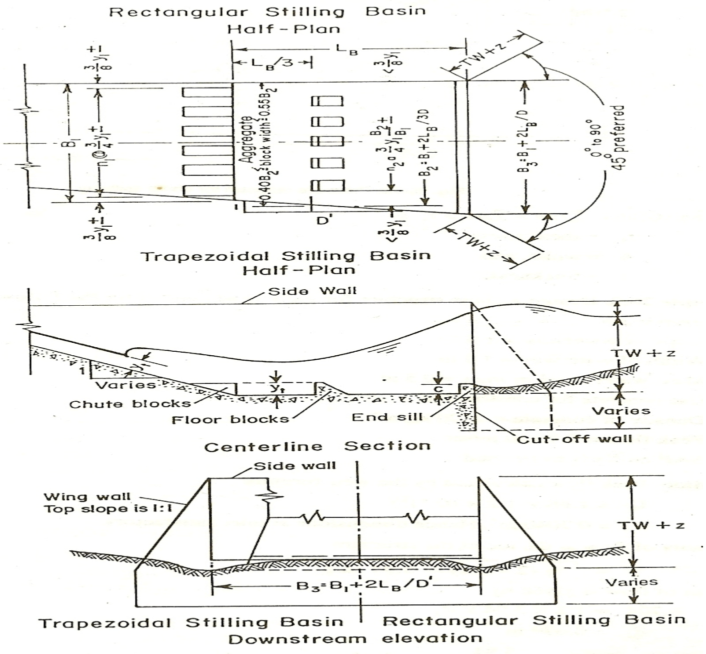


Fig 5.31 Chute Spillway Details

5.1.15 Drop Inlet Spillway

A drop inlet spillway is a closed conduit generally designed to carry water under pressure from above an embankment to a lower elevation. An earthen embankment is required to direct the discharge through the spillway. Thus, usual function of a drop inlet is to convey a portion of the runoff through or under an embankment without erosion.

Materials

The riser of a drop inlet spillway may be of plain concrete, reinforced concrete blocks, masonry or pipe. The barrel may be of reinforced concrete, concrete or clay tile, or corrugated or smooth metal pipe having watertight joints. In India RCC pipes are generally used.

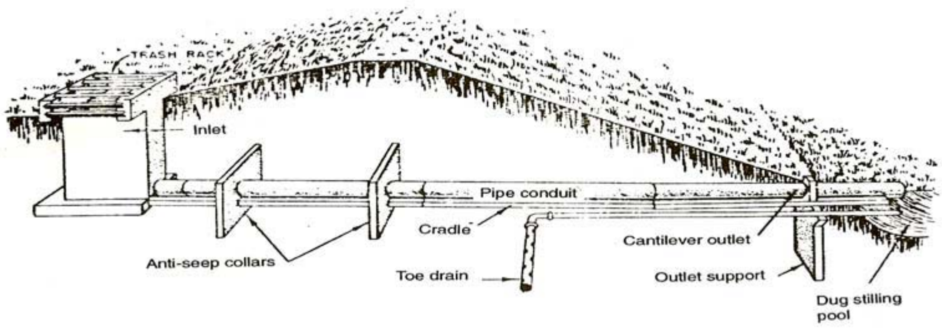


Fig .5.32 Drop Inlet Spillway

Functional use

- ✓ Principal spillways for farm ponds or reservoirs
- ✓ Grade stabilization
- ✓ Disposal system at lower end

- ✓ Principal spillways for debris basins
- ✓ Roadway structure
- ✓ Flood prevention structures
- ✓ Surface water inlet for drainage or irrigation

Location

This structure is very efficient structure for controlling relatively high gully heads, usually above 3m. It is well adapted to sites providing an appreciable amount of temporary storage above the inlet.

Advantage

For high heads, it requires less material than a drop spillway. Besides effecting a reduction in cost, this reduction of discharge results in a lower peak channel flow below, and can be favourable factor in downstream channel grade stabilization and flood prevention.

Limitations

Small drop inlets are subject to blockage by debris. They are limited to locations where satisfactory earth embankment can be constructed.

Design

Large size pipe drop inlets require the services of an engineer. When corrugated pipe is planned, only the heavier ones should be used. A coating of bituminous material will extend the effective life of this type of pipe. All joints should be provided with water tight metal bonds caulked or otherwise sealed against leakage, and anti-seep collars used to prevent seepage along the pipe. Sheet metal anti-seep collars, or diaphragms with a water tight connection to the outside of the pipe are superior to concrete collars for metal pipe, because distortion of the pipe from loading may crack the concrete collar or rupture the pipe whereas a metal anti-seep collar will adjust and remain intact.

The design should provide for sufficient temporary storage between the crest of the inlet and the emergency spillway to permit a drop inlet spillway of reasonable size and cost. The size of the drop inlet spillway depends largely on the amount of this temporary storage. Tail-water will influence the layout of the spillway and the amount of hydraulic head available to produce discharge through the spillway.

Reinforced concrete culvert pipe or water pipe will make a more satisfactory pipe drop inlet than corrugated metal, particularly for embankment heights greater than 6 m, or where long service life is desired. Concrete pipe must be properly cradled and bedded. All joints must be water tight. The size of the riser pipe in relation to pipe conduit can be determined as follows:

Inlet Proportions					
Pipe conduit D (cm)	20 – 30	45	60	75	90
Pipe riser D (cm)	45	60	75	90	120

The minimum height of riser is 0.6 m and can be less than or greater than 5D according to need. The outlet of the drop inlet spillway should be in line with the downstream channel. The layout providing the shortest conduit will exist when the conduit is straight and at a 90° angle with the centerline of the embankment.

5.1.16 Water Harvesting Structures

Water harvesting structures are intended to store rainwater flowing from the catchment for ground water recharge and life saving irrigation to the crops at a later time when the crops need it. Small-scale water harvesting is most successful when operated as a system with three components: 1) the watershed or catchment area that generates the runoff, 2) the reservoir which holds or collects the runoff, 3) and the serviced area where the harvested water is used for production.

Purpose

- To intercept and reduce runoff thereby inducing larger and extensive absorption of available rain water.
- To trap eroded materials thus reduces sediment production rate either in to streams or to the reservoirs.
- To create irrigation potential in mini commands
- To provide remunerative single or double crop base agriculture and generates regular or casual job opportunity in remote areas
- To increase total production and stabilized environment

Location

Water harvesting by external catchments is suitable in areas where there is a lot of uncultivated, open land available. It is not suitable in densely populated areas where most of the land is cultivated. Sites that are communally owned should be properly managed to ensure sharing among the intended beneficiaries.

Advantages of W. H. S

- Runoff harvesting structures are small in size and low cost
- The construction can be completed in a time frame of less than a year without escalation of cost and can start functioning from subsequent rainy season
- The structures are small in size with a low reservoir capacity which can be filled up with a single shower of rain and become operative immediately in comparison to big reservoir. It can also be recharged / refilled number of times as against big reservoir.
- Runoff harvesting structures provide irrigation facilities even to the isolated remote areas and drought prone pockets where benefits may not flow from major medium or minor irrigation projects. The inter district, even intra block imbalance in development of irrigation facility can overcome to a great extent rectified by W. H. S.
- The runoff harvesting structures can provide protective irrigation to the lands close to the donor catchments and even to donor catchments by way of recycling the storage water by lifting.
- WHS constructed in remote rural areas can generate substantial casual and regular employment opportunity to rural labours through sustained profitable cultivation.

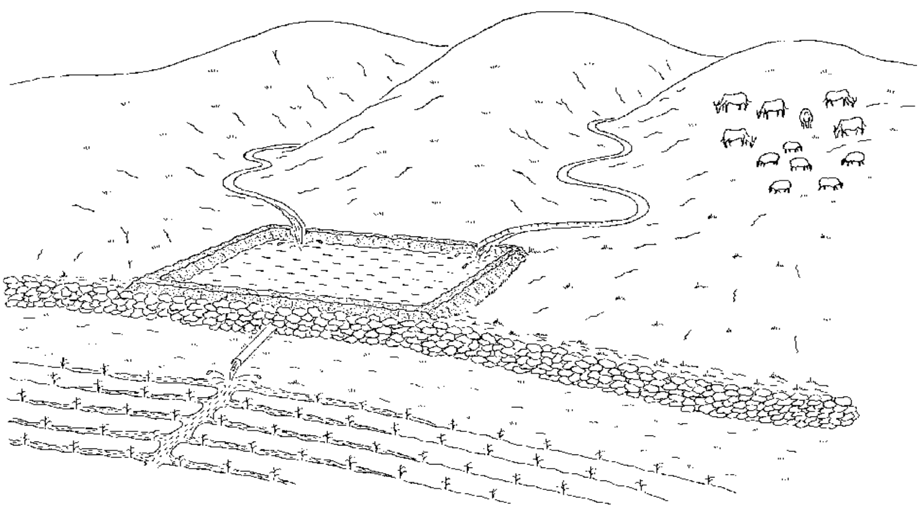


Fig.5.33 Water Harvesting Structure

Fig.5.34 Water Harvesting Structure

Table: 5.9 Tentative estimate for WHS (Catchment 10 ha, Intensity of rainfall 7.5 cm/hr)

Sl.No	Items of works	Labor(MD)	Rate(Rs)	Amount in Rs.
1	Survey, demarcation &alignment,	6.	90	540.00
2	Side cleaning	5	90	450.00
3	Earthwork stony earth mixed with gravel within initial lead and lift for base stripping work	83.82cum(43MD)	90	3870
4	Earthwork excavation for the bund i. With initial lead and lift of 50m and 1.5m respectively ii. With one extra lift of 1.5m over the initial lift.	635.83 cum(325MD) 280.95 cum(143MD)	90	29250 12870
5	Fine dressing and turfing of the bund with locally available grass with 3 extra lead over the initial lead and lift of 50m and 1.5m respectively	378.00sqm(21MD)	90	1890
6	Provision for masonry sluice	Mason(5MD) Labor(10)	116 90	580 900
7	Dry stone packed open surplus for safe	Mason(2MD) Labor(4)	116 90	232 360

	disposal of water			
	Total			**50942**

ABSTRACT

Labor Component

Skilled Labor(Mason etc)	7MD	@ Rs116	Rs 812.00
Ordinary labor	557MD	@ Rs 90	Rs 50,130.00
		Total	Rs 50,942.00

Material Component

Cement	7Bags	@ Rs270	Rs 1890
Sand	1 truck	@ Rs200	Rs 200
Stone	½ truck	@ Rs2000	Rs 1000
Brick	800 no	@ Rs 5	Rs 4000
		Total	Rs 7090/-

Total cost of the structure = Rs 50,942/-+Rs 7090/-=Rs 58,032/-

Tentative estimate for WHS (Catchment 20 ha, Intensity of rainfall 7.5 cm/hr)

Sl.No	Items of works	Labor(MD)	Rate(Rs)	Amount in Rs.
1	Survey, demarcation & alignment,	6	90	540.00
2	Cleaning of site	20	90	1800.00
3	Earthwork stony earth mixed with gravel within initial lead and lift for base stripping work	150cum(77MD)	90	6930
4	Earthwork excavation for the bund i. With initial lead and lift of 50m and 1.5m respectively ii. With one extra lift of 1.5m over the initial lift	1251.48(640MD) cum 602.50(339) cum	90 90	57600 30510
5	Fine dressing and turfing of the bund with locally available grass with 3 extra lead over the initial lead and lift of 50m and 1.5m respectively	694.74sqm(38MD)	90	3420
6	Provision for masonry sluice	Mason(8MD) Labor(16)	116 90	928 1440
7	Dry stone packed open surplus for safe disposal of water	Mason(4MD) Labor(8)	116 90	464 720
	Total			**104352**

ABSTRACT

Labor Component

Skilled Labor(Mason etc)	12MD	@ Rs116	Rs 1,392
Ordinary labor	1144MD	@ Rs 90	Rs 1, 02,960
		Total	**Rs 1, 04,352**

Material Component

Cement	12Bags	@Rs270	Rs 3240
Sand	2 truck	@Rs200	Rs 400
Stone	1 truck	@Rs2000	Rs 2000
Brick	1000 no	@Rs 5	Rs 5000
		Total	**Rs 10,640/-**

Total cost of the structure = Rs 1, 04,352/-+Rs 10,640/-=Rs 1, 14,992/-

Mahabandh is a large sized water harvesting structure for harvesting the excess runoff water on larger catchment basis. This structure is feasible only when a minimum catchment area of 100 ha is available and submergence areas of 3 ha are available with a possible depth of 5 m. This technology can be used in plateau areas with 2 to 5% slope. Generally the site should be selected in such a way that some depression is already available and maximum storage area can be achieved with minimum of earthwork.

Design

Area of the catchment = 100 ha.
Reliable runoff at 80 % probability = 165 mm
Hence total runoff = $100 \times 10^4 \times 0.165$ = 1,65,000 m^3.
Area of the *Mahabandh* = 134m×134 m (found by trial and error)
Considering average seepage loss of 6 mm/day and average evaporation loss of 4 mm/day, Total loss through seepage and evaporation = $134 \times 134 \times 0.01 \times 365$ = 65,540 m^3.
Hence, capacity of the *Mahabandh* = 1,65,000 − 65,540 = 99,460 $m^3 \approx$ 1,00,000 m^3.
But the location of *Mahabandh* is decided in such a way that some depression is already available and a significant storage is achieved by the embankments. Hence the effective earthwork that is required is 50,000 m^3.
For excavation of 50,000 m^3 the design dimensions are as follows
Area of *Mahabandh* at ground level = 134m × 134 m
Area of *Mahabandh* at bottom = 124m × 124 m
Depth = 3 m.
Side slope = 1: 1
One berm of 2 m width is provided at 1.5 m depth.
Embankment height = 3 m
Embankment top width =6 m
Embankment bottom width = 16 m
Side slope = 1:1.
Berms of 2m width are provided both in the upstream and down stream side at 1.5 m height.
Inlet of 5 m width will be provided and a spillway will be provided for safe disposal of excess water.
Area covered by *Mahabandh* 170×170m = 2.89 ha.
All the soils that are excavated can not be used in the embankment. Rest of the soil can be used for filling up the nearby depression area or transported to a distant area. Some more soil can be accommodated by increasing the dimension of the embankment. The diagram of the *Mahabandh* is shown in Figure 7.

Tentative Estimate

(i) Earthwork @ Rs. 46.00/ m^3 for 50,000 m^3	Rs. 23,00,000.00
(ii) Spillway and inlet	Rs. 1,00,000.00
(iii) Conveyance network	Rs. 1,00,000.00
Total	**Rs. 25,00,000**

5.1.17 Farm Ponds

Construction of earthen embankment across a natural basin to store water for various uses is always not feasible and in such cases dug out or excavated ponds can be constructed in a relatively flat terrain. In this method storage space is man-made.

Purpose

To collect surplus water from individual fields at the lower part to conserve water from runoff and provide protective irrigation

Location

In lowest point of private field adjacent to the bund.

Selection of site

For selecting site for excavated pond, the watershed characteristic, silting possibility, topography and the soil types are taken to consideration. The watershed must be capable of yielding annual runoff sufficient to fill the dug cut. Diversion channel and ditches are often used in adding supplemental drainage. The low point of a natural depression is often a good location for a dug out pond. The soil type at the site should be thoroughly investigated to determine the permeability of the soil that will form the bottom and sides of the dug out as well as to avoid cutting on very hard stuff. In case the seepage rate is excessive, suitable lining may have to be provided i.e. puddling and compacting or Bitumen spray plastic covers etc. At locations where the water table rises within a few meters of ground surface, dug out can be constructed to intercept the water adjusting the depth to the fluctuation expected. Location of this type may furnish supplies all the year around.

Planning of dug out pond

Excavated ponds may be constructed in any shape desired. However, a rectangular shape is usually convenient. The size of the pond depends on the extent of area draining into the pond, the extent of area that should put under the pond and its surrounding bund of excavated soil, the amount of capital investment, the nature and amount of rainfall, soil type and expected runoff into the pond. The length and width of excavated pond will not ordinarily be limited except that the type and size of excavating equipment. Its use may become a factor of consideration. The side slopes of a dug out pond should not be steeper than natural angle of repose of the material being excavated. In most cases, the side slope should be flatter than 1:1.

Disposal of excavated material

Proper disposal of excavated material will prolong the useful life of the pond, improve its appearance and facilitate in maintenance and establishment of vegetation. The excavated material should be placed in a manner that its weight will not endanger the stability of the side slope and the rain fall will not wash back the material back into the pond. A berm with a width equal to depth of pond may be adopted as shown in Fig. 5.35

Fig. Disposal of excavated material

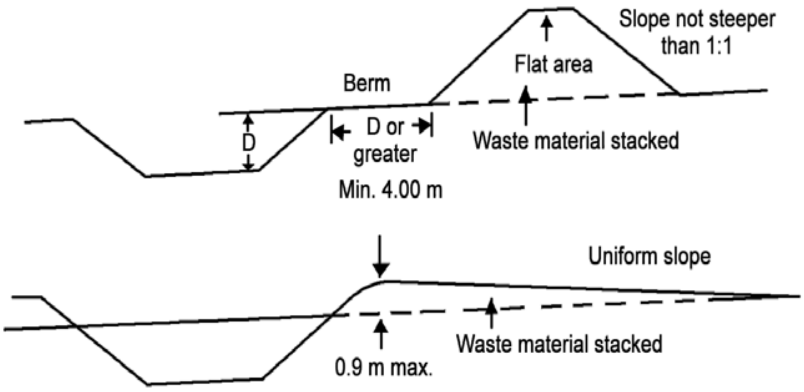


Fig.5.35 Excavation of Farm Pond

Construction

The pond site and the waste area should be cleared of all vegetation. The limit of excavation and soil placement area should be demarcated and excavated using manual labour. Excavation and placement of excavated material are the principal items of work required in the construction of this type of pond.

For ease of excavation step like cross section (each step representing rectangular cross section is usually adopted as shown in Fig.   .

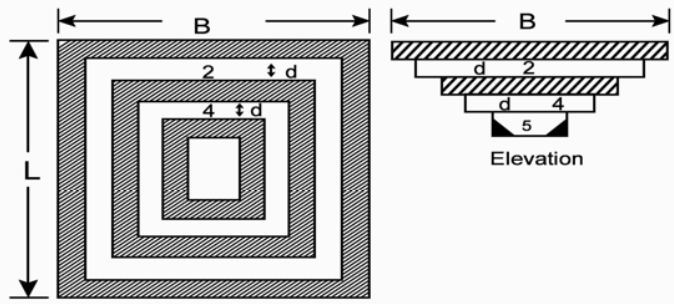


Fig. 10 : Excavation of dugout from pond. 1, 2, 3, 4, 5 ... n etc. are segments from top to bottom. *L* = length; *B = breadth; d = depth of each segment*

Fig.5.36 Excavation of dug out Farm Pond

Estimation of volume of earth work of a pond

The volume of excavation required can be estimated with sufficient accuracy by use of the prisomoidal formula given by:

$$V = \frac{A + 4B + C}{6} \times D$$

Where, V = Volume of excavation M^3

A = Area of excavation at ground surface M^2

B = Area of excavation of mid point (½depth D/2) M^2

C = Area of the excavation at the bottom of the pond M^2

and

D = Average depth of pond in (M)

Fig: 5.37 A dug out farm pond

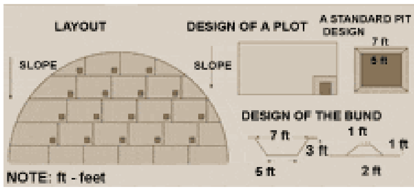
5.1.18 The Five Per cent Model

The five percent model: The main objective of this model is to ensure that all small land holdings should have their own water body for harvesting rain. These pits are usually 1.5 square metre in size, occupying 5 per cent area of individual fields. The plot is leveled properly and bunded to allow water to accumulate to a height of 100mm; this pit also facilitates the subsurface flow of water to downstream plots and improves the moisture regime of the area as the whole.

The details of 5% and 30x40 models of PRADAN are given below.

Pit in 30x40 model

Field showing 30x40 model



Design & Layout of the model

Fig 5.38 Details of 5% and 30 x 40 models

The 30 x 40 model is a method of in-situ soil and water conservation. It involves dividing uplands into small plots of 30 x 40 ft (30 ft along the slope and 40 ft across the slope), digging pits at the lowest point in each plot and bunding plot using the soil dug out of the pits.

Objectives:

- To break the velocity of the runoff to stop soil erosion (as the water gets arrested before reaching the eroding velocity)
- Harvesting the runoff to percolate through the soil slowly, thus improving the soil moisture condition and hastening the growth of vegetation.

Suitability:

- Unbunded or un-terraced with 3–8% slope
- Minimum stretch of land required for treatment= 3 ha.

Construction steps:

- Divide and mark the selected area into30 x 40 ft, starting from the ridgeline, with the help of a measuring tape, rope and lime. The size of the plots may be altered up to + 10% to fit the boundary and ownership.

- Identify the lowest point in each plot.
- Dig a 3-ft deep pit that is 7 x 7 ft at the top. The pit should have a sloping wall such that the bottom of the pit is 5 X 5 ft.
- Bund the plot with the excavated soil from the pit. The bund across the slope should be 1 ft high with a top width of 1 ft and bottom width of 2 ft.
- Use the rest of the excavated earth to construct the field bund at the side, along the slope

Standard dimensions for plot:

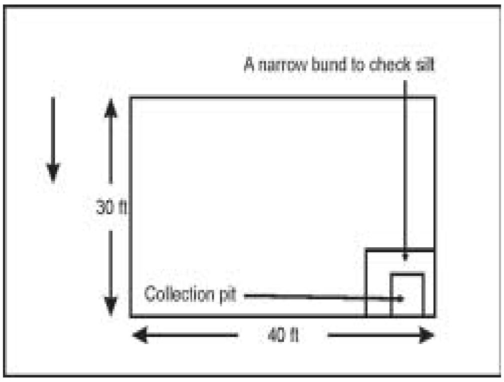
- Length of the plot = 40 ft (across the slope)
- Width of the plot = 30 ft (along the slope)

Pit:

- Pit size at top= 7 ft x 7 ft
- Pit size at bottom= 5 ft x 5 ft
- Depth of the pit = 3 ft

Bund dimension (across the slope):

- Bottom width= 2 ft
- Top width= 1 ft (0.5 – 1.5 ft)



- Height= 1 ft
- Side slope= 1:1 in general

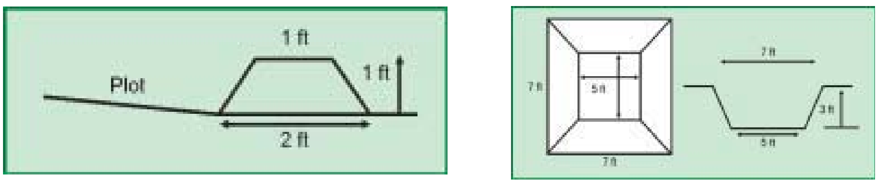


Fig. 5.39 Standard bund & pit designs

Note:

- In case it is not possible to treat the area from the ridge, a diversion channel should be constructed above the patch to be treated; to safely dispose the runoff that otherwise would have entered the patch.
- While removing the topsoil care should be taken not to expose the hard strata that are not suitable for cultivation. In extreme cases, the topsoil may be kept separately and replaced once the final level of the plot is attained

5% Model:

This is a model of in-situ rainwater harvesting suitable for medium uplands, in which every plot has its own water body, the area of which equals5% of the total area of the plot. The pit is able to hold rainwater those otherwise flows out of the plot as runoff. The water held in the pits irrigates the plots during water scarcity.

Objective:

- In-situ harvesting of rainwater.

- To increase moisture status of individual plot
- To provide life saving irrigation to standing crops
- To arrest silt from the land.
- To increase water availability for downstream plots.
- To increase farmer's access to water as it is available at his own plot.

Suitability:

- Medium uplands with unidirectional slope with maximum slope up to 5%
- Soil should have medium porosity with good soil cover.
- The patch should be of 4.0 ha. minimum to make the treatment more effective.

Construction steps:

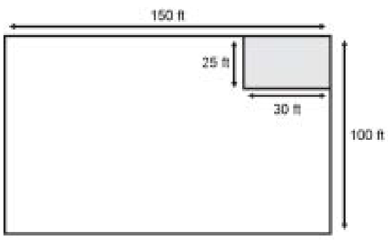
- Measure the length and width of each individual plot.
- Demarcate 5% area of the plot in the following manner. Mark an area of one fifth of the length and one-fourth of the width at the upper right corner of the plot to dig the pit. (Suppose, a plot is 150 ft long and 100 ft wide. The pit area then needs to be 30 ft x 25 ft or 750 sq ft.)
- The pit is dug to the following dimensions. Depth: 5 ft–7 ft depending upon the type of the soil and wall slope1:1.
- Use the excavated earth to strengthen the field bunds.
- Make a small 4-inch high bund around the pit to keep some standing water in the field.

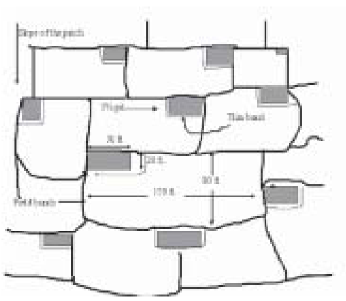
Pit dimensions:

- Length of the pit= 1/5th of length of the plot
- Width of the pit= 1/4th of width of the plot
- Depth of the pit= 5 ft to 7 ft depending on the depth of the soil
- Side slope= 1:1

a 5% tank in medium upland

Fig. 5.40





demarcation of 5% area & location of pit

Note:

- The norm for allocating 5% area is not rigid.
- One needs to consider land qualities and farmers' preferences and other crop plans.
- A bigger pit is required to store more water.

While laying out the pits in successive plots along the slope, one need to make sure that the pits are rather staggered and not in straight line.

5.1.19 Percolation Tank

Percolation tank is a farm pond type structure constructed in relatively permeable soils in the upper reaches of the watershed to facilitate groundwater recharge. The runoff from the catchment gets harvested in the percolation tank where it gets sufficient time to slowly recharge the groundwater. The percolation tanks are generally constructed in the first and second order streams. The average catchment area in these streams is 50 ha. So, one percolation tank can be constructed in a 50 ha catchment area.

Purpose

The purpose is to arrest runoff, to enable collection and percolation of surface water in order to recharge the ground water table.

Location

Usually suitable in upper and middle reach in common/ revenue/degraded/forest lands. These percolation tanks are required to be constructed in hilly terrain where rainfall is inadequate or badly distributed and there is not enough time for the rain water to infiltrate and soak into the ground. It is observed that streams or nalas in such tracts get floods of short duration and remains dry for the major period. The percolation tanks are essential in these area to impound the short flow, spreading to large area and allow it to stand for long period so that water percolate down in to soil and recharge the ground water. The catchment should be above 40 ha.

Construction

Percolation tanks usually are meant to absorb all the runoff from the catchment and hence there may not be need of providing waste weir or surplus arrangement. However, to safe guard the safety of structure in a year of good or intense rainfall, construction of a waste weir or a safety outlet with much less capacity can be provided. The main aim of the tank is to hold the runoff, spread it to larger area may be in shallow depth and allow it to longer time for the water to percolate into the soil. In cases where ponding is not feasible, masonry drop structures are to be constructed across the stream to spread the water to a large area by diverting the flow. Even spreading can be allowed over cropped lands to allowable depth without hampering growth of crop like paddy. The type of structures required for percolation are earthen embankments or drop structure.

Fig. 5.41 Percolation Tank under Construction

Design

Area of the tank at the ground level=30m x 30m
Area of the tank at the bottom =26m x 26m
Depth= 2m
Side slope=1:1
Total earthwork (square area with 1:1 side slope) =$1/6(30^3-26^3)=1570m^3$
Top width of embankment = 3m
Bottom width of embankment = 7m
Height of embankment = 2m
Side slope = 1:1
The diagram of the percolation tank is shown in Figure 2
Assume seepage rate = 10 mm/day
So, total recharge = 30x30x0.01x150 days= 1350 m^3

Tentative Estimate

(i) Earthwork@ Rs.46.00/m^3 for 1570 m^3 (802 MD @Rs 90)	Rs 72,220.00
(ii) Pipe spillway	Rs 5,000.00
Total	**Rs 77,220.00**

5.1.20 V- Ditch

Where construction of contour bund is not possible, there conversation trenches like V-ditches are preferred. This is mainly done in black soils in Agricultural fields.

Purpose

- To conserve *in situ* moisture and reduce soil loss
- Circular basin of one meter dia for level lands depending upon infiltration and rainfall
- ‘ V’ ditches of size 5m x 5m with trees planted centre and height according to the rainfall and slope of sloppy lands
- Saucer basins / semi circular bunds with 2m diameter to a height of 15-20cm across the slope

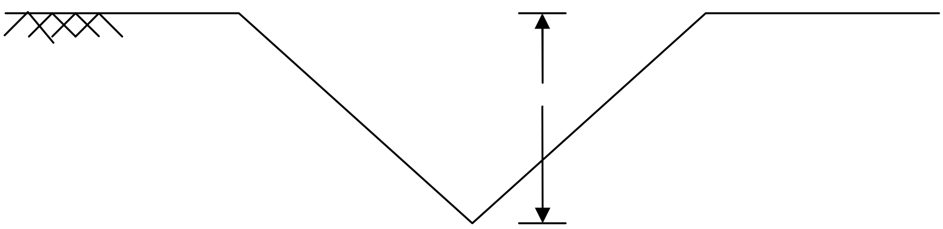


Fig: 5.42 V- Ditch

Location

This is suitable in

(i) Agricultural field with black soil
(ii) spacing between ditches should be 80m to 100m
(iii) Maximum length of the ditch: 50m
(iv) cross section area-1.8m² to 3.2 m²
(v) depth of the ditch -0.6m to 0.8m

Construction Procedure

(i) Mark the contour line
(ii) Construct the ditch with the help of a tractor driven V-scrapper
(iii) Adjust and dress the bund by manual labour
(iv) Put grasses on the both side of the ditch

Cost Estimate of the Structure (for 50m)

Use of tractor for 2 hours @ Rs. 150/- hr	=	Rs.300/-
Dressing the bond, 2 man days @ Rs. 90/-manday	=	Rs.180/-
Grass turfing 4 man days @ Rs. 90/- per man day	=	Rs.360/-
Total cost	**=**	**Rs.840/-**

Per meter length = Rs.16.80/-

5.1.21 Design of Watercourse and Field Channel

Farmers mostly use earthen channels for conveying water without bottom or side lining of the channel. It can be built and maintained by unskilled persons and requires no special equipment or materials. The low initial cost is a major advantage of earthen channels. However these channels generally become defunct over time and need for their renovation arises. For efficient irrigation field channels are necessary. In some places, field channels to supply irrigation water to individual's fields are found absent. Therefore, emphasis has been laid on the construction of field channels in addition to the water course to irrigate 25 ha of area i.e. command area of 1 outlet, approximately 375metre long watercourse and four numbers of 100m long field channel are proposed.

The standard carrying capacity of the watercourse is 35 lps and field channel is 12 lps.

Design of Watercourse:

Assuming depth of flow d = 30 cm
Standard side slope = 1:1
Bottom width = b
Top width = 2.8 d
Length of Side = 1.4 d
Wetted perimeter = p = 3.6 d
Area of cross section A = $1.d^2$
Hydraulic radius = R = A/P = d/2
Assuming channel slope = 0.1% = 0.001 m/m and n= 0.04
Using Manning's formula, $V = 1/n \times R^{2/3} \times S^{1/2} = 0.223$ m/sec
Hence, the velocity is in the permissible range. The excavated soil will be deposited on both sides to act as freeboard.
Volume of earth = AxL
Cost of excavation = V × Rs. 45
No. of man days generated = 2784/60 = 31 (unskilled)
Design of field channel can be done using above techniques

5.1.22 Dug out sunken ponds

This is a dug out in *nala*. The soils are placed below the slope as an embankment. The spill way is also provided.

Purpose

The purpose is to recharge ground water.

Location

These structures are to be constructed on the lower middle reaches of the watershed mostly in the arable land. The beneficiary should be convinced about the utility of the structure A dug-out pit having inlets and outlets with vegetable support should be provided. The dug-out earth is to be used as a side bund on the U/S side.

Requirements

- The slope should be gentle (about 2%) of the *nala* when it is being constructed

- The gullies that have rainwater into stream should be properly treated, plugging with loose boulders and supported by vegetation.
- The depth should not be more than 2 m to avoid casualties of livestock or children .
- The soil should be more porous as the sunken ponds are meant for recharging ground water.

Tentative estimate

Sl. No	Details of work	Rate	Amount in Rs.
1	Survey, demarcation & alignment, 2 man days	90	180.00
2	Excavation earth work in stony earth mixed with gravel within initial lead and lift 7m* 6m * 1.0m = 42.0cum 6m* 5m * 1.0m = 30.0cum 72.0cum (37 MD)	90	3330.00
3	The dug-out earth is to be deposited on the U/S side of the created pondage as follows Length = 16.0m U/S and D/S slope = 1: 1.25 Top width = 1.2m Avg. height = 1.5 m Cross section = 4.62 sq m Volume of the earth required is 16* {2(1.88 + 1.2)/2}*1.5 = 73.92 cum Overall the dug-out earth is adjusted.		Nil
4	Vegetative in-let and out-let on L/S (6 MD)	90	540
5	Fine dressing and turfing both sides of the bund with three extra lead over the initial lead and lift 16*2* ((1.88*1.88+(1.5*1.5))=76.8squm (5 MD)	90	450
	Total		**4500.00**

Abstract

Mulia 50 MD @ Rs 90= Rs 4500.00

Sunken ponds in rice field

Sunken ponds are usually recommended in rainfed medium lands where water is not available for irrigation after monsoon prohibiting cultivation of *rabi* crop. In this approach approximately 5-10% of total area is converted to a dugout sunken pond. A broad crested brick masonry rectangular weir is to be kept, so that it allows excess water in the field to drain into the pond. The pond is to be kept at the lower most corner of the field or on the down stream side of the field. This pond can be used for aquaculture during monsoon and dyke can be used for on-dyke horticulture. The stored water is used for giving supplemental irrigations to *Kharif* crops and irrigating *rabi* crops. The area of pond is kept at 5-10% of the field area; depth is kept as 2.5 m and side slope 1:1. The excavated soil is used for making dyke around the pond and excess soil is transported from there to nearby areas.

Design and estimate for 1 ha field

Area used for dugout sunken pond should be less than 10% of the field, where seepage loss is less than 6 mm/day.

Size of the pond = 800 m^2 at top (Assuming 8% area to be used for pond)

Size of the pond at top= 28 m x 28 m.

Depth of pond = 2.5 m, Side slope= 1:1.

Size of the pond at bottom = 23 m x 23 m.

Total volume of earth work=1641 m^3 (approx.).

Assuming cost of excavation is Rs. 46 m^3

Cost of excavation=1641 x 46 = Rs. 75,486 (**838.7 MD)**
Volume of soil to be used in the bund = {(1.5 +4.5)/2}x1.5x30.5x4 =545 m^3.
The drawing of the pond cum bund is presented in Figure 8.
Cost of transportation of excess soil @ Rs 15 /m^3 for (1641-545= 1096 m^3) = Rs.16,440 (**182 MD)**
Brick masonry surplus weir or inlet pipe along with catch pit= Rs. 1000 lump sum.

Total cost of the work = 75,486+16,440+1,000= Rs. 92,926
Total mandays generated = 900
Unskilled=870, skilled=30.

5.1.23 Diversion weirs

Diversion weirs are constructed across a *Nala* with the objective of soil and water conservation and irrigation by diverting water from *nala*. Check dams can be temporary structures or permanent structures. Drop structures are generally constructed across the gullies as permanent check dams. The eroded soils are checked by the drop structures and soil is conserved. Pipe networks can be provided to divert the water stored in the *Nala* for meeting the irrigation requirement. The design of the check dam/ diversion weir has been done hereunder for a catchment area of 200ha.

Design
Catchment area = 200 ha.
Intensity of rainfall at 10 year frequency for the region= 60 mm/hr
Runoff coefficient = 0.35
Peak discharge = 0.35× 60× 200 = 11.66 cumecs
The dimensions of the diversion weir will be calculated in same way as check dams.
Thickness of apron for different values of overall F are given below

Overfall, F(m)	0.5-0.75m	1.0-1.75 m	2.0-3.0 m
Apron thickness (cm)	20 cm	25 cm	30 cm

So, a thickness of 25 cm is selected here
Wall thickness- top widths and minimum base widths of headwall, sidewall, wing wall and headwall extensions for different wall heights for masonry construction are given below.

Description	**Head wall**	**Side wall**	**Wing wall and head wall extension**
Minimum top Width (m)	0.45	0.30	0.30
Height (m)	Recommended base widths		
0.5	0.45	0.30	0.30
1.0	0.67	0.55	0.40
1.5	1.0	0.82	0.60
2.0	1.33	1.10	0.80
2.5	1.67	1.37	1.00
3.0	2.0	1.65	1.20
3.5	-	-	1.40
4.0	-	-	1.60
4.5	-	-	1.80

Using the above table following dimensions is finalized in the present case.
Headwall – Top width 0.45 m and bottom width 1.15 m
Sidewall- Top width 0.30 m and bottom width 0.95 m
Wing wall and headwall extension – Top width 0.30 m and bottom width 0.70 m.

The above design has been done for extreme cases which very rarely occur. So, by taking a little worthwhile risk, the dimensions and thereby price can be reduced.

Rough Estimate

Drop structure/ check dam = Rs. 1,20,000.00
Pipelines (300 m) & accessories = Rs. 30,000.00
Total Rs. 1,50,000.00

Mandays required – 150 skilled and 500 unskilled per one check dam and conveyance system.

Table: 5.10 Details of tentative estimate for diversion weir

Sl. No	Items of works	Quantity	Rate	Amount in Rs.
1	Survey, demarcation & slide cutting etc,	L.S	S/A	3500.00
2	Earthwork excavation in stony earth mixed with gravel with initial lead and lift Including labeling and dressing	35.93 cum	Rs. 4514.17 / 100 cum	1622.00
3	Cement concrete 1:3:6 with 40 mm size H.G metal	30.91 cum	1575.50 per cum	48698.70
4	Cement concrete (1:2:4) with 12 mm hard granite chips	2.02 cum	2186.66 per cum	4421.09
5	Rough stone dry packing in previous apron	3.60 cum	283.18 per cum	1019.45
6	R.R.H.G stone masonry in C.M (1:6) in super structure	39.14 cum	926.07 per cum	36246.00
7	20 mm thick cement plaster (1:6) over stone work	80.89 sqm	51.40 per sqm	4157.74
8	Transportation charges of materials and royalty charges	L.S	S/A	16600.00
9	Provision for one number of masonry irrigation sluice of 6 " dia	L.S	S/A	6500.00
10	Earth work for side bunds			29250.00
11	Grass turfing over side bunds			6500.00
12	Contingencies for unforeseen expenditure	L.S	S/A	1485.02
	Total			**160000.00**

ABSTRACT

Labor Component

Skilled Labor (Mason etc)	50MD	@Rs116	Rs 5,800
Ordinary labor	380MD	@ Rs 90	Rs 34,200
		Total	**Rs 40,000**

Material Component

Cement	200Bags	@Rs270/-	Rs 54,000
Sand	8 Truck	@Rs200/-	Rs 1,600
Aggregate	8 Trucks	@Rs 4000/-	Rs 32,000
Stone	7 truck	@Rs3000/-	Rs 21,000
Brick	2000 no	@Rs 5 /-	Rs 10,000
		Total	**Rs 1, 18,600/-**

Contingencies **Rs 1,400/-**

Total cost of the structure = Rs 40,000/-+Rs 1, 18,600/- +Rs 1,400=Rs 1, 60,000

5.2 Biological Measures

5.2.1 Contour cultivation

Contour cultivation is nothing but carrying out agricultural operations like planting, tillage and inter-cultivation very neatly on the contour.

Purpose

Contour cultivation reduces the velocity of overland flow and retards soil erosion. Crops like maize, sorghum, pearl millet which are normally grown in rows are ideally suited for contour cultivation. When contour cropping is adopted, the downward movement of soil and erosion by rains is reduced considerably

Location

Contour cultivation on terraces is practiced on a large scale for soil and water conservation. It has the capacity to retard runoff, increase infiltration of rainfall and conserve soil and water. In the field, guidelines are to be marked across the slope using a dumpy level or even a hand level. All subsequent agricultural operations are carried out making use of the guideline.

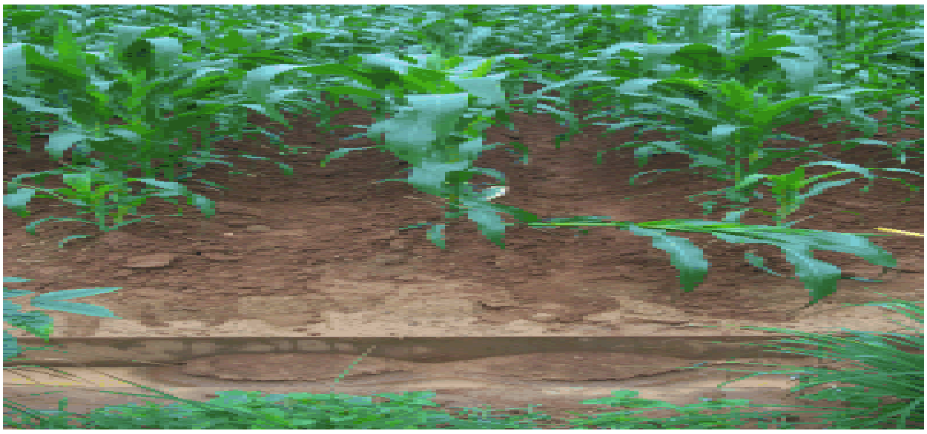


Fig.5.43 Contour cultivation and maize cropping

5.2.2 Strip cropping

Strip cropping is the growing of a soil-exposing and erosion-permitting crop in strips of suitable widths across the slopes on contour, alternating with strip of soil-protecting and erosion-resisting crop. The dense foliage of the erosion resistant crop prevents the rain from beating the soil surface directly. The alternate strip consists of close growing erosion resisting crop (close growing crops such as moong, urad, moth bean, groundnut, grasses) to erosion permitting crops like (row crops such as maize, jowar, bajra, cotton, etc). To achieve the best result, strip cropping is to be done in combination with other farming practices, like good crop rotation, contour cultivation etc. There are four types of strip cropping systems. They are: (1) contour strip cropping, (2) field strip cropping, (3) buffer strip cropping and (4) wind strip cropping.

Purpose

Strip cropping reduces soil erosion by reducing the effective slope length and facilitating absorption of rain water by the soil in undulating terrain. This is achieved by growing in strips and in an alternating fashion a minimum of two different crops along a slope. The crops usually differ substantially in their planting and harvesting date, thereby ensuring that at any time at least half of the slope is covered by vegetation. Strip cropping permits crop rotation, maximises the use of rainfall and allows use of modern machinery.

Location

This method is useful on regular slopes and with the soil of high infiltration rates.

Design

The strip width depends on the steepness of the slope. The following management practices are to be employed.

- In the designing of a strip cropping system, strip widths are fine tuned to accommodate equipment widths i.e. planters, sprayers and harvesters.
- An even number of passes along each strip will allow field operations to start and finish at the same end of the field.
- Grass headlands are an integral part of any strip cropping system. They provide access lanes to each strip and protect against erosion.

Types of strip cropping

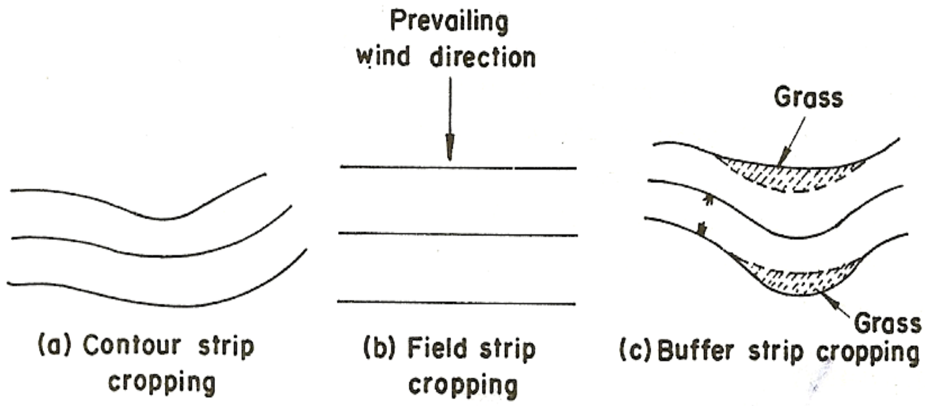


Fig. 5.44 Strip cropping

For laying out a strip cropping system, the following points should be taken into account:

- ✓ The width of the strip should be decided after taking into consideration soil, slope, rainfall and degree of erosion.
- ✓ For maximum benefit, the strip should conform to the contours, as far as possible.
- ✓ The strip cropping should fit into the existing and prevalent farming system.
- ✓ Regular rotation of the strips should be followed from year to year by shifting the erosion-resistant strip upward.
- ✓ The strip should be of sufficient width for economical farming.

Generally, both edges of the strips are preferred on the contour. Deviation of around 1% to 2% slope from the contour may be permitted. It is advisable to rotate the strip planting by showing a non-resistant crop, following an erosion-resistant crop and vice versa. i. Groundnut, moth bean and horse gram are the most efficient and suitable crop for checking erosion. ii. The normal seed-rates of leguminous crop, other than groundnut do not give sufficiently dense canopies to prevent rain drops from beating the soil surface. The seed rate should be treble. iii. The most effective width of the contour strips for cereals, such as jowar and bajra is 21.6m and for the intervening legume 7.2m.

5.2.3 Retention Ditches

Retention ditches are large ditches, designed to catch and retain all incoming runoff and hold it until it infiltrates into the ground. They are sometimes also called infiltration ditches.

Purpose

In semi-arid areas retention ditches are commonly used for trapping rainwater and for growing crops that have high water requirements, such as bananas. These crops can be planted in the ditch and thereby get increased supply of moisture.

Location

Retention ditches are particularly beneficial in semi-arid areas where non-availability of soil moisture is a problem. They should be constructed on flat or gentle sloping land and soils should be permeable, deep and stable. Retention ditches are not suitable on shallow soils or in areas prone to landslides.

Design

The design of retention ditches is usually determined by trial and error. Often the ditch is about 0.3-0.6 m deep and 0.5-1 m wide. In very stable soils it is possible to make the sides nearly vertical, but in most cases the top width of the ditch needs to be wider than the bottom width. The spacing between the ditches varies according to slope. On flat land the ditches are usually spaced at 20 m and have close ends so that all rainwater is trapped. On sloping land the spacing is kept between 10-15m and the ditches may have open ends so that excess water can exit. Retention ditches can also be used for the purpose of harvesting water from roads or tracks. The location of such ditches will be specific to the site. When constructing the ditches, the soil is thrown to the lower side to form an embankment that prevents soil from falling back in. In order to stabilize the ,rass can be planted on top of the embankment.

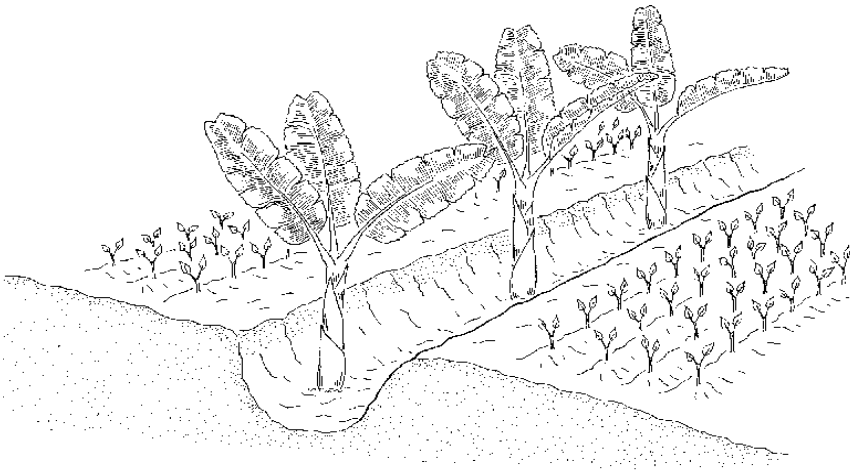


Fig.5.45 Retention ditch with banana plantation

5.2.4 Contour Farming

Contour farming means that field activities such as ploughing, furrowing and planting are carried out along contours, and not up and down the slope.

Purpose

The purpose is to prevent surface runoff down slope and encourage infiltration of water into the soil. Structures and plants are established along the contour lines following the configuration on the ground. Contour farming may involve construction of soil traps, bench terraces or bunds, or the establishment of hedgerows.

Location

Contour ploughing is successful on slopes with a gradient of less than 10%. On steeper slopes contour ploughing should be combined with other measures, such as terracing or strip cropping. The fields should have an even slope, since on very irregular slopes it is too time-consuming to follow the contours when ploughing.

Construction

The first step in contour farming is to determine a contour guide line. All subsequent water conservation measures are related to the contour guide lines. Contour ploughing ensures that rainfall and runoff are spread evenly over a field by making furrows parallel to the contours. If ploughing is not done along the contour, water will run down the furrows and erode soils when it rains. Small dams made of earth can be made at regular intervals in the furrows, to trap rainwater and prevent it from flowing along the contour; these are known as tied ridges.

Fig. 5.46 Ploughing and furrowing carried out on the contour

5.2.5 Contour Furrows

Contour furrows are, small earthen banks, with a furrow on the higher side which collects runoff from the catchment area between the ridges.

Purpose

The catchment area is left uncultivated and clear of vegetation to maximize runoff. Crops can be planted on the sides of the furrow and on the ridges. Plants with high water requirements, such as beans and peas are usually planted on the higher side of the furrow, and cereal crops such as maize and millet are usually planted on the ridges.

Location

Contour furrows are suitable for areas with annual average rainfall amounts of 350-700mm. The topography should be even to facilitate an even distribution of the water. Contour furrows are most suitable on gentle slopes of about 0.5-3%. Soils should be fairly light. On heavier clayey soils these are less effective because of the lower infiltration rate.

Design

The distance between the ridges varies between 1 and 2 m depending on the slope gradient, the size of the catchment area desired and available rainfall. The drier is the area, the larger is the distance between the furrows. Small cross–ties in the furrows can be constructed at regular intervals and at right angle to the ridges to prevent flow of runoff and to ensure an evenly distribution of captured water.

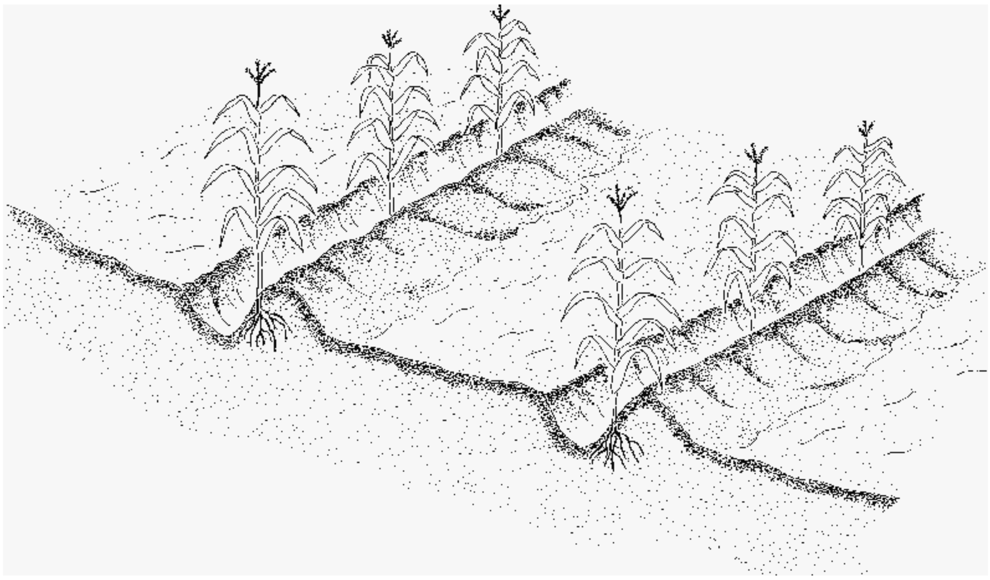


Fig : 5.47 Contour furrows

5.2.6 Broad Bed and Furrows

The Broad Bed and Furrow system has been mainly introduced by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) in India. Broad beds of 100 cm width are prepared and 50 cm furrows are provided in between two beds.

Purpose

To encourage moisture storage in the soil profile to support plants through mid-season or late-season spells of drought and to provide a better drained and more easily cultivated soil in the beds. Double cropping by means of inter-cropping or sequential cropping is also possible.

Location

The BBF system is particularly suitable for the vertisols. The technique works best on deep black soils in areas with dependable rainfall averaging 750 mm or more. It has not been as productive in areas of less dependable rainfall, or on alfisols or shallower black soils - although in the later cases more productivity is achieved than with traditional farming methods. The broad bed and furrow system is laid within the field boundaries. The land levels taken and it is laid using either animal drawn or tractor drawn ridgers

Design

The recommended system consists of broad beds about 100 cm wide separated by sunken furrows about 50 cm wide. The preferred slope along the furrow is between 0.4 and 0.8 per cent on vertisols (heavy black soil). Two, three, or four rows of crop can be grown on the broad bed, and the bed width and crop geometry can be varied to suit the cultivation and planting equipment.

Construction

BBF system is constructed by using a tropiculter, developed by ICRISAT. The equipment is run by a pair of bullocks. In absence of such equipment the BBF can be constructed by using Phowrah or bund former.

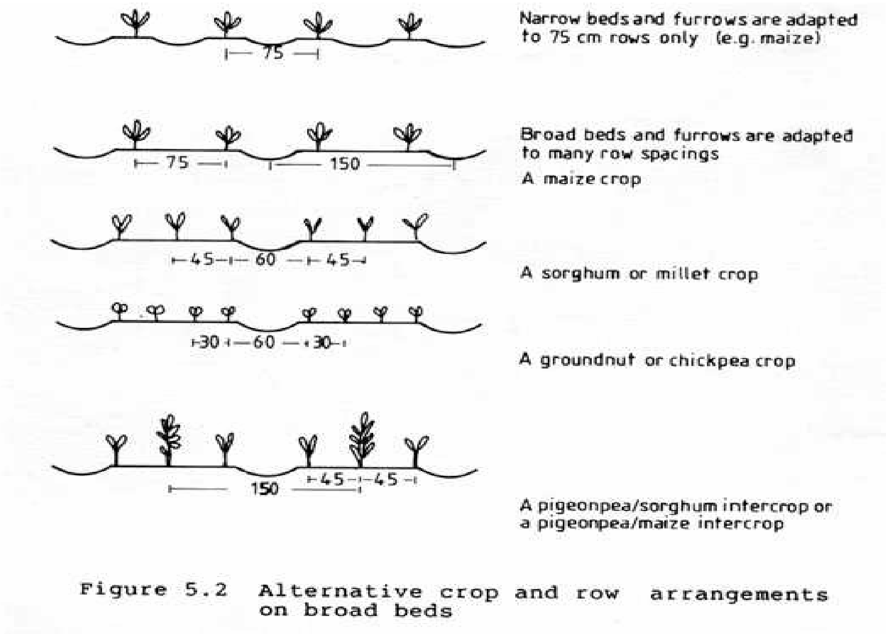


Fig: 5.48 Alternative crop and row arrangements on broad beds

5.2.7 Grass Strips

Grass strips are cheap alternatives to terracing. Grass is planted in dense strips, up to a meter wide, along the contour.

Purpose

Grass strips create barriers that minimize soil erosion and runoff. Silt builds up in front of the strip, and within time benches are formed.

Location

Grass strips are suitable in areas where there is a need of fodder or mulch. If farmers do not have livestock, they have little incentive to plant grasses. Grass strips are not applicable on steep slopes and in very dry areas since grasses might not withstand drought.

Design

The spacing of the strips depends on the slope of the land. On gentle sloping land the strips should have a wide spacing (20-30 m). On steep land the spacing needs to be less (10-1 5m). Grass strips can be planted along ditches to stabilize them, or on the rises of bench terraces to prevent erosion. The grass needs to be trimmed regularly, to prevent them from shading and spreading to the cropped area between strips. The cut grass can be used as livestock fodder or as mulch.

Materials

Many locally available grass varieties can be used. Vetiver grass is a good grass to reduce erosion and resists drought well. Other examples of grasses that can be used are Napier, Guinea and Guatemala grass.

Maintenance

If not properly maintained the grass might spread and become a weed problem. Regular pruning will be necessary to maintain the strips.

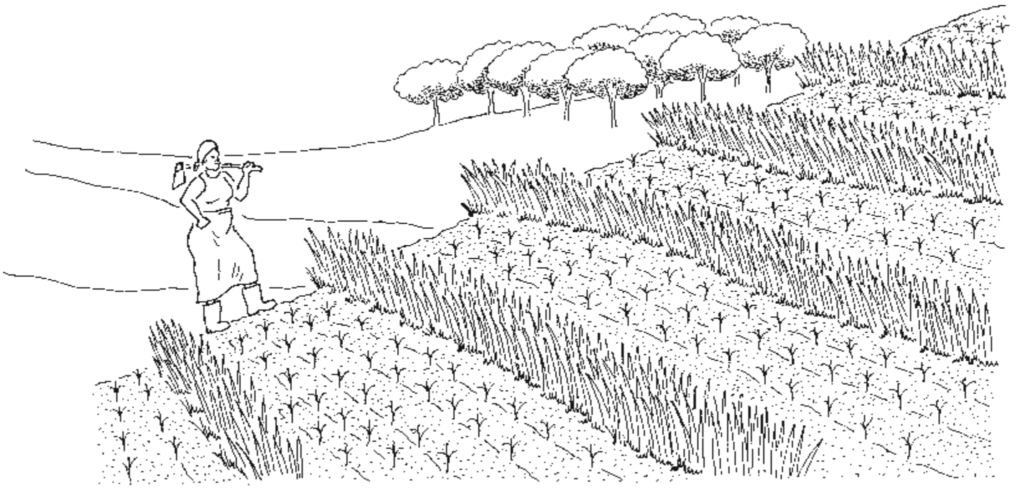


Fig :5.49 Grass strips along the contour

5.2.8 Planting Pits

Planting pits are the simplest form of water harvesting. They have proved successful especially for growing sorghum and millet in areas with minimal rainfall.

Purpose

The purpose is to trap runoff, increase soil moisture status and reduce erosion.

Location

Planting pits have been proven successful in areas with annual rainfall of 200-750 mm. They are particularly useful for rehabilitating barren, crusted soils and clay slopes, where infiltration is limited and tillage is difficult. The slope should be gentle (below 2%) and soils should be fairly deep. Where soils are already shallow, they become even shallower when planting pits are dug. In those cases farmers should not plant in the pit, but in top of the ridge of excavated soils in order to maximize rooting depth.

Design

Small holes are dug at a spacing of about 1 m. During rainstorms the planting pits catch runoff and concentrate it around the growing plant. Crops are planted in the pits and thereby benefit from the increased moisture availability in the pits. Compost or manure is placed in the pits before planting to improve soil fertility. It is not necessary to follow the contour when constructing pits. Dimensions of the pits vary according to the type of soil in which they are dug. Usually they are 10-30 cm in diameter and 5-15 cm deep. In the second year, farmers may sow into the existing holes or, if spacing of the pits is large, they may dig new ones in-between the existing ones.

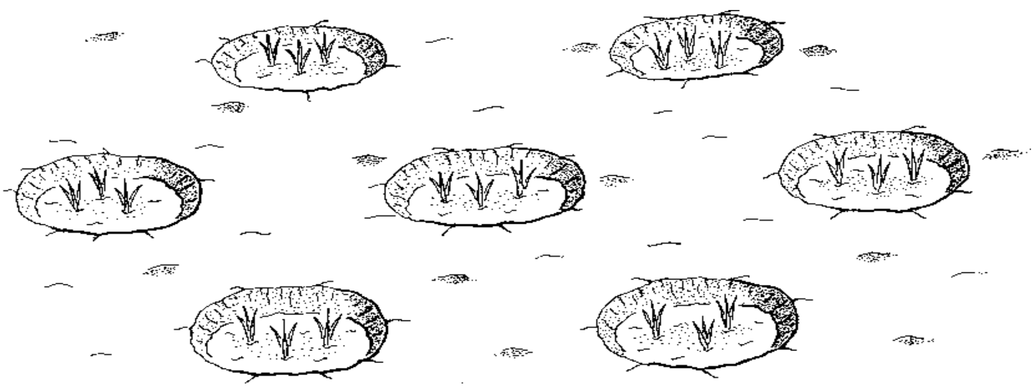


Fig5.50 Planting pits

5.2.9 Mulching

Mulching is done by covering the soil between crop rows or around trees or vegetables with cut grass, crop residues, straw or other plant material. This practice help to retain soil moisture by limiting evaporation prevents weed growth and enhances soil structure.

Purpose

Mulching is used in areas subject to drought and weed infestation. The mulch layer is rougher than the surface of the soil and thus inhibits runoff. The layer of plant material protects the soil from splash erosion and limits the formation of crust.

Location

Areas with limited rainfall usually respond very well to mulching. Mulching is not applicable in wet conditions. The fields should have good drainage

Design

The optimal proportion of soil cover ranges between 30% and 70 %. The choice of mulch depends on locally available materials. In alley-cropping systems, hedgerow biomass is often used as mulch; another strategy is to leave crop residues, such as maize stalks on the ground after harvesting. Mulch can be spread on a seedbed or around planting holes. It can also be applied in strips. Large pieces of crop residues should be cut into smaller pieces before application. The mulch may be covered with a layer of soil to protect it against wind.

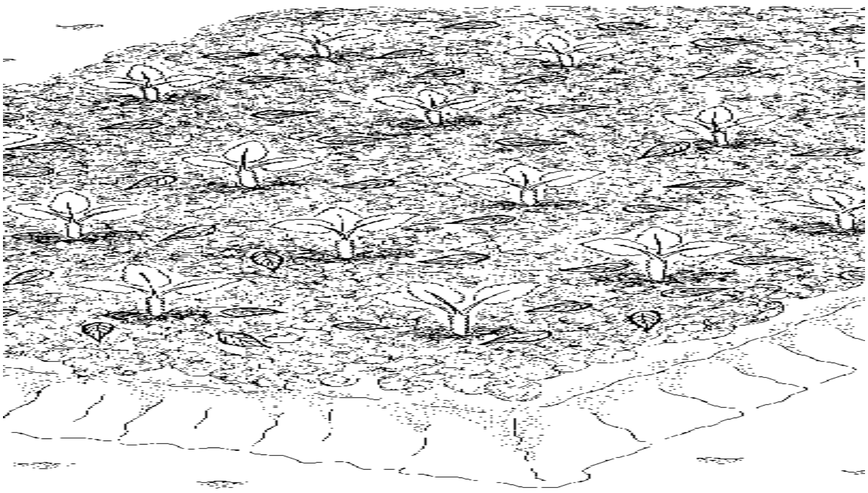


Fig.5.51 Mulching

5.2.10 Cover Crops

Cover crops are usually creeping legumes which cover the ground surface between widely spaced perennial crops such as fruit trees and coffee, or between rows of grain crops such as maize. Often cover crops are combined with mulching.

Purpose

Cover crops are grown to protect the soil from erosion and to improve soil fertility. They protect the soil from splashing raindrops and too much of heat from the sun.

Location

Cover crops are suitable in dry areas, with annual rainfall of more than 500 mm. Cover crops are good alternative source of mulch, especially useful in semi-arid lands where crop residue are important animal feed.

Materials

Most of the plants used as ground cover are legumes, such as different varieties of beans and peas. Pigeon peas and other crops with strong tap roots and longer growing season than maize and beans make good mix and can be used to break hard-pans in semi-arid areas. Over 100 species of cover crops are in use around the world. For the cover crop to compete with the main crop as little as possible the cover crop should be of a low yielding variety.

Planting time

Cover crops should be planted as soon as possible after tillage to be fully beneficial. This can be done at the same time as sowing the main crop, or after the main crop has established, to avoid competition at crop nutrition level.

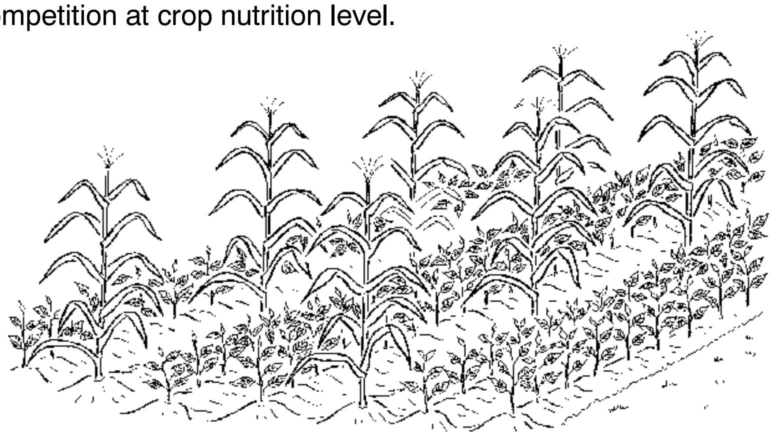


Fig.5.52 Cover crop grown to cover the soil in between maize rows

5.2.11 Conservation Tillage

Conservation Tillage refers to the practice in which soil manipulation is reduced to a minimum. This practice preserves soil structure and, increases soil moisture availability and reduces runoff and erosion.

Purpose

To reduce labour and farm power requirements, costs, energy requirement and increase crop yield due to less direct impact of raindrops on bare soil and increased soil moisture status.

Location

Conservation tillage takes various forms, depending on the prevailing soil and farming conditions. When introducing conservation tillage, it is important to focus on the needs of the specific farming conditions. Each farmer's plot has specific soil characteristics and management needs.

Methods

No soil turning includes a *No-till* subsystem where the land is prepared without the use of a conventional mould board plough, or a *Minimum-tillage* sub-system where tine based implements are used to open soil to a minimum extent, only to make the insertion of seed possible. Minimum tillage may also be applied to break the hard pans, and where access to equipment is possible, the operation can be advanced to simultaneously insert seed (and even fertiliser) into the soil while breaking the hard pan in the same single pass. The principle is also applicable for manual (hand hoe) operations where sharp heavy hoes are applied to till only the spots where seeds are to be placed. This operation is referred to as *pitting* or *pot-holing.*

5.2.12 Vegetative Barrier

Vegetative barriers inhibit surface runoff, slowing and ponding water and capturing and preventing sediment from flowing downhill (figure 3.50). Vegetative barriers have potential to not only reduce erosion but can enhance vegetated filter strips in the uptake of nutrients.

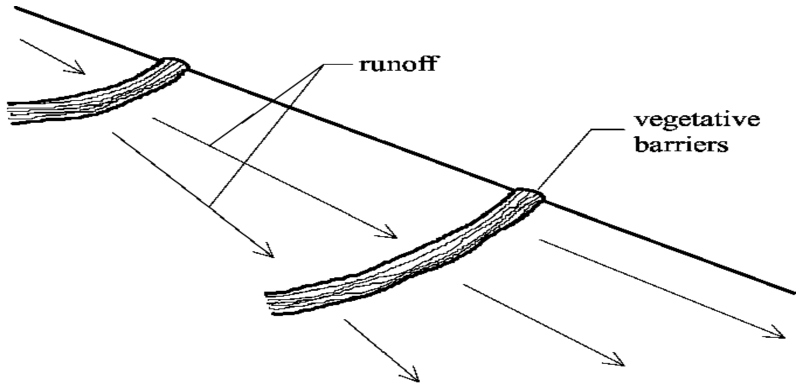


Fig:5.53 Vegetative Barrier

Purpose

Vegetative barriers are narrow strips of vegetation which are created primarily to slow runoff, capture sediment and resist gully development. A vegetative barrier reduces water velocities and establishes a broad uniform vegetative surface for the uptake of nutrients.

Location

Vegetative barriers can be used to eroding sites on areas of cropland, pastureland, feedlots, mined land, gullies, and ditches. This practice should be used in conjunction with other conservation practices in a conservation management system.

Fig.5.54 Vegetative Barrier

Materials

Various types of vegetation can be used in vegetative barriers keeping in view the following requirements.

- Perennial with stiff stems that remain intact year-round; not invasive.
- Tolerant to both dry and wet soil conditions.
- Ability to emerge through several inches of sediment or to resume growth from buried stem nodes and with rhizomatous or stoloniferous growth characteristics.

Vetiver as a dual purpose grass is suitable for this. However, local grasses can be used as per availability. *Cynadon dactylon*, *Paspalam dilatum*, *Agave, Ipomoea imperata*, *Vitex negundu* etc are found suitable.

Methods

Vegetative barriers can be established either vegetatively or from seed. Vegetatively propagated barriers take less time to establish than seeding. Seeding requires less material and labor and, therefore, is less expensive. Because of the number of row feet involved in terrace applications, seeding is recommended. For critical flow areas, the use of live plants is recommended. Barriers established vegetatively should be planted with close spacing to ensure a functional hedge in one growing season. Although planting a continuous sod strip would be best, planting a single row of slips (bare-root seedlings or greenhouse-grown transplants) at 6-inch spacing can create a functional hedge in two years. Even where gaps between transplanted clumps are still distinguishable, crop residue bridges these gaps and makes the hedge effective in slowing runoff and trapping sediment. In concentrated flow areas, a double row of continuous sod strips, or rows planted 12 to 18 inches apart with a 6- to 8-inch spacing of 4-inch-diameter clumps is recommended.

Seed should be sown, either in a strip at least 3 feet wide or in rows, (a minimum of three rows is recommended) with at least one seed every inch. Seeds should be placed at optimum depth, and the seedbed should be packed after seeding. In most cases this mandates the use of a drill to place the seed at the precise rate and recommended depth. Installing straw bales may enhance establishment by plants or seed; burlap silt fences or fiber rolls should be placed immediately down slope of the barrier location in concentrated flow areas. This reduces scour and promotes water conservation for the young plants.

Design and lay-out

The *vertical interval* (VI), or vertical fall between successive barrier centers, sets the limit on hedge design spacing. The maximum vertical interval for this purpose is 6 feet or less if the spacing calculated by formulas for terraces yield smaller values. Tillage not only creates conditions conducive to water erosion but also moves soil directly down slope. Where conventional tillage is used, slope gradients between barriers become flatter and more uniform over time, and contour lines gradually align with the barriers. Some tillage operations move soil directly into vegetative barriers. Berms formed in this way may divert runoff along the barriers in the same way that terraces redirect water. This diversion of runoff reduces erosion between barriers, but also results in increased flow of water and wetness where barriers cross low spots in a field. In these low areas, concentrated runoff is retarded and dispersed as it passes through the vegetative barriers. Gradients along barriers should be 0.6 percent or less except where the vegetative barriers cross concentrated flow areas. Steeper gradients may exist for a distance of 100 feet on either side of the concentrated flow area. Where the gradient along the crop row is too steep, barriers serve no purpose.

Seeding

The appropriate perennial grass species for seeding vegetative barriers are the ones which produces abundant stiff erect stems that are resistant to water flow and tolerant of sediment deposition. They must also have the following characteristics: (a) long lived and manageable as a narrow strip; (b) non-weedy and not too competitive with adjacent cultivated crops; and (c) relatively tolerant to defoliation if crop residues are grazed.

According to the permissible velocity the type of vegetation is decided as follows:

Permissible velocity	*Vegetation needed*
Up to 0.9	Sparse
0.9-1.2	Vegetation by seedling
1.2-1.5	Dense sod
1.5-1.8	Well established, good quality sod
1.8-2.1	As above, but excellent

Management of barriers

Management of barriers is simple. If residue becomes so thick that it starts to smother the barriers, it can be either burned or mowed. Because of the height difference above and below well-established barriers, it may be necessary to use a sickle bar mower rather than a brush hog. Burning will reduce the barrier's effectiveness temporarily. Tillage or use of herbicides in the crop field adjacent to the barrier will prevent barriers from spreading. If openings are seen within barrier, it can be repaired simply by planting a few plants in the gap.

5.2.13 In situ Rain Water Conservation

(i) Ploughing and planting on flat land

The shaping of small depressions created during the ploughing operation has the objective of impeding surface runoff of the rainwater so that it remains stored in the soil and so available to the crop for a longer period.

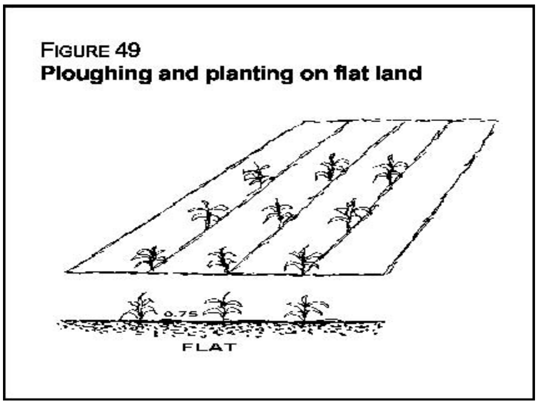


Fig: 5.55 Ploughing and planting on flat land

(ii) Ridging after planting

Ridging after planting is a rainwater harvesting technique that consists of ploughing and sowing the flat area followed by ridging between the crop rows and ridging up again a second and third time according to the crop, using either animal drawn or tractor operated ridgers . When crops such as maize and sorghum are well developed, it becomes difficult to use the toolbar equipped with more than a single ridger body. In such situation use of single animal one-row ridger along the row is the solution.

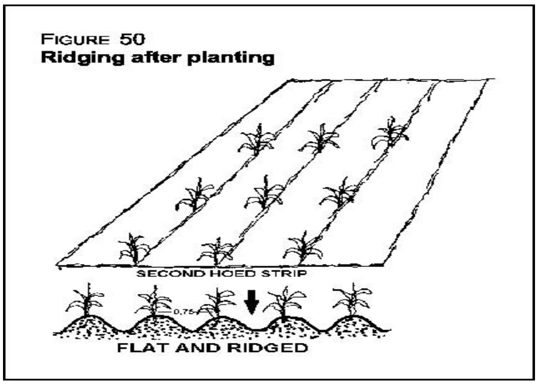


Fig: 5.56 Ridging after planting

(iii) Tied ridges

It consists of ploughing and ridging at 0.75 m row spacing, followed by an operation to tie the ridges with small mounds along each furrow so as to impede the runoff of the rainwater. Tying the ridges is done with an implement designed for use with animal traction and should be undertaken before planting on the ridges.

The mounds are made at intervals between two and three metres by way of controlling the implement. Care is to be taken to leave them at a height that is less than that of the main ridge to be used for planting (Figure 54). For this hoeing or weeding is done by using a ridger between the rows and making a second pass with a hand hoe between the plants.

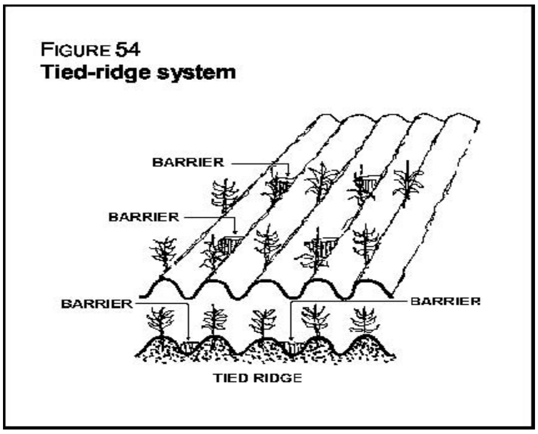


Fig:5.57 Tied ridges

(iv) Partial ploughing

In situ capture of rainwater through partial ploughing consists of two successive passes with a reversible animal-drawn plough, leaving a distance of 0.60 m from each second furrows. In this manner, the work time is reduced by half due to the ploughing being accomplished in strips. The unploughed land between the strips is used for harvesting the rainwater, leading it to the seed zone. Using a punch planter sowing is done in the second furrow with a punch planter into the second furrow left by the plough in each strip.

FIGURE 55
Strip ploughing system

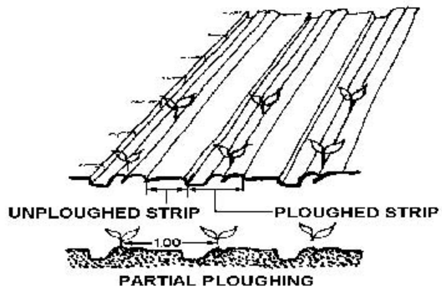


Fig.5.58 Strip Ploughing

5.3.1 Stabilising stream bank by vegetation

Purpose

The purpose of this is to prevent nala banks from collapsing and to maintain natural course so as to avoid the water from damaging the adjoining lands.

Location

Where the soil is more prone to collapse or where the nala bunds and changes direction and makes the bank vulnerable to damage.

Method

Stream bank erosion can be effectively controlled by vegetation. The planting can be taken up in a phased manner in three years.

First year:

- Survey and demarcation
- Raising green fence around the area
- Digging of pits inside the plantation block
- Preparation of nursery for raising seedlings

Second year:

- Refilling the pits, application of fertilizer and manure
- Planting of seedlings
- Maintenance of live fence and gap filling
- Watch and ward

Third year:

- Maintenance and repair of live fence
- Gap filling of main plantation
- Weeding , manuring and plant protection
- Watch and ward

Fig.5.59 Vegetative cover on stream banks

5.3.2 Protection of stream banks and slopes

Slope protection by sodding or turfing

- Cover the slopes with sodding or turfing with local grasses
- Establish shrubs or creepers
- Bushes like *vitex, ipomea* and *lantana* can be planted
- Maintain the slopes at 1 ½ : 1

Protection by revetment

- Adopt dry stone packing during summer in small streams
- The toe wall should be at least 1 m to 1.2 m below the bed of the stream and connected to a stone paving
- The stone paving should not be less than 60 cm in thickness and well packed

Log Toes

Utilize a large log, or group of logs to protect the toe of a stream-bank from erosion. A log toe is a natural alternative to a rock toe and is potential habitat for fish or vegetation. Log toes are typically used in conjunction with other vegetative controls for erosion protection on areas higher up the stream-bank.

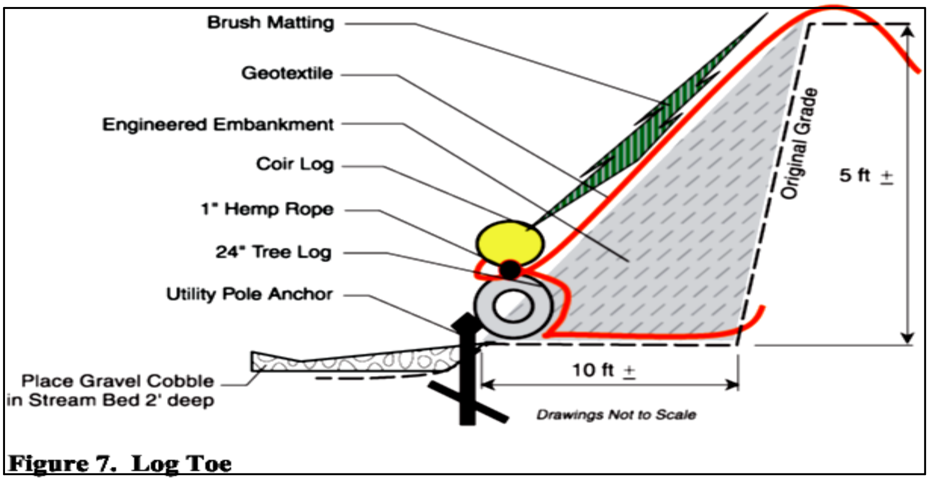


Fig. 5.60 Log Toes

Rock toes and armoring

Large boulders are used to resist erosive forces at the toe and along stream-banks. The expected stream velocity determines the size of the boulders. Rock toes do not typically provide exceptional habitat for species and vegetation. Rock toes and armoring are used in areas where log structures may lead to bank erosion. The rock toes and armoring should incorporate gravel backing with geotextile fabrics to prevent erosion of bank material behind the armoring. Whenever possible, rock toes and armoring should be used in conjunction with vegetative erosion control measures for areas higher up the stream-bank.

Fig: 5.61 Rough Construction Detail for a Rock Toe

Brush mattresses and wattling

Wattles are long bundles of plant stems, straw, or coir that are bound using twine and are anchored in shallow trenches with wooden stakes. Stakes are then partially driven into the bank on approximately three-foot centers in areas that are to be covered by the brush mattress. The brush mattress, consisting of willow branches or other appropriate woody brush, is then placed over the staked area. Finally, cross branches are placed over the mattress and are tied to the stakes using twine.

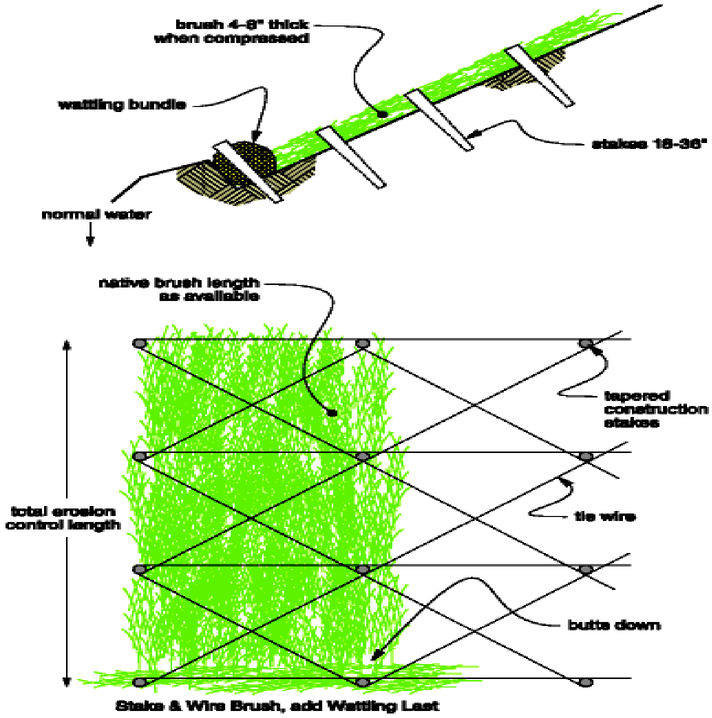


Figure 11. Brush Mattress and Wattling

Fig. 5.62 Brush Mattress and Wattling

Table:5 .11 Tentative estimate for stream bank erosion control

Stream bank erosion controlwork/1 unit				
Branching	3 sq m	16.8	90	1512
Cleaning	12 sq m	54	90	4860
Packing	3 cum	12	90	1080
Skilled	3 sq m	3.8	116	440.80
Cleaning	12 sq m	4.2	116	487.20
Packing	3 cum	2.4	116	278.40
LA Material	48m	0.1 unit		832
			Total	**9490.40**

Chapter- 6
Alternate Soil Management Technologies

6.1 Introduction

There are various information sources on new soil management technologies. It is recommended to seek published information on technologies that have been investigated in the same recommendation domain where the work is being undertaken, and which have been evaluated and validated by the farmers in their own properties. In this manner, one may have confidence in the suitability of these technologies for the conditions under which they were evaluated. The farmers would test the new technology on a small part of the farm and compare it with their normal practice. The tests may be made without plot replications but if possible, the total number of tests should be sufficient to permit statistical analysis of the results as if the tests on different farmers' fields were true replications.

A production system is composed of various components such as land preparation, tillage, crops and their rotation, seeding, possibly application of herbicides and pesticides, fertilization, harvest, grain storage, residue management, machinery, implements and equipment, systems for drainage, irrigation and soil conservation. If a new technology requires changes to some of these components, this will often entail changes to other components. For instance, crop rotation systems become more important when zero tillage systems are introduced as the crop residues remain on the soil surface. This may stimulate the survival and proliferation of certain diseases and pests in the soil that would not occur in a conventional tillage system. It should not be expected that from one day to the next, the farmer will completely change the production and soil management systems which he or she has practised for many years. The process of change should be gradual, in stages, and at a rate that is acceptable to the farmer.

6.2 Socio-economic factors

Both soil management and production systems are influenced by socio-economic factors. It follows that the socio-economic limitations should be taken into account when selecting soil management systems so that they are specially and economically acceptable. The socio-economic limitations that should be considered include the following:

- ***Farm size and production levels***
  The farm size and the level of production influence the profitability and so have a great influence over the most appropriate level of technology to be introduced. The scale of production can also prove to be a limiting factor for introducing certain management systems with high installation costs such as irrigation and drainage systems.

- ***Financial resources, prices, costs and availability of inputs and credit***
  All these factors influence the profitability of the existing management systems and the possibilities to successfully introduce new production systems. Often, systems which appear technically appropriate are not feasible due to the shortage of economic resources of the farmer, difficulty to obtain inputs on time, or uncertain crop prices. Many farmers do not have easy access to institutional credit. Alternatively, high interest rates combined with short payback period forces the farmers to sell his entire crop when the market is saturated and prices are very low. In this way there are difficulties for the introduction of new soil management systems.

- ***Marketing, access, transport and crop storage***
  The decisions regarding the introduction of new production systems are guided by above factors at farms. It is only worthwhile for a farmer to sow a certain crop if communication to

the market is available. For those farmers living in isolated places where the roads are in a poor state during the harvest season, it would not be advisable to introduce perishable crops. The feasibility to introduce new production and soil management systems may also be influenced by whether or not the farmer has options to store the crop.

- ***Manual labour***

There is often shortage of manual labour at critical times such as during planting, the first weeding operation and harvest, which influences the feasibility of introducing a new production system. For small farmers, the availability of manual labour can vary considerably from one family to another, depending on the family size.

- ***Farmer organizations***

The production systems can be more profitable in situations where farmers are organized into groups. This is because they will then be able to purchase the necessary inputs and sell their crops in a co-operative manner at better prices, and will not remain at the mercy of intermediary traders. For the development of irrigation systems it is necessary to organize user groups, particularly for rational water use.

- ***Land tenure***

Land tenure problems have considerable influence on the soil management systems. If the land upon which the crops are grown is rented, a farmer would be unwilling to contemplate changes or technologies that offer benefits over a longer period than the rental period. Frequently, this leads to annual production systems that are not sustainable because many technologies which promote sustainability, such as soil conservation practices, only yield benefits over the long term.

- ***Technical assistance***

Generally, the successful farmers are those who receive the greatest direct and personal contact from extension workers. The successful development of new agricultural practices requires the presence of government or non-governmental institutions that are skilful in techniques of technology transfer. The progressive farmers may be trained to transfer the new technologies to other farmers.

6.3 Environmental factors

Soil management systems must not cause negative impacts on the environment, which includes human and animal life, land, water and the atmosphere. The use of toxic pesticides that seriously affect health, even to the extent of causing mortality amongst humans and livestock and which contaminates the soil causing harm to the population, diversity and activity of soil fauna and micro-organisms should be avoided. In addition, one should avoid management systems that lead to the contamination of waters through leaching of pesticides and nutrients such as nitrates due to excessive applications of nitrogen, or through contaminated runoff water and soil flowing into the rivers.

It is important to consider the impact of soil management systems not only in the agricultural region where they are applied, but also in downstream areas towards the sea. For example, the loss of nitrates due to the excessive application of nitrogenous fertilizer in agricultural areas can cause toxic concentrations of nitrates in the drinking water supplies of downstream populations.

6.4 “Problem – Solution” Relationship Factors

Soil management systems should be developed from the presently used systems by the farmers. These depend upon the characteristics of the soil, climate, land use potentials and very importantly, on the markets, prices, financial resources, and family needs of the farmer. The economic and market factors are important to farmers who wish to diversify their production so as to generate increased income and improve their living standards., The farmer together with the extension worker must identify the factors that most limit the productivity, profitability and sustainability of the production systems while selecting the technology. These include edaphological, climatic, environmental and socio-economic factors. The possible limitations, causes and solutions are presented in the following Table.

Limitation	Cause	Possible solutions
Poor crop germination	Lack of soil moisture	Leave crop residues Sow a cover crop Conservation tillage; zero tillage Application of mulch Wind breaks Deep seeding for dryland farming
	Excess moisture	Sub-soiling Drainage canals Ridge tillage Cut-off drains Levelling
	Excess temperature	Leave crop residues Sow a cover crop Application of mulch Conservation tillage; zero tillage Ridge tillage
	Low temperature	Leave crop residues Sow a cover crop Application of mulch Conservation tillage; zero tillage Ridge tillage
	Large & hard clay	Remove surface residues Tillage with clod-breaking rollers Tillage with a disc harrow or rotary cultivator Fallow the land
Poor crop emergence	Crusting	Leave crop residue Sow cover crop Provide a mulch Zero tillage Increase seeding density Reduce seed depth
	Hard setting layers	Tined tillage with cultivator Sub-soiling
Restricted root growth	Severe compaction	Sub-soiling Tined tillage
	Incipient compaction	Tined tillage
	Hard setting layers	Deep tillage
	Excess moisture	Provide drainage
	Lack of phosphorus	Apply P Placement of P
Low fertility and production	Nutrient deficiency	Fertiliser application Timely and split application Incorporation of GM Crop rotation Apply org. manure
	Less organic manure	Rotate with legume Conservation tillage Sow a cover crop Incorporate GM Apply FYM/Compost
	Leaching	Apply lime Rotate with deep rooted crop Perennial crop/Alley crop
	Al & Mn toxicity	Apply lime Apply gypsum

	Weeds and pests	Incorporate org. manure Rotate crop Use IPM practice
Edaphic and Climatic factors		
(i)Lack of moisture	Evaporation and low infiltration	Leave crop residues Sow cover crop Apply organic matter
	Low moisture retention	Off season tillage Incorporate organic manure Sow cover crop Use soil conservation measures
(ii)Excess moisture	High water table or impermeable layer	Raised bed cultivation Provide drainage Sub-soiling Change the crops
(iii)Low biological activity	Shortage of residues	Legume cropping Apply mulches Sow cover crop Apply organic manure Adopt rotation of crops
	Exhaustive soil	Leave crop residue Apply mulch Apply organic matter Sow intercrop/ relay crop
Water erosion	Lack of soil cover and low infiltration rate	Minimum tillage Avoid straw burning Minimize grazing Increase chemical fertility of soil Use varieties with higher biomass Control weeds
	Lack of surface roughness	Use varieties and species of high biomass Control weeds with Contour tillage and seeding Sowing in strips Ploughing after the rains and sowing in strips
	Excess runoff	Sow live vegetative barriers Alley cropping Stone walls Basins Hillside ditches Diversion drains Bench terraces Orchard terraces Individual terraces
High production cost	High labour and input cost	Use seed drill Adopt IPM/INM practices Rotate crops Sow legume crops Use organic manure Apply economic dose of fertilizer Use bio-fertilisers Timeliness of fertilizer application
Environmental contamination	Toxic pesticides	Use less toxic chemicals Use bio-pesticides Adopt IPM
	Loss of liquid fertiliser	Place fertilizer Split application

		Sow legume crops Increase organic manure content Use compost

6.5 Poor crop germination conditions

Poor germination can be attributable to poor seed quality, particularly if the farmer uses his own seed. It may also be due to lack or excess of soil moisture, temperatures that are either too high or too low, or degraded soil structure in the germination zone. Sometimes, the low productivity of subsistence farmers is mainly due to a low plant population.

Possible solutions

i. Lack of soil moisture

If lack of soil moisture is the main limiting factor, possible solutions are to leave crop residues or to apply mulch to the surface to reduce the evaporation. Another possibility is to sow a cover crop during the preceding season and to mow it at least several weeks before sowing the main crop. This provides a mulch cover reducing moisture losses through evaporation. Leaving a straw cover or a killed cover crop on the surface at the time of sowing implies the adoption of systems of conservation tillage, preferably zero tillage, which requires the acquisition of machinery or equipment for direct drilling. Another solution in well-structured soils is to sow in the dry soil before the rains commence, placing the seed at a greater depth so that it only germinates when there have been sufficient rains to raise adequate soil moisture in the seed zone to allow good germination.

ii. Excessive soil moisture

When excess soil moisture is a problem, drainage ditches and canals should be installed. Deep tillage with a subsoiler used transversely to the line of the drainage canals will ease the drainage. Forming raised beds and ridges and planting on the ridge will serve to raise the rooting zone above the saturated soil horizon. If the excessive soil moisture is due to the entry of runoff water from adjacent higher areas, it will only be necessary to make a cut-off drain to prevent the runoff from entering the field. Irregular topography with drainage problem should be leveled.

iii. Excessively high soil temperatures

If the poor germination is attributed to excessively high soil temperatures, a straw cover or a killed cover crop can be given on the surface to lower the temperatures. Conservation tillage may also be practiced in such situations.

iv. .Excessively low soil temperatures

When the poor germination is due to excessively cold soil temperatures, forming ridges is a valid option, sowing on the ridges that are devoid of a cover of residues. Another alternative, which does not constitute a conservation tillage system, is to till the soil leaving no surface residues. Both these practices help to avoid crop residues remaining over the seeding zone, which would lower the soil temperature.

v. Large and hard clay aggregates

Poor germination is a problem at times due to large and hard clay aggregates. These aggregates normally break down very slowly under the action of the rain. As a general guide, in conventional tillage systems where aggregates are exposed to the rain, the land preparation should leave clods that are about 5 cm in diameter in clay soils. Later, with onset of the rain, the size of the aggregates will diminish until they reach an optimum size for germination, which varies from 0.5 to 8 mm in diameter. Over the long term, the structure of these soils can be improved by leaving the land fallow under pasture for several years. The dense network of the grass roots causes the formation of smaller soil aggregates. However, the beneficial effects only last a short time after cultivating the soil again with conventional tillage systems, perhaps as little as a year. If there are no problems of deficient drainage in these soils, it would be better to introduce zero tillage after the fallow period so as to prolong the beneficial effects.

6.6 Adverse conditions for emergence

Causes of poor plant emergence can be attributed to the formation of surface crusts, particularly in soils with a high content of fine sand, or to the formation of a massive, compacted and hard structure in hard setting soils when they dry out after a heavy rainfall. The texture of hard setting soils varies from light to medium.

Possible solutions

i. For surface crusts

Crust formation can be avoided by leaving crop residues on the surface, sowing a cover crop, or by applying mulch or organic manure over the soil surface. These practices protect the soil aggregates from the energy of the rain droplets, the aggregates do not break up and crusts do not form. In addition, the vegetative cover reduces evaporation and so maintains higher moisture content in the topsoil, which reduces soil strength. However, the maintenance of a vegetative cover over the surface implies the use of conservation tillage techniques and availability of the respective machinery.

Another solution is making narrow ridges and planting on top of these. Although the crusts still form, their resistance is much less on the crest of the ridge and tension cracks are frequently formed which eases the emergence of the seedlings.

In order to decrease the force that the seedlings need to break through the crust, seeds can be sown at a higher density or a shallower depth. These practices will increase the probability of higher emergence.

ii. For hard setting layers

A temporary solution to the problem of hard setting soils is through tillage to loosen the soil before sowing. In these soils it is practically impossible to undertake tillage when the soil is dry, even with a disc plough as the discs will not penetrate. The soil can be loosened when it is friable using a pass of a disc plough followed by one or two harrowings, but this type of tillage will leave the soil bare and very susceptible to erosion and renewed crust formation. Loosening the massive hardened layers will not prevent the soils from again becoming compacted when they dry out following a heavy rainfall, so restricting the seedlings.

6.7 Adverse conditions for root development

Conditions that are prejudicial for the growth and functioning of roots include soil compaction due to tillage or natural processes, hard setting soils, large hard aggregates that cannot be penetrated by roots, deficit or excess of soil moisture, lack of phosphorus or the presence of toxic elements such as aluminium or manganese.

Possible solutions

i. For severe compaction (i.e. recuperation)

Two crossed passes with a subsoiler when the soil is dry are necessary to loosen compacted layers. The tines should penetrate to a depth of about 1.5 times the depth of the lower limit of the compacted stratum. The reason for tilling so deep is to ensure that the soil between the rows where the tines pass is loosened and the lower limit of the compacted zone is broken up. The tine spacing should be approximately equal to the depth of penetration of the tines so as to ensure that the entire compacted layer is broken up.

ii. For incipient compaction

Tined tillage is the best way to avoid problems of incipient compaction and the system works well for different soil types, including those with drainage problems and those that are susceptible to compaction. Tined tillage combined with controlled traffic is the best soil management system to avoid compaction. In this system, all machinery passes over the same tracks. The soil under the tracks becomes compacted and suitable for traffic, whereas the rest of the land is not passed over by the machinery and so does not become compact. However, all the machinery should have the same track width, and requires skill on the part of the tractor drivers/operators.

iii. For hard setting layers

The solutions to rooting problems due to hard setting are identical to those for compaction problems.

6.8 Conditions of low fertility and productivity

Identification of adverse nutritional conditions

As a first step in formulating a soil management strategy it is very important to identify any nutritional problems in the soils as crop growth is limited by nutritional factors of the soils . Together with soil analysis, foliar analysis is an important tool that should be used with greater frequency. In order to correctly interpret foliar analysis it is essential to sample the correct part of the crop at the appropriate stage of growth. Often the symptoms of foliar deficiencies serve as useful indicators, but in general they only appear when the deficiencies are already accentuated.

Possible solutions

i. For nutritional deficiencies and/or imbalances

Application of fertilizers, including organic manure. When applying inorganic fertilizers, it is important to know both the economic application rate and the dose required to attain the maximum yield. The fertilizer management system should consider the method of application (broadcast or placed) and the number and timing of the applications to maximize efficiency, avoid fixing phosphorus, and avoid excessive applications of nitrogen and other soluble nutrients.

It is also important to apply fertilizers that do not cause acidity so as to avoid chemical degradation of the soils. However, if the soils have low sulphur content, application of gypsum (calcium sulphate) may be needed when substituting ammonium sulphate, a nitrogenous fertilizer that most acidifies soils but which contains sulphur, with less acidifying fertilizers such as calcium nitrate, calcium-magnesium nitrate, calcium-ammonium nitrate or urea.

In a situation where nitrogen is the limiting nutrient, sowing and incorporating green manure and using legumes in the crop rotation pattern can assist in largely overcoming the nitrogen deficiency. Furthermore, the presence of legumes in the crop rotation will ease the control of graminaceous weeds. It is advisable to use legumes that readily form nodules without the need for inoculation, because of the difficulty of obtaining inoculants and maintaining their efficiency until they are applied in the field. The efficiency of legumes to fix nitrogen depends on an adequate availability of phosphorus in the soil, and one cannot expect a good production from legumes if the soils are phosphorus deficient. For some legumes such as soybean, continued harvesting of the grain will result in a reduction of the overall nitrogen content of the soil.

iii. For poor soils with low organic matter and clay contents

Valid options available for improving the chemical fertility of these soils include applications of organic manures and composts, and agronomic practices such as leaving crop residues, cover crops, crop rotations that include legumes, deep rooting crops, inter-cropped legumes, the inoculation of legumes and the incorporation of green manure. The application of organic manures and compost can be more important for small farmers because of the low costs .In contrast, because there are often limited supplies of organic manure and compost and because of the large labour input required, the practice may be more difficult for large farmers. As organic manures and compost are advantageous in containing a wide range of nutrients and they benefit the physical properties of the soil, farmers may be available to use organic manure and compost whenever possible even in small quantities.

iii. For soil with serious leaching problems

In zones where there are serious leaching problems, a cover crop with deep roots is desirable. Suitable cover crops are *Crotalaria spp., Glycine wightii, Centrosema macrocarpum, Cajanus cajan etc.* The cover crop can be grown during the preceding season, after harvest, or within the same season as the main crop. However, if the two crops are grown at the same time, sowing dates and growth rates of the two crops are to be taken into account to overcome the problems of competition.

One may also take advantage of deep-rooting crops such as perennial crops in pure systems, or crops such as cassava and banana in association with shallower rooting crops, which will reduce the loss of nutrients through leaching. Another similar but more systematic practice is that of alley cropping where the bush and tree species form the alleys and have deep roots. Alley cropping systems may be more acceptable to non-mechanized farmers in hillside areas where there are erosion problems and high pressure on the land, but where plot sizes are not very small.

iv. For soils with toxic levels of aluminium or manganese

The best option is often to change the crop variety for one that is more tolerant to aluminium. Alternatively, one could change the crop for one that is more tolerant to aluminium. Where there are no varieties tolerant to aluminium, lime or dolomite limestone can be incorporated into the soil to neutralize and replace aluminium with calcium and magnesium. This practice is applicable where the cost to buy and transport lime is low, and where the toxic concentrations of aluminium are in the surface layers.

Application of organic manure can also have a beneficial effect due to the formation of aluminium-organic complexes, which reduces the activity of aluminium in the soil solution. Enhanced applications of phosphorus can also reduce the toxic effects of aluminium. When high concentrations of aluminium are found in the subsoil, it is more difficult to neutralize it due to the low solubility of lime and its slow movement into the deeper layers. In these cases, gypsum can be applied, or even better, gypsum mixed with lime because the gypsum is soluble and the calcium in the gypsum more rapidly replaces the aluminium in the lower layers.

v. For soils infested with weeds, pests or diseases and “tired” soils

Crop rotation overcomes or reduces problems due to weeds, diseases, insects, loss of fertility and the structural degradation of the soil. The crop rotation must take account of the following elements:

- sowing broad-leaved crops (for example, soybean, sunflower and beans) before and after graminaceous crops (such as maize and sorghum) so as to allow good weed control;
- sowing legume type crops before other crops so that the latter crops can benefit from the fixed nitrogen;
- presence of crops that supply large quantities of residues, which do not readily decompose (for example, maize, grain sorghum, sunflower or cotton) so as to maintain or increase the organic matter content of the soil ;
- a sequence of crops that do not act as hosts to the same diseases and/or pests.

Selection of crops to be included in crop rotation is on a number of factors such as the crops for which there are markets, soil types, management systems, climate, weeds, diseases and pests. It will be necessary to identify for each zone, the rotations that are technically, economically and socially the most acceptable.

6.9 Adverse edapho-climatic effects for crop development and field operations

Interactions between the rainfall and soil characteristics can result in problems of moisture shortage which adversely affect crop development, or of excess moisture which generates problems for crop growth and field operations such as spraying and the harvesting.

Lack of moisture

Shortage of soil moisture can be caused by a low infiltration rate, high evaporation, low moisture retention capacity of the soil, low or irregular rainfall.

Possible solutions

i. For soils with moisture deficit due to low infiltration or high evaporation (where there are residues)

Leaving a surface cover of crop residues is a solution to such problem. The residue cover will increase the infiltration rate and reduce the evaporation of moisture from the soil. The options available are to leave the residues from the preceding crop, to apply a mulch or organic manure, or to sow a cover crop. The presence of a vegetative cover on the surface implies the use of conservation tillage techniques, preferably zero tillage, which will leave more residues on the surface and so reduce evaporation. In addition, the control of weeds using herbicides or by tillage that does not incorporate the weeds, such as with a stubble mulch cultivator, will maintain a better residue cover. Another option is to change the crop variety for one that is more resistant, or can better withstand drought condition. The sowing dates and the date when the cover crop is to be eliminated should be fixed so as not to cause an excessive reduction of soil moisture.

ii. For soils with moisture deficiency due to low infiltration and high evaporation (where there are no residues)

Strip tillage is an option where the narrow tilled bands are sown. The areas between the strips are left untouched and the rough surface, dead weeds and crop residues from the preceding crops assist infiltration of the rainwater. Alternatively, the areas between the crop rows can be loosened with cultivators after each rainfall to break up surface crusts and increase the infiltration. However, numerous cultivations will accelerate the rate of decomposition of the soil organic matter (biological degradation).

Tined tillage is an appropriate solution for soils susceptible to crust formation and compaction. Sowing and all tillage operations should be parallel to the contour lines so as to encourage infiltration in the small surface undulations.

iv. For soils with moisture deficits due to a low moisture retention capacity

The moisture retention capacity of sandy soils can be increased through practices that increase their organic matter content, such as incorporating organic manure or green manures, or by planting a cover crop. In soils where impermeable layers impede water percolation to deeper layers, subsoiling that breaks up these layers will increase the amount of moisture retained. In clay soils, subsoiling can also increase moisture retention capacity by increasing the surface area available for absorption of the moisture.

Another possible option is to change the crop variety for one that is better adapted to, or that can escape, the periods of drought.

v. For soils with moisture deficit due to runoff and low moisture retention capacity

Changing the slope of the land is another option to increase infiltration.. The construction of terraces will increase the infiltration of rainfall but involves high cost. The construction of individual terraces will also increase infiltration and moisture retention capacity and is suitable for orchards.

Excessive moisture

When soils have moisture content that is higher than the optimum, field operations with machinery and implements will increase the risks of soil compaction. This situation can occur during primary tillage, spraying or cultivation operations, or during harvest. The excessive moisture may be due to ingress of runoff water, the presence of impermeable layers, or a high water table.

Possible solutions

i. For excess moisture due to runoff

The only solution is to construct cut-off ditches. It is very important to ensure that the discharge of the diverted water does not cause problems at the point of discharge.

ii. For excess moisture due to a high water table or impermeable layers.

If the problem is due to an impermeable layer within the first 60 cm of soil depth, a system of shallow open ditches should be installed. However, if the impermeable layer is at a depth between 80 and 100 cm, deeper drainage ditches will need to be installed with their bases located above the impermeable layer. In addition, clay soils will need a narrower spacing between the ditches. The practice of deep tillage with a subsoiler working in a direction perpendicular to the line of the ditches will assist drainage. When the excess moisture is due to compacted layers, deep tillage with a subsoiler to break up the hard pan will improve the drainage.

6.10 Lack of biological activity *possible solutions*

The lack of biological activity may be due to a lack of crop residues, “tired” soils or to the application of toxic pesticides.

i. For soils with little crop residue cover

In order to increase biological activity in the soil, a persistent cover of dead vegetative material is needed, which can be obtained by leaving crop residues on the surface, applying mulch or organic manure, and by sowing a cover crop. The active presence of earthworms in a soil needs supply of dead vegetative material throughout the season when the soil is moist. If there is good soil moisture but lack of dead vegetative material, the earthworms will move elsewhere. The only way to maintain a residue cover is through conservation tillage, particularly zero tillage. Conventional tillage involving soil inversion will not leave sufficient quantity of residues on the surface.

Another option is to increase crop residue production by increasing the chemical fertility of the soil through the application of organic manures or fertilizer. Alternatively, crops and varieties that produce large amounts of biomass may be sown, and which preferably produce residues that do not decompose rapidly.

ii. For “tired” soils

It is probable that the phenomenon of “tired” soils can be overcome through changing the crop rotation. This has been discussed in Section D.

iii. For soils receiving high concentrations of pesticides

The application of massive amounts of non-specific pesticides reduces the biological activity of soils. This activity can be better maintained through the application of biological and botanical pesticides, integrated pest management, and by the application of selective pesticides. Integrated control of weeds can also reduce the quantities of herbicides that are needed.

6.11 Erosion by water

Possible solutions

Problems of water erosion can be considered as the result of low infiltration due to a lack of soil cover or surface roughness on sloping land. The presence of cover which is in contact with the soil and surface roughness will give more time for rainwater to infiltrate and so reduce the risks of erosion. Tillage practices that increase surface roughness are only suitable for gentle slopes. Some practices, such as levelling or drastically reducing the land slope, will hinder the initiation of runoff, whereas other practices only trap the runoff after it has had an opportunity to cause erosion.

i. To increase infiltration through increasing soil cover.

Increasing the soil cover involves increasing residue production by means of all practices of fertilization and manuring that increase soil fertility, through the introduction of crops or varieties that produce greater quantities of residues, or more resistant residues, and through sowing higher plant population densities. Sowing cover crops, intercrops or fallow crops will also increase soil cover and provide more crop residue to protect the soil. Another option is to apply materials such as mulch and organic manure.

In order to reduce the losses in crop residues, the straw and stubble should not be burnt and grazing should be reduced to a minimum in livestock zones.

For manual tillage systems, the presence of stones on the soil surface will act as a cover and protect the soil. It is better to leave them in place rather than remove them to construct stone barriers.

ii. To increase infiltration through increasing surface roughness

Every practice causing irregularities parallel to contour lines will assist infiltration of the rainwater. Practising tillage and sowing parallel to the contour lines will increase infiltration but these practices will only function on gentle slopes.

Systems of beds and furrows, such as ridge tillage, reduce the erosion. However for slopes steeper than about seven percent there is an increased risk of collapse and overspill, which can cause very serious erosion due to the downhill flow of the water that has accumulated in the furrows. Strip tillage leaves I the area between the crop rows undisturbed. If there is a protective cover of straw and dead weeds, this will have the effect of slightly increasing surface roughness and improving infiltration. A variation of this practice involves ploughing after the rainy season, which will increase surface roughness; secondary tillage is then undertaken only along the strips where the crop is to be sown. In this manner, the zone between the rows is rougher but the soil is left with little cover. In areas where crop residues are not available, this practice may be accepted although it does not protect the soil and does not favour biological activity.

iii. To reduce the quantity and velocity of runoff

In manual or animal traction systems, alley cropping parallel to the contours will reduce the velocity of the runoff and through this soil losses, providing there is sufficient vegetative cover, both dead and alive, to form a dense barrier in contact with the soil. Only those materials in contact with the soil can reduce runoff velocity and cause sediment to be deposited. In order to accelerate the development of the barriers, all the clippings from the pruning operations should be placed along the upslope side of the row of trees and parallel to the contour.

Live barriers planted along contour lines will also reduce runoff velocity provided they form a dense barrier. Perennial or semi-perennial plants may be used, planted parallel to the contour and with appropriate spacing between the barriers. The species should be adaptable to the zone, should provide additional benefits to the farmer such as grass, forage, fruit, spices or grain, and they must not invade, shade or compete with neighbouring crops.

It is more difficult to obtain and maintain a residue cover over soil in semiarid climates due to the lower biomass production in the lower rainfall regime, which is often accompanied by an intense termite activity. There are also situations where, due to economic factors, the farmers can only sow crops that produce small amounts of straw such as soybean or beans, without the possibility of sowing cover crops. The combination of these factors, associated with high temperatures, makes it difficult to produce and maintain an adequate cover of residues over the soil. Under these circumstances, the reduction of runoff velocity requires a combination of live barriers with physical structures such as hillside ditches and stone walls.

Stone walls are not recommended for manual systems because they remove the surface stones needed for their construction, so removing the cover that was encouraging infiltration. Blind ditches are pits that are normally constructed in perennial crops, which trap the runoff according to their location, size and the spacing between them.

When the erosion problems are due to runoff entering from areas outside the field, diversion drains should be constructed to capture the runoff and to carry it away from the field to a safe disposal point. All practices that trap runoff will reduce overall problems of erosion, but will not prevent erosion occurring between one structure and another. The construction of bench terraces, orchard terraces and individual terraces with level slopes will have the effect of impeding the initiation of runoff.

Chapter -7
Alternative Methods of Shifting Cultivation

7.1 Introduction

Shifting cultivation, locally known as the *podu* cultivation amongst tribals in Orissa is an age old practice. This is generally practiced in a particular sequence right from clearing the patch of land till harvesting the crop for continuous 3-5 years and cultivation is shifted to new patch abandoning the present patch of land for natural regeneration. Shifting cultivation in short cycles of 3-5 years is detrimental to the forest ecosystem. Due to shifting cultivation practice on slopes, down-stream siltation of the water bodies is apparent in many districts. Protection and repair of drainage basins for conservation of ecological resources including water need higher investment. Due to splash forces generated from the raindrops, the erosion of precious topsoil occurs which is influenced by major factors like rainfall, the topography of the terrain, and the kind of vegetation and soil conditions. The mountain eco-systems with shifting cultivation practice, therefore, have to be ecologically sustainable.

7.2 Alternative Methods

The recommendation of ICAR as well as World Bank for sustainability has been (a) to promote forestry on upper reaches with silvi-pasture development. (b) To break middle slope length for annual or perennial fruit trees and inter-crop, and (c) to put lower slopes under agricultural crops. Slopping Agricultural Land Technology (SALT) is an ideal measure to substitute shifting cultivation while achieving sustainability as articulated above needs to be successfully demonstrated in Orissa.

Formulating an eco-development plan for the area with shifting cultivation practice for environmental sustainability, could consider completely replacing agricultural practice with farm forestry. Loss of energy from the forests per unit of agricultural production may be far greater in shifting-cultivation areas. Farm forestry may be one of the solutions to redress this loss. The advantages of farm forestry are:

- The protective values of trees are far greater than those of annual crops
- Unlike annual crops which require frequent ploughing, tree plantations cause minimal soil disturbance
- Net above-ground primary productivity of forests is notably greater than that of agricultural crops and grassland.

Providing employment opportunities and income generation on a regular basis through proper utilization of the land resources, i.e. by equitable distribution of wasteland among the tribals and development of wastelands through agro-forestry and silvi-pasture practices would help reduction of shifting cultivation. Cooperative efforts for carrying out forest-based activities, i.e. basket making, rope making, cane furniture making processing of minor forest produce, honey collection, etc. have to be made commercially viable by providing proper marketing facilities. This will not only discourage tribals from practicing shifting cultivation but will also strengthen their socio-economic condition.

7.3 SALT

SALT is a form of alley farming in which field and perennial crops are grown in bands 4-5 m wide between contoured rows of leguminous trees and shrubs. The later are thickly planted in double rows to form hedgerows. When the hedge reaches 1.5-2.0 m in height, it is cut back to 40 cm and the cuttings are placed in the alleys between the hedgerows to serve as mulch and organic fertiliser or green manure. The species used in the hedgerows include *Leucaena* *leucocephala, L. diversifolia, Calliandra calothyrsus, Gliricidia sepium, Flemingia macrophylla* and *Desmodium rensonii.*

Rows of perennial crops such as coffee, cacao, citrus and banana are planted on every third alley created by contoured hedgerows. The alleys not occupied by permanent crops are planted alternately by cereals (e.g. com, upland rice or sorghum) or other crops (e.g. sweet potato, melon or pineapple) and legumes (e.g. mung bean, string bean, soybean or peanut). This cyclical cropping provides the farmer with several harvests throughout the year.

7.4 Various Forms of SALT

There are several forms of SALT, and a farmer may wish to use the **SALT system** in several variations. Simple Agro-Livestock Land Technology (SALT 2), Sustainable Agroforest Land Technology (SALT 3) and Small Agrofruit Livelihood Technology (SALT 4) are three variations of SALT that have been developed at the Mindanao Baptist Rural Life Center, Philippines.

SALT 2 (*Simple Agro-Livestock Land Technology*) is a small livestock-based agroforestry preferably dairy goats with a land use of 40% for agriculture, 20% for forestry and 40% for livestock. As in a conventional SALT project, hedgerows of different nitrogen fixing trees and shrubs are established on the contour lines. The manure from the animals is utilized as fertilizer both for agricultural crops and the forage crops.

SALT 3 (*Sustainable Agro-forest Land Technology*) is a cropping system in which a farmer can incorporate food production, fruit production, and forest trees that can be marketed. The farmer first develops a conventional SALT project to produce food for his family and possibly food for livestock. On another area of land he can plant fruit trees between the contour lines. The plants in the hedgerows will be cut and piled around the fruit trees for fertilizer and soil conservation purposes. A small forest of about one hectare will be developed in which trees of different species may be grown for firewood and charcoal for short-range production. Other species that would produce wood and building materials may be grown for medium and long-range production.

SALT 4 (*Small Agro-fruit Livelihood Technology*) is based on half-a-hectare of sloping land with 2/3 devoted to fruit trees and 1/3 intended for food crops. Hedgerows of different nitrogen-fixing trees and shrubs (*Flemingia macrophylla, Desmodium rensonii, and Gliricidia sepium*, etc.) are planted along the contours of the farm.

7.5 Sloping Agricultural Land Technology (SALT-1)

The Sloping Agricultural Land Technology (SALT) is a farming system developed during 1970s. Basically attuned to the production needs of small-scale hill farmers, this agro-forestry technology has gained wide popularity in Asia because it is culturally appropriate, economically sound and is designed to limit soil erosion. This farmer friendly technology was developed for farmers with few tools, little capital and little training to meet the specific culture, resources and abilities of local communities.

Process

SALT is basically a method of growing crops (both arable and permanent) between rows of nitrogen-fixing shrubs and trees such as *Gliricidia sepium* and *Leucaena leucocephala* (Subabool) established four to six metres apart and planted along contour lines. The Leucaena is planted in very dense double rows in order to make hedgerows that serve as erosion barriers. When the trees are 1.5-2.0 meters tall they are cut back to about 40 cm and the tops are used as a green manure in the alleys where the crops are growing. SALT is a diversified farming system. In addition to Leucaena, rows of perennial crops may be grown amongst the maize.

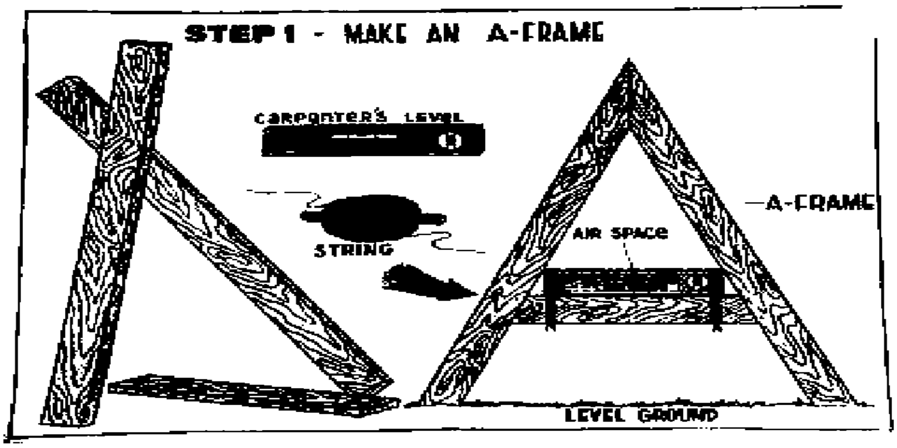
The annual crops are rotated: maize is followed by soybeans or groundnuts or mung beans, and then by maize again. Thus a farmer has something to harvest all year round.

Purpose: SALT restricts soil erosion, conserves soil, helps to maintain soil fertility and health, substitutes shifting (*podu*) cultivation thereby ensuring enhanced livelihood and food security of farmers while retaining the traditional cropping pattern and farming techniques.

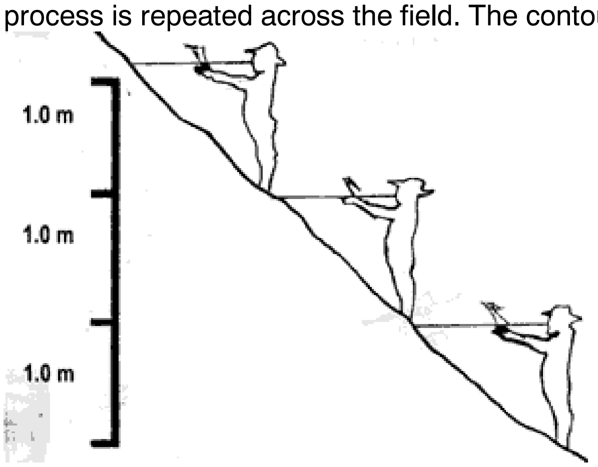
Location: The system is suitable for slopping lands where shifting cultivation practices are adopted by the farmers.

The Ten Steps of SALT-1

Step 1. ***Making the A-frame.*** The A-frame is a simple device for laying out contour lines across the slope. It is made of a carpenter level and three wooden or bamboo poles nailed or tied together in the shape of a capital letter A with a base about 90 centimeters wide. A carpenter's level is mounted on the crossbar.



Step 2. ***Determining the contour lines.*** One leg of the A-frame is planted on the ground, and the other leg is swung until the carpenter's level shows that both legs are touching the ground on the same level. A helper drives a stake beside the frame's rear (first) leg. The process is repeated across the field. The contour lines should be spaced 4-5 m apart.



Step 3. ***Cultivating on the contour lines.***

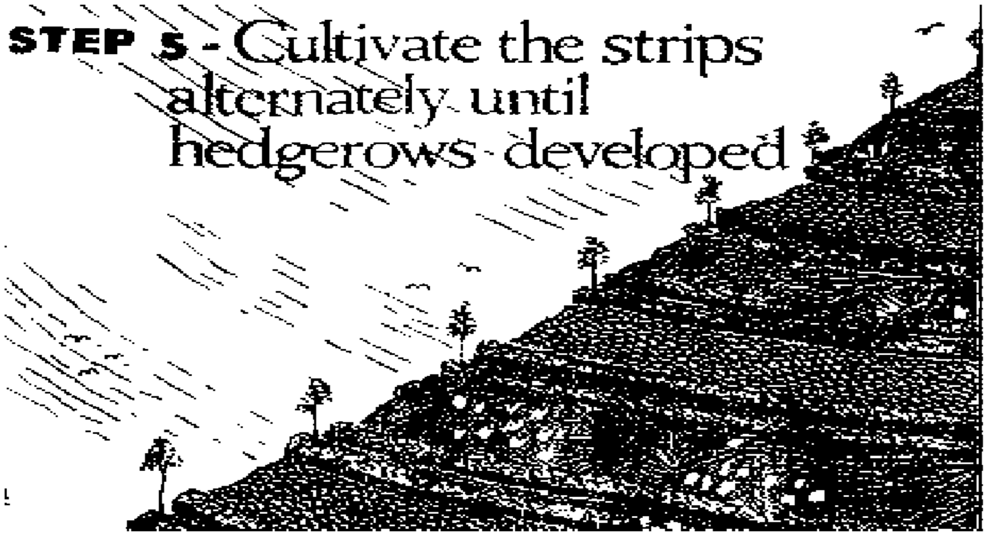
One-meter strips along the contour lines should be ploughed and harrowed to prepare for planting. The stakes serve as a guide during ploughing.

Step 4. ***Planting seeds of different nitrogen fixing trees and shrubs.***

Along each prepared contour line, two furrows should be laid out. Two to three seeds are planted per hill, with a distance of 12 centimeters between hills. The seeds should be covered firmly with soil. When the hedgerows are fully grown, they hold the soil and serve as a source of fertilizer.

Step 5. ***Cultivating alternate strips.***

The space between the rows of nitrogen fixing trees on which the crops are to be planted is called a strip or alley. Cultivation is done on alternate strips (strips 2, 4, 6 and so on). Alternate cultivation prevents erosion because the unploughed strips will hold the soil in place.

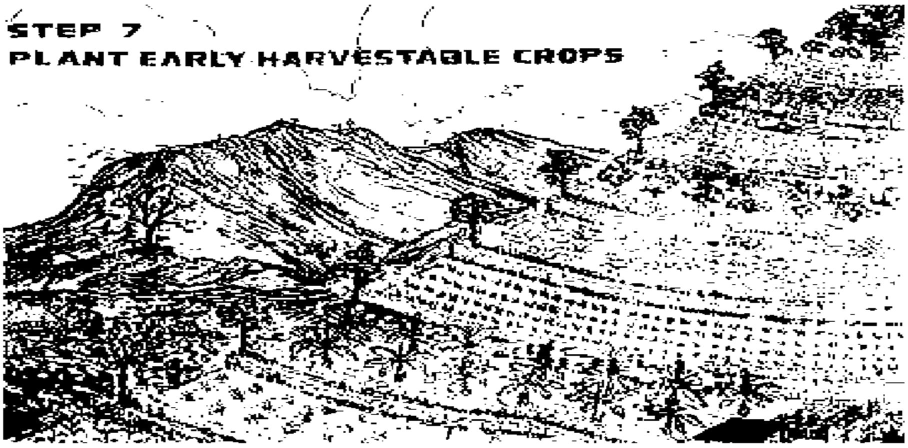


Step 6. ***Planting permanent crops.***

Permanent crops like citrus and others of the same height may be planted when the nitrogen fixing species are sown. Only the spots for planting, however, are cleared and dug, and later only ring weeding is employed until the hedgerows are large enough to hold the soil in place. Permanent crops are planted in every third strip. Tall crops should be planted at the bottom of the farm while the short ones are planted at the top.

Step 7. ***Planting short-term crops.***

Short and medium-term income producing crops (pineapple, ginger, taro, sweet potato, peanut, mung bean, melon, sorghum, corn, upland rice, etc.) should be planted between the strips of permanent crops as a source of food and soil conservation.

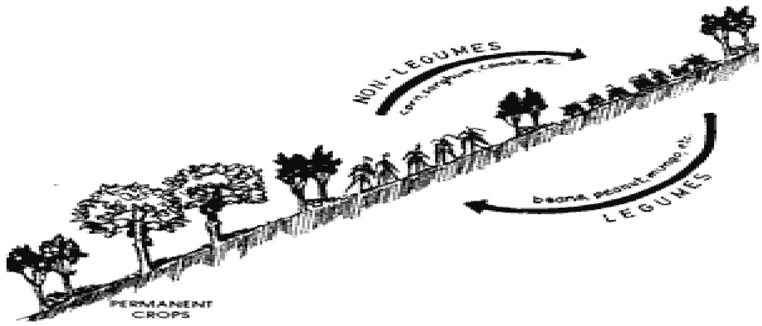


Step 8. ***Trimming of nitrogen-fixing trees.***

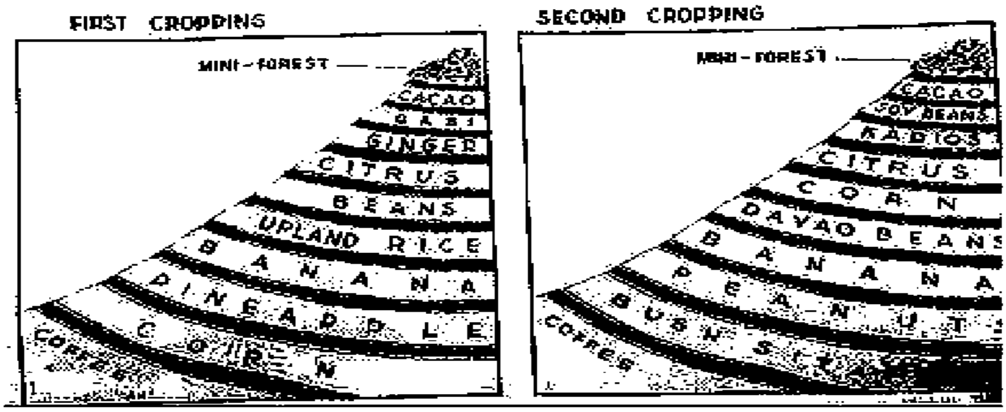
Every 30 to 45 days, the growing hedgerows are cut to a height of 1.0 to 1.5 m from the ground. The cut leaves and twigs should be piled on the soil around the crops, where they serve as an excellent organic fertilizer. In this way, only a minimal amount of commercial fertilizer (about 1/4 of the total fertilizer requirements) is necessary.

Step 9. ***Practicing crop rotation.***

A good way of rotating is to plant cereals such as corn or upland rice, tubers and other crops on strips where legumes were planted previously, and vice versa. This practice will help maintain the fertility and good condition of the soil. Other management practices in crop growing, such as weeding and pest control should be carried out regularly.

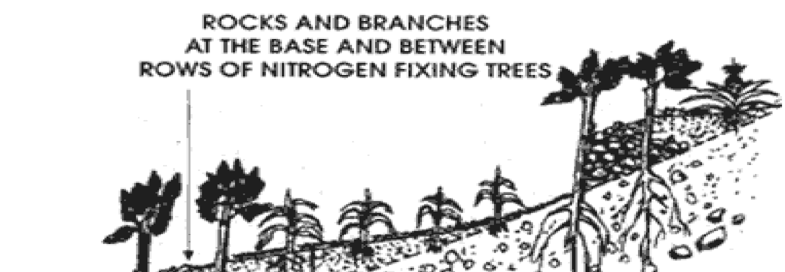


STEP 9- Practice crop rotation

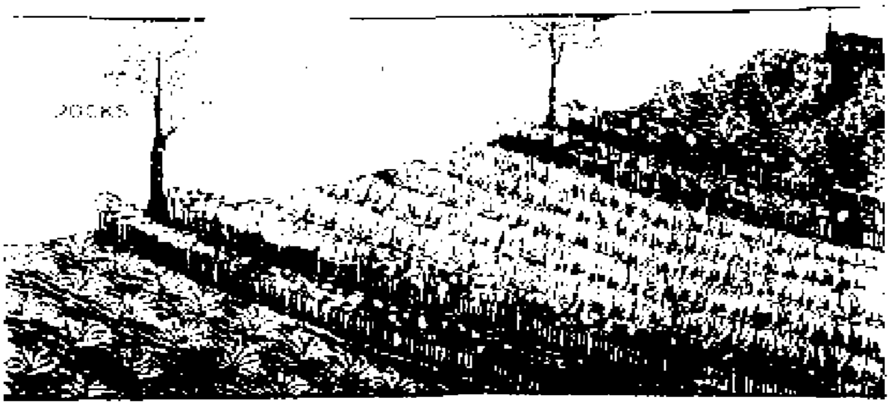


Step 10. ***Building green terraces.***

To enrich the soil and effectively control erosion, organic materials such as straw, stalks, twigs, branches and leaves, and also rocks and stones, are piled at the base of the rows of nitrogen fixing trees. As the years go by, strong, permanent terraces will be formed which will anchor the precious soil in its right place.



STEP 10



7.6 Simple Agro-Livestock Land Technology (SALT-2)

In SALT-2 production of food crops is integrated with livestock production system on sloping lands.

Purpose: SALT-2 encourages farmers to integrate dairy, goats into their upland farms, thus, increasing profitability without the fear that goats may destroy plants/crops.

Location: In sloping areas where *Podu* cultivation is practiced.

Step-wise practices

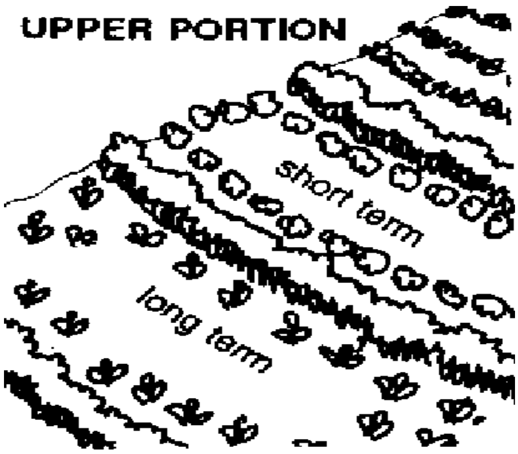
Step 1. Locate the contour lines by using "A" frame

Step 2: Establish hedgerows.

Cultivate the contour lines thoroughly, forming raised beds, 1 m wide. Make 2 furrows, 1/2 meter apart, on each contour line. Plant thickly the nitrogen-fixing trees and shrubs (NFT/S) on the furrows, at the uppermost part and along the borders of the farm. Examples of hedgerow species are *Leucaena leucocephala and Glincidia sepium.*

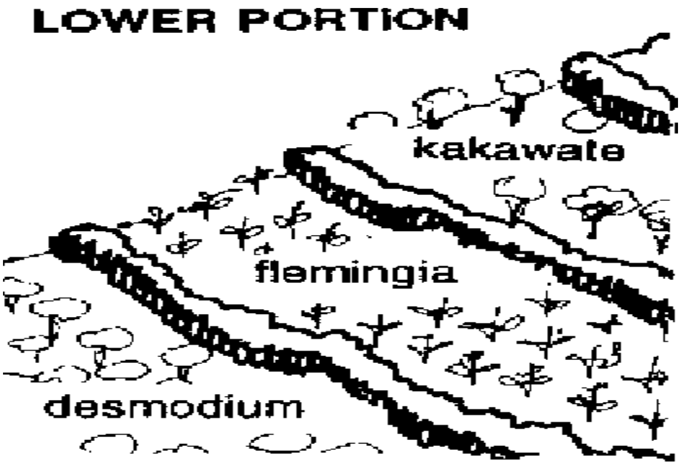
Step 3: Plant food and cash crops.

Grow food and cash crops on the upper half of the farm so that loosened soil due to cultivation is caught at the lower half portion by the forage crops. To avoid further disturbance of the soil, plant 3/4 of the agricultural area to long term crops (e.g., coffee and cassava) and the remaining 1/4 to short-term ones (e.g., beans and peanut). Plant food and cash crops.



Step 4: Develop forage garden.

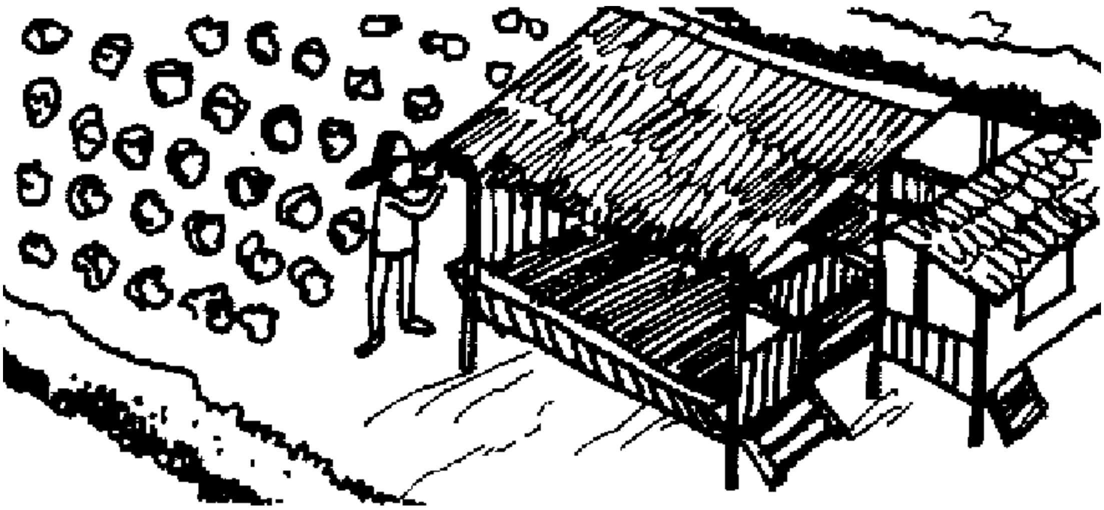
Plant the other half of the area to forage crops. This should be established six to eight months before bringing in the goats. Plant forage crops which are palatable, high in protein, fast-coppicing and high-yielding. A suggested composition of forage crops is 50 percent Desmodium rensonii, 25 percent Flemingia congesta, 20 percent Gliricidia sepium and 5 percent grasses like napier.



Develop your forage garden.

Step 5: Build the goat barn.

Construct the goat bam at the middle of the farm between the boundary of the "forage garden" and agricultural area. This will save time and labor in hauling manure out to the farm and in carrying forage to the goats. Provide floor space of 2025 sq ft per goat using local materials. For convenient removal of manure, raise the floor 4 fl above the ground with floor slots nailed, 1/2 inch apart. Essential divisions and fixtures in your goat house are kids' separation pen, milking stanchion, milkroom, storeroom, feeding trough, grass rack, water and salt trough.



Build the goat barn.

Step 6: Bring in the breeding stock at the right time

Do this only when the "forage garden" has been fully established and is already capable of supplying sufficient forage for the goats i.e. six to eight months after planting the forage crops. The recommended breeds are the pure breeds or crossbreds. Without these breeds, start with the biggest goat you can buy. A good stocking rate is 1 buck: 12 does per half ha of a well-developed agro-forest farm.

Step 7: Feed the goats sufficiently.

Dairy goats essentially need concentrates (high-energy feeds) aside from the forage (high-fiber feeds). Give them feeds in the morning and in the afternoon. A good concentrate consists of 18 percent first class rice bran, 23 per cent corn grain or rice middling, 21 percent copra meal, 36 percent *Leacaena leacocephala* (Ipil-ipil) leaf meal, 1 percent salt and 1 percent limestone. A good forage is a mixture of 50 percent Desmodium rensonii, 25 percent Flemingia macrophylla, 20 percent Gliricidia sepium and 5 percent grasses like napier. Goats should be given forage of at least 10 percent of their body weight per day. Provide your goats with salt and plenty of water everyday

Step 8: Breed the goat

Breeding too early will stunt the animal. A doe should not be bred until she weighs 45-50 kg or is 10-12 month old. Breed the doe in the second day of the heat period. If the doe is not pregnant after being bred over three heat periods, she could be culled or placed under close observation if she is a valuable breeding animal. Rebreeding may be done 2-3 months after the doe has given birth.

Step 9: Market products wisely.

Milking, which is done daily, should have a definite procedure and time. A slight change in the routine of feeding and milking will result in unfavorable milk yield. Pasteurize the milk first (at 74°C about 30 seconds) before selling it. Do not delay marketing your other farm products. The kids of the goats can be marketed at the age of 10-12 months or when they weigh from 35-55 kilograms which should not be delayed.

Step 10: Maintain the SALT-2 farm regularly.

Cut the hedgerows half to one-meter from the ground when they start to shade the field crops. Replant missing hills of the hedgerows, weed and clean the crops and spray with chemicals only if necessary. Rotate the non-permanent crops.

7.7 Sustainable Agro-forest Land Technology (SALT-3)

SALT-3 is a variant of agro-forestry and this manual will guide on how to put it up in the hilly land. SALT 3 has also ten basic steps, which are discussed in this manual.

Purpose: The purpose of including agro-forestry in sloping land technology is to take up food production and reduce soil erosion.

Location: Sloping land where *Podu* cultivation is practiced.

Steps:

Step 1: Set-up Agro-forestry Nursery

Ensure sufficient supply of planting materials for your agro-forest farm by setting up your own nursery. Establish an accessible nursery (3 meter by 5 meters for nursery and about 5 feet by 10 feet) with the following fixtures: potting shed, transplant shed, and seedbeds. Basic materials like watering cans for sprinkling seedlings, shovel, and spade, should also be made available.

Step 2: Care and Manage Seedlings

For better growth and field survival, the production of healthy and vigorous planting stock is necessary. Here are some useful tips:

Sowing the seeds

Most forest tree seeds are hard to germinate so they need scarification. For most forestry seeds, the most common methods of scarification are mechanical, water soak or hot water treatment. The most common problem encountered in seedling establishment is damping off and insect defoliators. Sow the seeds in a sterilized seedbed to avoid damping off. Sterilization may be done by pouring boiling water in the soil media where you will sow the seeds. Keep the seedbeds moist at all times. Mulch and shade the plants.

Transplanting

Use compost mixed soil or top soil mixed with dried manure in the field where transplantation to be done. Do not allow weeds to compete with your transplanted seedlings. Before transplanting them to the field, harden the seedlings first by gradually exposing them to sunlight and more open conditions. Do this over a period of 6 months in order to develop sturdy, well-developed crown and many fine, fibrous lateral roots. After uprooting the saplings the roots may be pruned (teak etc.)

Step 3: Find the Contour Lines and Establish Your Food Crops on the Lower Portion of the Farm

Find the contour lines of the farms half lower portion by using an A-frame. Plant the identified contours with any of the following hedgerow species: *Gliricidia sepium, Leucaena diversifolia,* and *L. leucocephala.* In poorer acidic soils, *Flemingia* and *Indigofera tyesmani* are recommended.

The preferred short-term crops are ginger, maize, upland rice, sweet potato, mung bean, melon, etc. on every first and second strip. Plant long-term crops (citrus, cacao, coffee, banana, black pepper, etc.) on every third strip. These can be intercropped with fruit trees (guava, mango etc.) following appropriate planting distances. Multi-storey cropping may also be practiced (e.g., pineapple + ginger + banana) in one strip. Follow the SALT-1 steps in establishing your food crops.

Step 4: Prepare the Site for Wood Crops or Trees

Locate the woodlot at the upper half of the project so that the agricultural component on the lower portion will benefit from the conserved moisture and nutrients from the wood crops. On areas with steep slope and highly erodible soils, extra care must be exercised so as not to induce soil erosion when clearing the area. You can use either partial or complete removal of vegetation whichever is more favorable. **Avoid burning.**

Step 5: Compartmentalize and Space Trees

For a 3-fold objective of soil rehabilitation, firewood production and timber growing, you can maximize the use of land space by following the high density strategy of establishing small-scale woodlots.

Step 6: Out plant Trees

This may be done at the beginning or up to the middle of the rainy season so that seedlings can get established prior to the dry season. Follow the contour when out planting. Be sure not to break the earth-ball when setting the seedlings into the planting hole. The upper part of the earth-ball should be level or slightly deeper than the edge of the hole. Soil is filled into the spaces and tamped firmly all around. For fast recovery of the seedlings, apply animal manure. Mulch the seedlings to insure higher linability.

Step 7: Intercrop between Tree Crops

Short- and medium-term and cash crops (ginger, sweet potato, yam bean, and cassava) can be intercropped in the forestry component during the first two years. Long-term ones like black pepper and rattan can be incorporated at the start of the second year. For effective soil management, see to it that non-legume short-term crops are replaced by leguminous ones and vice versa in every cropping.

Step 8: Tree Stand Improvement

Apart from regular ring-weeding and liberation cutting, improve the stand of your trees. Remove the malformed trees. Prune unnecessary branches. Prune only the branches within the 505 of its total height from the ground to the top. But don't over-prune; otherwise, you will make your trees stunted. Replant the missing hills if you feel the replanted trees can still catch up. However, replanting is laborious and expensive and should be done only to maintain required spacing or density. This is also recommended only when mortality is more than 30%.

Step 9: Harvest of Agro-forest Products

Timely harvesting of crops saves waste. All households and useful products must be gathered, processed and marketed. In the forestry components - forage from tree prunings, fuel wood and round wood from thinning commence during the second year. Thin out regularly your forestry area until the timber crop spacing requirement is complied with. In some instances, minor forest crops can be planted under the trees.

Step 10: Maintain the SALT-3 Farm

7.8 Small Agro-fruit Livelihood Technology (SALT-4)

SALT 4 is a system intended to produce food, increase income and soil conservation measures in a limited sloping land. High value crops like fruits are included in the system.

Purpose: This system is taken up in sloping hilly areas as a substitute to *Podu* cultivation.

Location: Limited sloping land of about ½ ha.

Step-wise practices

Step 1.Establish a Nursery Area Located at the Center Portion of the Farm

To make sure that you have a sufficient supply of planting materials at lower cost, set up your own nursery. The nursery must be near the house with a reliable of water source and free from pest and disease problems.

Nursery shed

Upon selecting an area, remove debris and grasses. A nursery with a dimension of 3 meters by 1.5 meters is sufficient for half-a-hectare farm. You need only four poles and a roof made of locally-available materials.

Materials needed

Among the equipment needed in a nursery are watering cans (with sprinkling head or a can with small holes punched in it), plastic bags for potting, several seed boxes, a spray bottle, and cans for boiling water.

Step 2. Prepare High Quality Planting Materials of Fruit Trees

Fill the seed boxes with river sand (not sea sand). If sand is not available, you may use the ordinary soil. Pour boiling water over the seed box to sterilize the sand. The seed box and sand should be soaked thoroughly. Before sowing the seeds, wait for 3-4 hours for the sand to cool down.

Fruit selection

While choosing the fruit species, it is important to choose species that grow well in your locality. A simple way of finding this is by observing the fruits that grow well in the area. Fruits from other areas can also be used on a trial basis before planting them in large numbers.

Seed collection and grafting

Collect seeds which are very prolific and disease-free. Plant them in your sterilized seedbeds. Water the boxes 2 times a day, to keep the soil moist at all times. When the seedling has 2-true leaves, it is ready for transplanting and bagging. Punch several holes in the bottom of the nursery bags. For bagging, use a mixture of equal parts sand, soil and goat manure (other manures can be used but should be dried before using). Fill the bags with the mixture and transplant the seedlings. Care for the seedlings for 6-8 months. At this time, the seedlings are ready to be grafted. Fruit trees are grated for these reasons: (1) true-to-type (you get the exact type of fruits like the mother plant); (2) less time to fruiting; (3) the strengths of a native rootstock can be paired with the high quality fruit of an exotic (introduced) variety; (4) decreases the height of the fruit tree; (5) easy to adjust to its environment; and (6) resistant to pests and diseases. Collect scions (tip cuttings) from healthy fruit trees known to produce high quality fruit. Graft the scion to the seedling. Wrap the connection with thin plastic. Remove plastic after 21 days.

Hardening and transplanting

Allow the grafted planting materials to harden for 3 months. Hardening is done by gradually withdrawing water and exposing to the sun. At the end of the 3 months, the grafted materials are ready for planting in the field. Grow as many planting materials as you can. This ensures a steady supply of planting materials. Excess planting materials may be sold to other interested farmers or individuals.

Large planting materials

Many commercial fruit growers, however, leave their seedlings in the nursery for a longer period of time to become so-called large planting materials. This means the grafted seedlings are left in the nursery for up to 2 years before being taken for planting.

Step 3.Establish and Develop Contour Hedgerows

Locating contour lines

Contour lines of the farm may be found by using an A-frame as explained earlier. The recommended distance between contour lines is 3-4 meters. Be sure to locate the contour lines of the farm accurately. Cultivate the identified contour lines. If laid out haphazardly, you may create a channel on the slope, thus assisting erosion in removing your precious topsoil.

Contour lines preparation

After finding the contour lines, prepare them by ploughing and harrowing until ready for planting. The width of each area to be prepared should be one meter. The stakes will serve as your guide during cultivation. As in other SALT systems, every third step is cultivated at the beginning.

Recommended nitrogen fixing trees and shrubs

The recommended hedgerow species are nitrogen fixing trees and shrubs like *Gliricidia sepium*, *Leucaena leucocephala, L. diversifolia, Calliandra calothyrsu and* those are locally grown in the area.

Planting hedgerow species

On each prepared contour line, make two furrows at a distance of 50 centimeters apart. Plant one seed per cm. Planting must be done at the beginning or during rainy season. To avoid washing out of newly-planted seeds, cover them with mulching materials. Newly-planted hedgerows must be weeded and cultivated at least once a month or more if necessary.

Importance of nitrogen fixing species

Nitrogen fixing species are important because they manufacture their own nitrogen. Therefore cuttings of the leaves and stems have a lot of nutrients. These cuttings are very useful source of organic fertilizer when placed on the soil.

Step 4.Plant Food Crops at the Lower One-Third Portion of the Farm

Plant your preferred short-term crops on the lower 1/3 portion of the farm. Short-term crops (such as maize, upland rice, mung, beans, and others) should be planted in the strips between the hedgerows. Planting the food crops on the lower portion of the farm allows them to receive the maximum sunlight. The earlier you establish your food and cash crops, the better off you will be meeting your immediate needs.

Step 5.Plant Fruit Trees at the Upper Two-Thirds Portion of the Farm

Plant fruit tree seedlings when they are 9-11 months old and at the start of the rainy season. The fruit trees, which will be the farm's main cash provider in the future, must occupy about 2/3 of the whole farm. Draw a map showing the areas where you intend to plant your fruit trees along with the proper spacing. The map could serve as your guide and record of planting. Provide proper spacing for the fruit trees so as to prevent overlapping and competition for nutrients when full grown for proper planting distance). Design your pattern to suit the needs of your farm.

It is recommended that fruit trees with short production life 1-5 years of fruit production be planted together with fruit tree species that have longer production life (15-50 years), especially during the first year of establishing your SALT 4 farm. By doing this, you can have fruits within 2-3 years (from the short-term fruit trees). When production from short-term fruits declines, the long-term fruits will by then be in full production.

Alternate planting

Plant several and different fruit species in your SALT 4 farm to add diversity; 3-5 species is best. Alternate these species to help prevent disease and insect problems. Doing this will lessen monetary loss if there is a poor fruiting year from one species. A farmer can buy all the necessary planting materials from the outside reliable nursery also. By this you do not have to wait 9-11 months for the seedlings in your nursery to grow. The problem is that this can be very expensive. However, it is still important to maintain a nursery of own to ensure replacement of seedlings whenever needed.

Step 6.Intercrop Fruit Trees with Short-Term Crops

Intercropping is done to best use the space and the available sunlight. Banana, coffee, pineapple, papaya, or root crops can be planted around the fruit trees while they are still developing. Some intercrops provide the much-needed shade in the growing stage of trees. Continue growing intercrops until the fruit trees are big enough to shade them out. Even then, crops that require less sunlight (like pineapple, ginger etc) can be grown under the fruit trees. The short-term intercrops will serve as your primary source of income during the first 3 years. If ploughing is employed, it is important not to plough too close to the seedlings. A good rule is not to plough any closer than the leaf drop. This prevents the roots of the fruit tree seedling from being damaged.

Step 7.Practice Crop Rotation and Cover cropping

Crop Rotation

To make sure that nutrients are not depleted from the soil, rotate your food crops. This means that after planting corn, you can plant legumes (beans, pulses, and peas) in the next cropping season or vice versa. Do not burn anything. Slash the standing stalks and allow them and the remains of the legumes to rot in the field. They serve as mulching materials, suppress the growth of weeds, and add nutrients to the soil. In addition, they hold moisture and reduce raindrop splash erosion.

Cover cropping

When the fruit trees have fully grown and/or are starting to bear fruits, you may plant cover crops Aside from helping control erosion, cover crops can also be used as forage for rabbits.

Step 8.Trim Hedgerows Regularly for Mulching

Six months after planting, the hedgerows should be tall enough for their first pruning. The nitrogen-rich hedgerow pruning will become the fertility component of the system. When the young hedges reach a height of about 2-3 meters and have a waist high basal diameter of at least 2.5 centimeters, they are ready for their first trimming.

Pruning hedgerows

Prune them regularly to a height of one meter (or about waist-high) from the ground: Use a sharp bolo when pruning in order to avoid breaking the remaining twigs and branches which will eventually cause the hedgerows to die. Trimming of hedgerows is done every 30-45 days after the initial pruning.

Always pile the cut leaves and twigs at the base of the fruit trees or disperse them evenly over cash crops areas. In intercropping areas, some of the trimmings may be concentrated around the trees while the rest may be distributed over the cash crops.

Green manuring/fertilization

The prunings serve as fertilizer for both cash and fruit trees. In some instances, particularly during the developing stage of fruit trees and cash crops, you may fertilize them with organic matter. Should there be more than enough prunings for the crops - this happens during the rainy season - they may be used as forage for goats and other livestock raised in the farm. However, if prunings are used for animal feeds, manures should be brought back into the system by way of using them in plantations.

Step 9.Harvest and Market the Products on Time

Do not delay in harvesting the food crops. Corn must be harvested from 90-120 days after planting. Papaya is ready for harvest six months after planting. As for pineapple, you may harvest them after one year of planting and every month thereafter.

Methods of harvesting

You may harvest them using a sharp bolo or pruning shears. Some fruits just drop; harvest them by hand or by using a bamboo pole with a net attached (plucker). But before harvesting your fruit crops, plan ahead how and where you will market your products. Planning ahead will enable you to get the best price for your fruits.

Step 10. Maintain the SALT 4 Farm

Among the cultural practices that you need to follow in this kind of farming are weeding, pruning of hedgerows, planting hedgerow skips, and controlling of pests and diseases. Only ring weeding is recommended for fruit trees. The weeds may be used as mulching materials. Should there be skips and die-backs in hedgerows, be sure to do replanting. Also build your terraces by putting rocks and stones, twigs and branches, and leaves at the center of your hedgerows. By doing this regularly, you can build strong, permanent, naturally green and beautiful terraces which will hold the topsoil on your farm.

Cultural practices

Replant fruit trees that have died. Pruning is also needed by some fruit trees. Bagging of young fruits, such as jackfruit and mango, protects them against pests and diseases. Maintain your supply of nursery seedlings. Collect the seeds and grow them in your nursery. Take the scions and cuttings from healthy, high quality fruit trees.

Pest management

If fruit production is greatly affected by pests and diseases, spray the fruit trees with recommended chemical. Generally though, by having alternating species, healthy seedlings, proper spacing, and good fertilization, most pests and diseases will not greatly affect your fruit harvests. It is much easier to prevent pests and diseases than to treat them.

Fertilization

Fruit trees produce fruits even without fertilizer. But for high yields and quality, it is best to fertilize the fruit trees with manure and/or commercial fertilizer. As soil fertility is different in each area, it is not possible to suggest specific fertilizer needs. In addition, different fruit tree species require different amount of fertilizer. When fertilizing fruit trees, the fertilizer is to be in a ring around the trunk at 20 cm away from the trunk. On older trees, place the fertilizer at the leaf drop. Spread trimmings evenly throughout the field to check weeds, equally distribute your nutrient additions, and also conserve soil moisture.

Chapter- 8
Agro-Forestry

8.1 Introduction

Agro-forestry is a farming system that integrates crops and/or livestock with trees and shrubs. The resulting biological interactions provide multiple benefits, including diversified income sources, increased biological production, better water quality, and improved habitat for both humans and wildlife.

Farmers adopt agro-forestry practices for two reasons. They want to increase their economic stability and they want to improve the management of natural resources under their care. An agro-forestry system might produce fire wood; biomass feed stocks, pine straw mulch, fodder for grazing animals, and other traditional forestry products. At the same time, the trees provide shelters to livestock, provides habitat to wildlife, control soil erosion.

8.2 Benefits

- Enrichment of carbon and nitrogen
- Reduction in soil erosion and nutrient loss
- Siphoning of nutrients from lower layers to the surface
- Improvement in physical properties of soil profile
- Increase microbial activity
- People learn the value of local trees and gain confidence in their local knowledge
- The improvement of soil fertility and conservation
- The improvement of family nutrition
- Fuel wood becomes more available, benefiting the local environment
- The provision of opportunities to improve small holder income
- Provide herbal medicines

8.3 Types of Agro-forestry

- Agro-silviculture (agriculture+trees),
- Silvo-agroculture (trees+crops),
- Silvipastoral (trees+grasses),
- Agro-silvipastoral (treeas+grasses+crops),
- Pastoral silviculture (pasture+forest), and
- Forest based silviculture.

8.4 Qualities needed for agro-forestry trees

- They should have uses that help the farm family.
- Marketability of both wood itself and other products such as nuts or fruit, which would provide another source of income.
- Compatible with the companion crops or forage you choose. Some trees produce growth-inhibiting chemicals which may affect what you can grow.
- High quality.
- Fast growing or of such a high value that a species of medium growth rate is acceptable.
- Deep-rooted so the trees do not compete with the crops or forage for moisture.
- Have rapidly decomposing foliage.
- Be properly matched to the site. Site tolerant, suited to either a wet or dry site.

- The leaves should produce a light, rather than a heavy shade. This will be especially important as the trees mature and the canopy closes. The lighter the shade that is produced, the longer you can grow crops or forages.
- Make sure that the trees are capable of producing the products you desire

8.5 Suitable tree species for different locations

Situation	Tree species suitable
Trees suitable for alkaline soils	*Albezia lebbek (Siris)* *Leucaena leucocephala (Subbul)* *Pangania pinnata (Karanj)* *Terminalia arjun (Arjun)* *Tamarindus indica (Tamarind)* *Emblica officinalis (Amla)* *Acacia nilotica (Bamur)* *Madhuca latifolia (Mahua)* *Dalbergia latifolia (Indian rose wood)*
Best fodder trees	*Leucaena leucocephala (Subabul)* *Tamarindus indica (Tamarind)* *Acacia nilotica (Bamur)* *Ziziphus mauritiana (Ber)*
Best fuel wood trees	*Acacia nilotica (Bamur)* *Madhuca latifolia (Mahua)* *Albizia lebbek (Siris)* *Terminalia arjun (Arjun)* *Terminalia tomentosa (Asan)* *Cassia sp (Chakunda)* *Pongamia pinnata (Karanja)*
Best timber trees	*Dalbergia latifalia (Indian rose wood)* *Dalbergia sisoo (Sisoo)* *Eucalyptus camalldulensis (Eucalyptus)* *Terminalia arjun (Arjun)* *Gmelina arborea (Gambhari)* *Tectona grandis (Teak)* *Peterocarpus marupium (Piasal)* *Shorea robusta (Sal)*
Trees adapted to shallow, rocky soils	*Anacardium occidentale (Cashew)* *Annona squamosa (Custard apple)* *Madhuca latifolia (Mahua)* *Pongamia pinnata (Karanja)* *Azadirachta indica (Neem)*
Fruit trees suitable for dry lands	*Annona squamosa (Custard apple)* *Artocarpus heterophyllus (Jack fruit)* *Borassus flabellifer (Palmyra)* *Emblica officinalis (Amla)* *Feronia limonia (Wood apple)* *Punica granatum (Pomegranate)* *Eugenia jambolana (Jamun)* *Mangifera indica (Mango)* *Ziziphus mauritiana (Ber)*

8.6 Alley cropping

Alley cropping is broadly defined as the planting of two or more sets of single or multiple rows of trees or shrubs at wide spacing, creating alley-ways within which agricultural, horticultural, or forage crops are cultivated. The trees may include valuable hardwood species, such as nut trees, or trees desirable for wood products. This approach is sometimes called intercropping and multi-cropping.

Purpose

Alley cropping diversifies farm enterprises by way of providing short-term returns from annual crops while also providing medium to long-term products from the trees. Timber and non-timber products may contribute to income generation from the farm. In addition to the potential for producing nuts, berries, and fruits, well-managed timber can provide a long-term investment. Alley cropping protects fragile soils through a net-work of roots produced by the trees and supplemental ground-cover resulting from fallen leaves and the companion crop. Rows of trees, shrubs, and/or grasses planted on the contour of a slope will also serve to reduce soil movement down the slope.

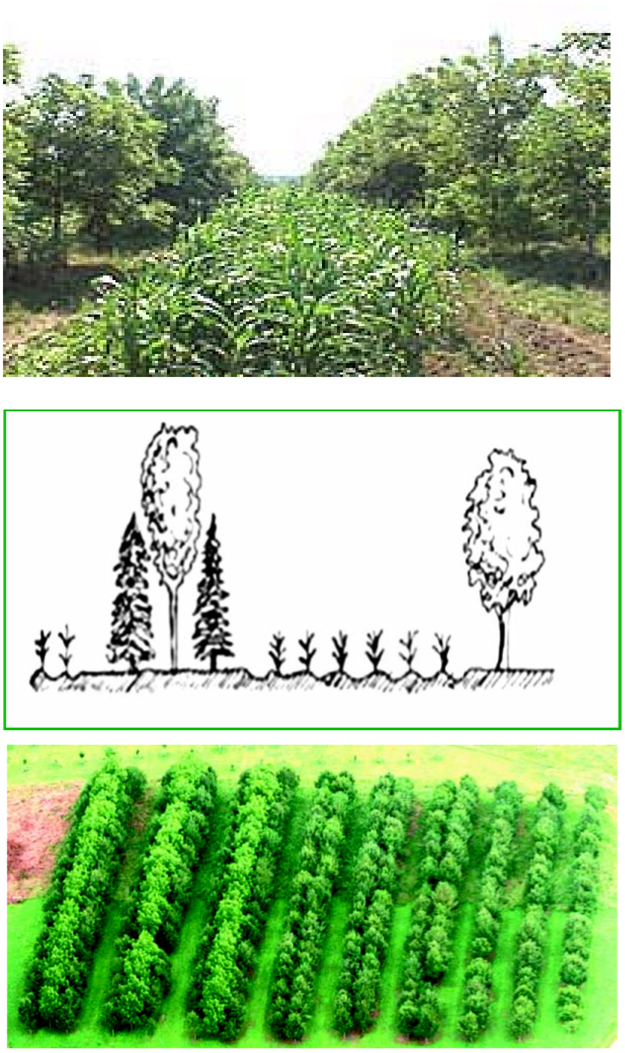


Fig.8.1 Alley Cropping

Desirable characteristics of trees and shrubs

There are a number of desirable characteristics of trees or shrubs that are to be grown in an alley cropping system. It is not necessary (probably not possible) that all the following characteristics be exhibited by one tree specie:

- *Produces a commercially valuable product or multiple products (i.e., timber, nuts) that has an acceptable local market.*
- *Relatively fast growing (medium growth rate on high value trees is acceptable) or highly valued for production or conservation benefits*
- *Produces appropriate shade for the companion crop*
- *Be adapted to a variety of sites and soils*
- *Deep-rooted with minimal roots at the soil surface to minimize competition with crops in the alleyway.*
- *Have foliage with minimal acid-generating potential if companion crops prefer a pH neutral soil. Conifers acidify soil, combine well with acid loving crops.*
- *Does not produce growth inhibitory chemicals (allelochemicals) that would prevent some crops from growing near them (e.g., black walnut)*
- *Have a growing season that complements the companion crop*
- *Produces wildlife benefits*

Species to Grow: The species of trees planted should be able to coppice (resprout and grow well after cuttings). Throughout the growing season, on a rotational system of 3-4 weeks, the branches, branch-lets and leaves of these trees are cut and dropped around the crops growing between the tree rows apart in the rows. The two rows are staggered. They quickly degrade, adding large keep the maximum distance (about 20 cm) amounts of organic matter & nutrients to the soil between the trees. *Firewood trees*

- Often trees are grown for timber. Women are not allowed to cut these trees for firewood.
- Special trees may also be planted by women on farmland for use as firewood. Many trees used in agro-forestry like *Sesbania, leuceana* and *Calliandra* are ideal for firewood.
- Such trees may also be planted as wood lots in a corner of the farm or along a particular border.

Trees for livestock fodder

- Many trees suitable for agro-forestry have leaves and pods that are edible by animals such as cattle, goats and sheep. They can be cut regularly and fed to livestock. Green leaves from trees can often be cut in seasons when other green fodder is unavailable.
- It is usually better to mix leaves from different kinds of trees with other kinds of fodder. Feeding animal’s leaves from just one kind of tree can sometimes cause problems.
- Fodder production will be much higher if leaves are cut and fed to animals rather than allowing animals to graze directly from the trees.

Fruit trees

- All kinds of fruit trees can be grown near crops. They are often very suitable to plant as boundary trees, near to the home or as small plantations mixed with other kinds of trees.
- Some fruit trees grow very large and develop dense shade. These need room to grow and are not suited to combine with growing crops nearby. They include mango and tamarind.
- Other trees have a more open growth and do not develop dense shade. These can be used as boundary trees or grown near crops. They include guava, citrus, banana and cashew nut.
- Passion fruit and chayote are climbers that can be trained to grow up established trees.
- Inter cropping can be taken up during gestation period

Intercropping in fruit orchard

Fruit	**Spacing (m)**	**Time for full coverage**	**Period for intercropping**
Mango	10x10	7 years	5 years
Citrus	6x6	5 years	4 years
Guava	6x8	5 years	3 years

Sapota	10x10	10 years	7 years
Ber	6x6	4 years	2 years
Pomegranate	6x6	4 years	2 years

Trees for farm boundaries

- It is useful to plant some trees on the edges of fields and farms to mark boundaries and provide protection from strong winds.
- Choose trees which are fast growing and which allow crops to grow nearby. They should be trees that will allow pruning or use as fence posts. If possible plant trees that have many uses: for fuel, fodder, timber and fruit production.
- Many local trees will make good boundary trees. It is often good to use a number of different species, especially if hedges are being planted. Boundary hedges help prevent soil erosion.

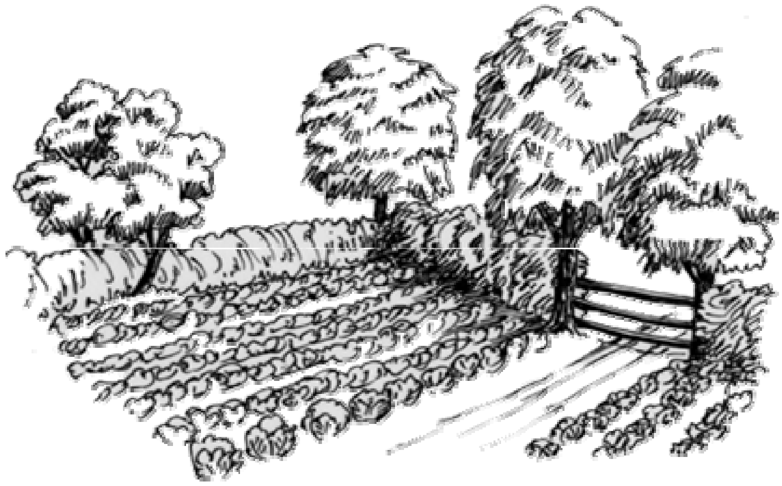


Fig 8.2 Trees on Boundary

Selecting companion crops

Companion crops are planted in the alleys between the tree rows. The choice of companion crop will vary depending on the types of trees selected and the crop(s) desired by the grower. There are three major groups of crops which can be grown in an alley cropping practice: 1) Row/cereal and forage crops; 2) Fruits and other specialty crops; and 3) biomass producing crops.

Steps to be taken

Like all integrated systems, alley cropping requires skillful management and careful planning. Both the crop and the trees have requirements that sometimes necessitate trade-offs between them. The design must allow sufficient room for the equipment needed to service each enterprise. If either crop requires chemical herbicides or insecticides, the other must be tolerant of these treatments. Animals may be kept away from the area during and after chemical use. Livestock can cause damage, even when the trees are fully grown; roots injured by livestock hooves are susceptible to disease. Soil compaction is a danger in wet weather. These examples indicate how crucial planning is to the ultimate success of an agro-forestry system. In most alley cropping systems, trees are planted in straight rows, sometimes with no regard for slope or contour. There are, however, advantages to planting the trees in curves or on the contour.

These include the slowing of surface-water movement and the reduction of soil erosion. The trees can be planted in single rows or in blocks of multiple rows between alleys. The first row in a block is planted on the contour line; subsequent rows are to be planted below the original line according to the slope of the land. The final row of trees in one block is planted parallel to the contour line on which the next block of trees will begin. The width of the tree blocks varies, but the cropping alleyways between them have parallel edges. This design avoids creating point rows within the alleys, thus facilitating easy maneuverance of implements/equipment. The width of the alleys is determined by the size of the equipment to be used.

If planting on the contour is not possible, then trees can be planted in curved zigzags so that water running downhill is captured or at least slowed. Islands of trees can offer some of the same advantages if they don't interfere with cropping operations. In large plantings, fast-growing hardwoods or pines are interplanted as trainers to ensure that the crop trees develop upright, unbranched trunks. Alternatively, the crop trees can be planted close together in the rows, to be thinned and pruned several times as they grow. Although these early-harvested trees may have little market value, their presence during the first years of growth increases the main crop's value. The goal should be to produce long, straight saw logs with few lower branches, for maximum profit at final harvest. Whatever the planting design, trees on the outside edge of a group will grow more side branches, or even a lopsided trunk, resulting in lower-value saw logs.

Operation and Maintenance

Pest management

Periodic inspection of the crops and trees is recommended to detect and identify possible pests. Insects and diseases can be significant factors in reducing the health and vigor of both the tree crop and the intercrop. The corrective actions would minimize the impacts on beneficial insects.

Fertilization and nutrient management

Fertilisers should be applied for the intercrop in the alleyway. Generally, fertilization of the tree crop is not needed, but fertilizing the intercrop may benefit the trees. Competition for nutrients can be minimized by root pruning or by adding more nutrients. Nutrients can be added in the form of chemical fertilizer, animal manure or a wide range of other materials. This may also include the use of living mulches or green manures.

Canopy management (Pruning)

If there is too much shade under an existing stand of trees, the canopy can be pruned to allow more light to reach the under storey plants. This can be accomplished by clear-stem pruning for improved timber production. This involves the removal of lower branches on the stem of a tree in order to raise the height at which the canopy begins. Remember, removing more than 40% of the trees foliage will significantly reduce the growth of the tree. It is best to always have 40-50% of a tree's height in crown or foliage.

Periodic root "training" will improve crop yields

Research findings have shown that even during the early years of tree development, competition for water and/or nutrients is the major reason for reduced crop yields. By early (beginning with young trees) and repeated (every couple of years) severing of lateral roots, the number of tree roots can be significantly decreased in the plow zone. Row crops will continue to produce commercial yields even as shade levels increase.

Weed Control

Weed control for an alley cropping includes both for the trees as well as the intercrop. For the tree row(s), weeds need to be minimized at least for the first three to five years in a band about three feet on each side of the trees. Weed removal can be done different ways, from herbicides and cutting to cultivation. An additional consideration for use in controlling weeds adjacent to trees may include mulch, fabric barriers or living mulches. Nothing will improve the growth of trees and shrubs like the control of competing grasses

Maintenance tasks specific to trees

- *Replanting: Replant all trees or shrubs that have failed during the first 3 years.*
- *Branch Pruning: Pruning of the trees may be necessary to improve wood quality, the micro-environment for the companion crop, allow equipment access, or correct storm damage.*
- *Root Pruning: Pruning tree roots (up to 24 inches deep) projecting into the companion crop area may reduce competition. Do not prune both sides of the trees the same year. Allow a 3-year interval before pruning the other side. Pruning will need to be repeated on a 5- to 8-year interval.*

Thinning

The tree rows will normally need to be thinned to increase light in the alley-ways and speed production of high value crop tree s. It is best to always have 40-50% of a tree's height in crown or foliage.

Design: Spacing among the rows of trees and among the trees themselves is highly variable. One of the major considerations is that the rows should run east to west - following the path of the sun to ensure that there is not too much shading among rows. Spacing between rows ranges from 4 to 20 meters, depending on the farmer's preferences. Spacing of 4-5 meters among rows will create a labor-intensive system that will produce large quantities of wood and quickly revitalize worn soils with the massive amount of leaf fall.

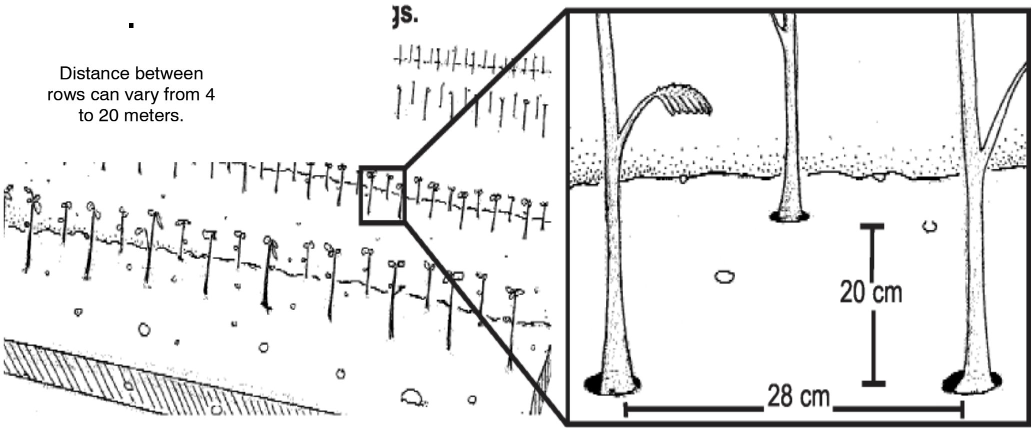


Fig.8.3 Spacing Among Seedlings

Harvesting: The rows of trees are often harvested at 50 cm to 1 meter height. Branches are used for construction and fuel wood, and leaves are mixed into the soil as an organic fertilizer, though leaves of some species like *leucaena* are also collected and used as a high-protein animal forage (after which the manure can be added back to the soil)

Silvo-pasture

Description

Tree and pasture combinations are called *silvo-pastoral agro-forestry*. Hardwoods (sometimes nut trees) and/or pines are planted in single or multiple rows, and livestock graze between them. Although both the trees and the livestock must be managed for production, some systems

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8.7 Silvo-pasture

Tree and pasture combinations are called *silvo-pastoral agro-forestry*. Hardwoods (sometimes nut trees) and/or pines are planted in single or multiple rows, and livestock graze between them. Although both the trees and the livestock must be managed for production, some systems emphasize one over the other. Usually, in the early years of establishment, crops or hay are harvested from the planting. Grazing generally begins after two or three years, when the trees are large enough that the livestock can't damage them. In other instances, tree tubes and electric fencing protect the young trees, and grazing begins immediately. Grazing livestock on silvo-pasture eliminates some of the costs of tree maintenance. With good grazing management, for example, herbicides and mowing may not be necessary. Grazing also enhances nutrient cycling and reduces commercial fertilizer costs; the animals remove few nutrients, and their waste is a valuable input for the trees. Well-managed grazing will increase organic matter and improve soil conditions. However, controlling the number of animals per acre, limiting the number of days those animals remain on each site, and avoiding compaction are critical for a successful silvo-pasture system.

Purpose

The objective of employing silvo-pastoral practices is to integrate trees, forage, and grazing herbivores for a production benefit.

Components of a Silvo-pasture Practice

Silvo-pasture practices are different from other types of agro-forestry because they require land-owners to manage livestock, as well as trees and forage plants. This three-way interaction means there are three factors to consider when designing the agro-forestry practice: live stock, trees and forages. The four variables in a silvo-pastoral practice that requires efficient management are livestock maintenance, tree species, tree density, and forage species. The majority of research conducted has evaluated silvo-pastoral practices under conifers (mostly pine) with only limited evaluation of hardwood-based practices. Most hardwood re-search has been conducted with either oak species or nut-bearing species (e.g., black walnut). In certain instances under deciduous tree stands, forage production has been reported to be equal or even greater than in open exposure to sunlight. Fescue and orchard grass production has been shown to be greater under a 35-year-old walnut canopy than in open pastures.

Establishing pastures in the forest

1. **Prepare your site for seeding as soon as possible** after thinning (crop tree) or harvesting (selection cutting or improvement harvest) from the forest, so native vegetation doesn't have a chance to respond to canopy removal and invade the site.

2. **Seed immediately after site preparation** (light fire or disking, and necessary soil amend-ments like lime or fertilizer) to give domestic forage the jump on native competitors.

3. **Lay out pastures and fencing** for rotational grazing.

4. **Install water supply** to meet livestock requirements.

Cultivation Techniques

Obtaining young trees

- You may be fortunate to have a nearby nursery that has a good supply of tree seedlings.
- However, most farmers who want to plant a lot of trees will find it best to grow their own trees. This means you can choose the kind of trees you want; you can have seeds or seedlings available when you need them and you can generate additional income by selling extra trees to other farmers.
- Many farmers simply let trees grow themselves. However, to grow trees and crops together, you need to plant useful trees exactly where you want them. For most local trees you will be able to collect your own seed. Ask an extension or forestry worker about how to obtain exotic tree seed.

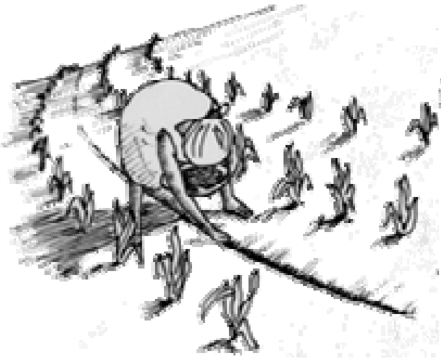
Collecting and storing tree seeds

- Make it a habit to carry some bags or old envelopes with you so that you can collect seed from good trees.
- Collect only fully ripened seed from strong healthy trees. Seeds in pods or fruits need to be removed. With sticky fruits like tamarind they need to be either eaten or soaked in water before the seeds can be removed and dried.
- Seed must be well dried before storing. Use clear labels. Some seeds, especially those that are very hard, may stay good for many years. However some soft seeds such as neem or kei apple can be kept for a few weeks. Use fresh seed whenever possible.

Fig.8.4 Seed Collection Storing

Direct planting of tree seeds

- Many trees can be sown directly into the ground. Plant lines of seeds following the contour line, or around the outside of a plot of land.
- Plant the seeds either just before the rains begin or early in the rainy season. If the rains fail, it may be worth the effort of watering the young seedlings once or twice if possible.



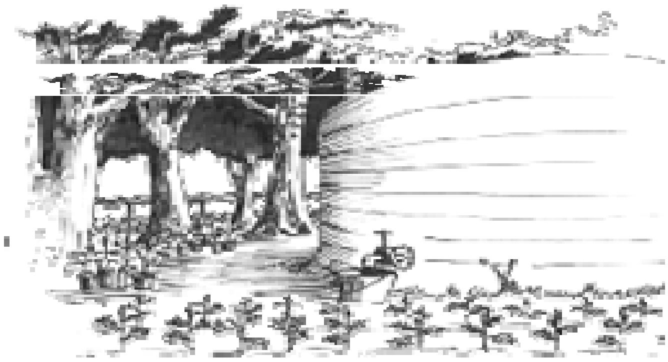
At planting Six months later

- Some trees can also be grown from cuttings or stakes. Cut poles from trees like gliricidia, moringa and calliandra into sections. Remove most of the leaves. The cuttings can either be 30–40cm long and planted at an angle, or alternatively they can be up to two metres long and planted upright so that the shoots will be out of reach of animals.

The spacing for tall growing trees should be 6x6m to 10x10m and for fuel and timber trees it should be 3x3m whereas for multipurpose trees it should be 5x5m.

Preparing a tree nursery

- It is very simple to build and look after a tree nursery. This can range from just a few trees growing in shade near your home to a large nursery with hundreds of young trees.
- A larger nursery should be close to a permanent water source and on level ground that does not flood during the rainy season. The soil should be fairly fertile. The site should be kept free from animals.
- For a small nursery, it is probably best to have it near the home where the young trees will be protected from animals and thieves.
- Unless there are large trees to provide good shade, you will have the need to build shades.



Suitable containers for tree seeds

Fig.8.5 Suitable containers for tree seeds

Seeds can be planted in all kinds of containers. Plastic tubes, milk cartons, plastic bags, tins or broken pots all make good growing containers. All should have a few holes in the base for water to drain out.

Fig.8.6 Seed Planting

Seeds can also be planted in beds. Make raised beds of 60cm wide and as long as required, using timber, split poles, stones or freshly split sisal poles. If you have plenty of timber you can also make small moveable boxes 40cm x 40cm with wooden bases. Paint timber with old engine oil.

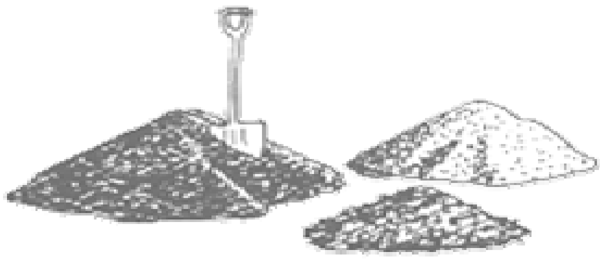


Fig.8.7 Soil Preparation

Use good fertile soil for filling containers and seed beds. If possible some of this soil should come from underneath well-established trees, as this soil will contain organisms that help the growth of tree roots. Mix four parts of good soil with two parts of clean river sand and one part of old dry manure. Mix together well when dry. Fill containers carefully and shake down the soil to allow for settling.

Nursery practices

- Raising seedlings
- Stump planting
- Branch planting/cutting
- Root cutting
- Layering
- Budding

Care of young seedlings

Fig.8.8 Care of young seedlings

As the seeds grow, they develop into seedlings. These need room to develop. Thin out to leave just one seedling in each container and well-spaced seedlings about 5cm (the length of a finger) apart in beds.

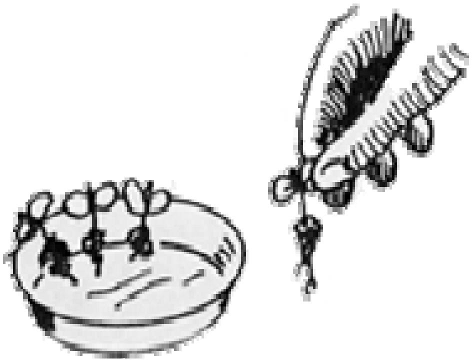


Fig.8.9 Thinning of Seedlings

With care, you can prick out seedlings into empty bags or new beds. Loosen the soil with a knife. Lift seedlings up gently with some soil attached to the roots. Replant them carefully into empty containers or beds.

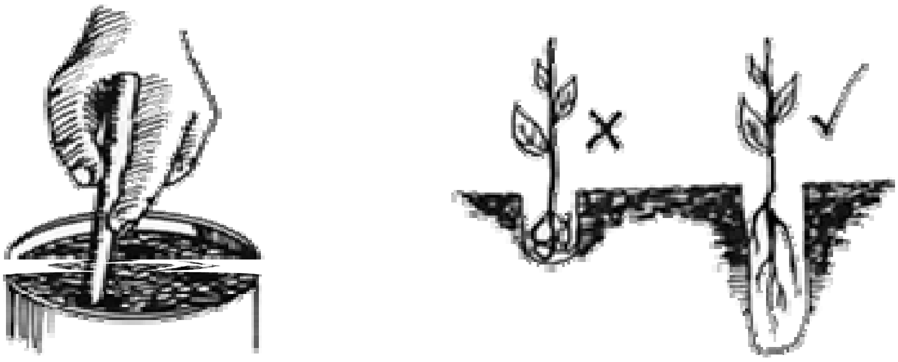


Fig .8.10 Planting of Seedlings

Use a stick to first make a hole and place the seedling into this, allowing plenty of room for the roots. Press soil firmly around the seedling. Do not plant it deeper than it was before. Keep young seedlings well weeded.

Root pruning

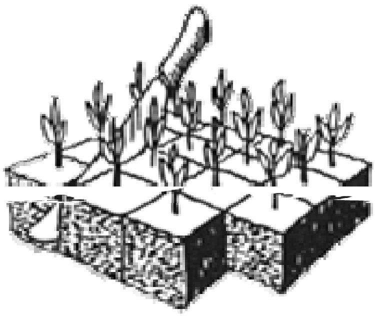
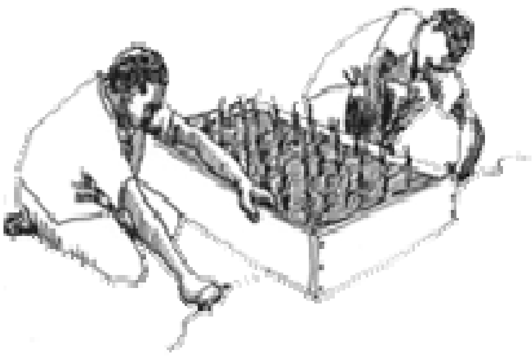
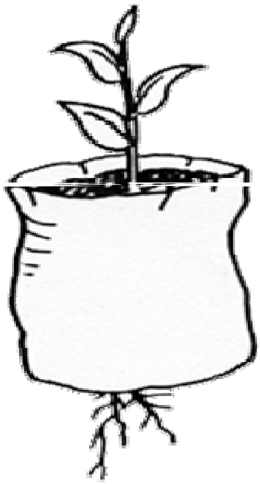


Fig .8.11 Root Pruning

Seedlings planted in large seed beds need special care to prevent the roots growing together and becoming mixed up. As the seedlings grow, the roots should be regularly pruned to encourage strong root growth. Cut the soil into squares to separate the roots.



Use a strong wire (such as an old guitar string) to prune the roots underneath the beds as well. This work is easier with two people.



With trees growing in containers, simply move them each month and cut any roots growing outside the container.

Hardening off

For the last four to six weeks in the nursery the seedling trees need to be 'taught' how to survive outside the nursery where there is no shade and where it does not rain every day. This is called 'hardening off '.

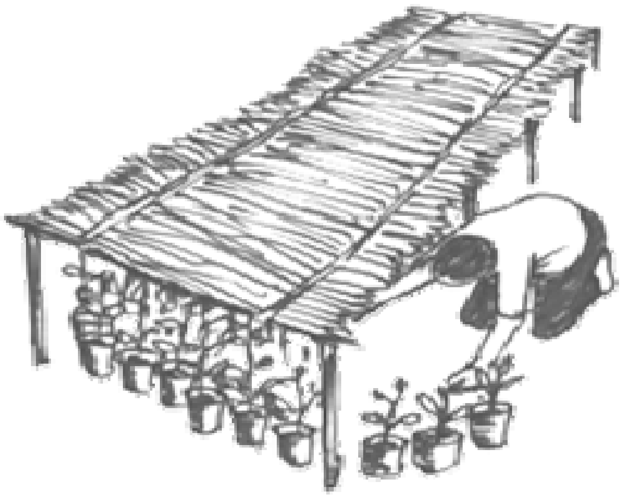


Fig. 8.12 Hardening off

If a shade has been built over the seedlings, gradually remove the shade over several weeks. Slowly reduce the amount of water. However, do not let the seedlings wilt in hot sun. If grown under a tree, move the seedlings to the edge of the shade so they are in full sun for part of the day.

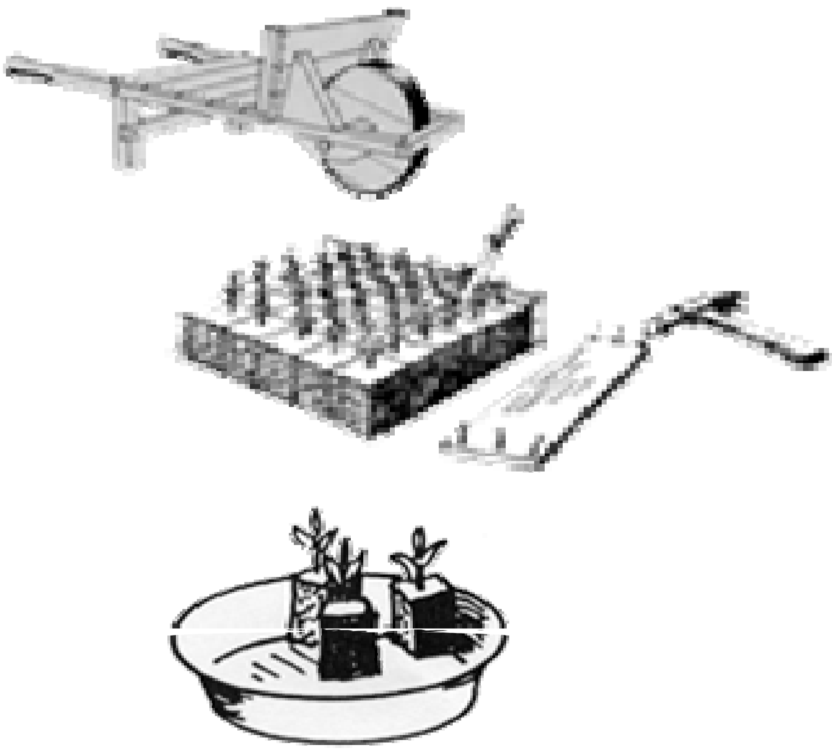
Fig .8.13 Prepare the Planting holes

A week or two before planting out, prepare planting holes. Dig a hole about half a metre deep (nearly knee deep). If possible, break up the hard rocky subsoil in the bottom of the hole and add a little manure.

Planting out tree seedlings

Ordinary pit, saucer pit, ring-pit, ridge-ditch, shelved trench, double trench, trench ridge, trench mound are usually prepared before planting

If possible, only plant out seedlings on cloudy days when rain has made the soil really wet. Late afternoon is the best time to plant them out. Water large seed beds well in the evening before planting. Remove two end pieces and cut the trees out carefully. Carry them carefully in a bowl or box to the planting site.



Don't water containers before planting. The soil will then stay firm when the container is removed so the roots will not be disturbed. They will also be easy to carry! Water them well straight after planting.

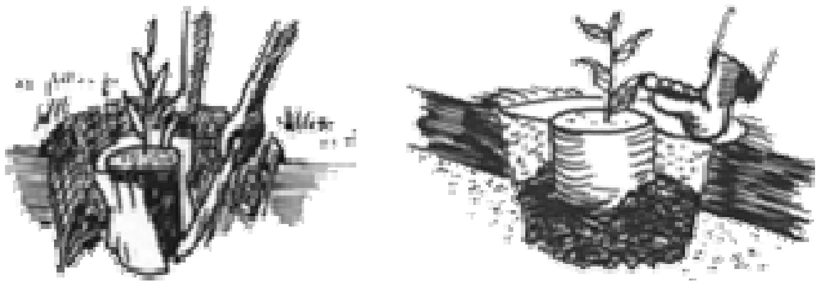
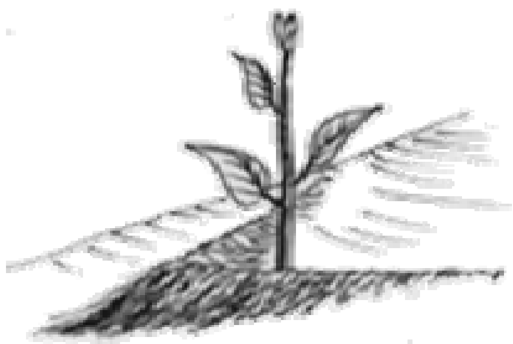


Fig .8.14 Planting & Seedling

Place the seedling in the hole at the right level, gently remove the bag or container without disturbing the roots, replace the soil and press down firmly. Cover the soil with cut grass or leaves to keep the soil damp.

Giving young trees a good start

Make a small hollow around the tree to catch water. Keep clear of weeds.



If trees are planted on a slope, make V-shaped ridges to catch and hold rainwater.

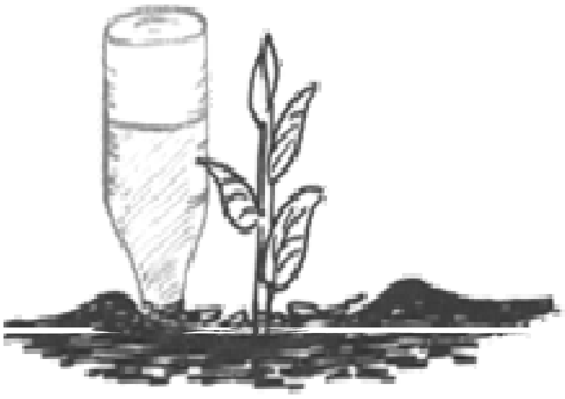


Fig .8.15 Watering the Seedling

During dry periods, if seedlings are planted near the house or a water source, fill a bottle with water. Quickly turn it upside-down and press it into the soil near the roots. The water will slowly seep into the soil.

Fig .8.16 Protection of Seedling

Protect the trees from animals by using branches or thorns or a fence built round the tree.

Planting steps for polythene bagged seedlings.

- Dig cubical/circular pit and refill with mixture of good earth, manure and sand up to ¾ depth
- Remove polythene carefully cutting the bag
- Open the bag and remove the earthen ball without injury
- Place it in the pit gently
- Firmly and gently soil around the stem
- Water the seedling
- Put a stick near the plant and tie it loosely with the plant

8.8 Living Fence

Purpose: A living fence is an animal-proof barrier composed of trees and shrubs planted at close spacing around the perimeter of a field. Not only do living fences reduce the need (and cost) for standard fencing, but the trees and shrubs utilized in living fences can produce tangible benefits such as food, fuel wood, fodder, and other raw materials

Desirable characteristics of trees used in living fences: Tolerate minor "injuries": living fences are susceptible to frequent injuries from pruning or animals and should tolerate them well.
•Fast growing: provide benefits to families as soon as possible.
•Compatible with crops: cannot have adverse effects on other tree species or crops they are associated with.
•Produce useful products like fodder, green manure, & fuel wood
•Protection- stiff branches, thorns, spines, nettles, or irritating latex to keep animals out.
•Vegetative propagation: ensures fast establishment while reducing the chance of spreading to pasture and cultivated areas.

Design: Thorny species *(Acacia sp., Parkinsonia, Prosopis, Ziziphus,* etc.) tend to work best in living fences, though many people also use non-thorny species. Spacing among individual trees for most living fences varies between 25 and 75 cm, depending on the amount of rain and the rate of growth of the species used. Cuttings of euphorbia bushes and other non-thorny species must be planted very close together (10-20 cm). Most living fences in trees for the future's projects tend to space seedlings 40-50 cm apart. Farmers who can afford barbed wire will often plant trees for living posts, and attach barbed wire once the trees reach the appropriate size . If the trees are being planted inside a dead fence, plant the seedlings 1 meter away from the existing fence (even if it looks like you will be losing ground), or falling sticks and weeds near the old fence can crowd and kill the seedlings. It is best to stagger two rows of trees for any living fence instead of having only one line. A variety of species should be planted & branches should be woven into the lower levels of the fence to create a strong barrier.

Pruning & Harvesting: The key for a good fence is to encourage early branching, because animals can only penetrate a living fence if there is not enough lower branching. If you wait too long and let the trees grow tall, it will be difficult to get them to grow lower branches. The seedlings must have their terminal buds pruned in the nursery stage and then again after they grow to 75 cm. Once mature, the trees can be pruned at the 1.5 to 2 meter height every year. Major pruning is best done during the dry season while trees are still in dormancy.

8.9 Contour Planting

Contour planting can minimize soil erosion on hillsides by up to 50%. Contour lines refer to a set of points on a hillside that are all at the same altitude.

Purpose: Contour plantings are vegetative strips that follow contour lines. They minimize hillside erosion by creating living terraces that encourage the infiltration of rainwater into the soil while slowing the speed of water washing down the hillside.

Planting

Step 1) Find and Mark the Contours

Find the contour using an A-frame, a water tube, or markers. Start creating contour lines at the top of the hill and move down to the bottom. Start on one side of the field and, using the A-frame, find the contour as it meanders across the hillside, marking it with sticks or rocks. To provide maximum protection, the rows should be properly spaced. The vertical drop between contour rows should be about 1-2 meters. This does not mean 1-2 meters between rows, but rather the vertical drop (also known as the vertical interval) between rows should be 1-2 meters. Hillsides with a gentle slope will have long distances between rows (though it is best to limit this to 5 meters), while those on steeper mountain-sides will be closer together.

Step 2) Prepare the Lines

Using your markers as a guide, dig two channels along each contour line, leaving about 50 cm between channels. An animal drawn plow will greatly help. These channels will be used for seeding the trees. Note well: Some technicians suggest digging one major channel along the contour and seeding on the uphill mound created by the channel.

Step 3) Plant the Seeds/Seedlings

Pretreated seeds of multipurpose, fast-growing, nitrogen fixing trees can be sprinkled heavily along the channels. Cover the seeds lightly yet firmly with soil. Suggested species include *G. sepium, C. calothyrsus,* and *L. leucocephala.* You may also decide to plant seedlings or cuttings along the channels.

Step 4) Protect the Seedlings

The first year is critical for success. Extremely heavy rains, animals, and farmers themselves can ruin the work. If possible, the fields containing the newly planted contour rows should either not be cultivated in the first year or cultivation should be minimized. Be sure to weed the newly planted seedlings.

Step 5) Diversify

Beginning in the 2nd year, diversify the contour hedges with short-, medium-and long-term crops.

8.10 Important Agro-Forestry Trees with N-Fixing Quality

Leucaena sp (Subabul)

It is a fast growing, deciduous small tree or shrub, reaching up to 20 m tall. Native to the American tropics, improved varieties of Leucaena are now being developed on nearly every continent. It is predominantly self-pollinating and therefore gives forth offspring similar to the mother tree.

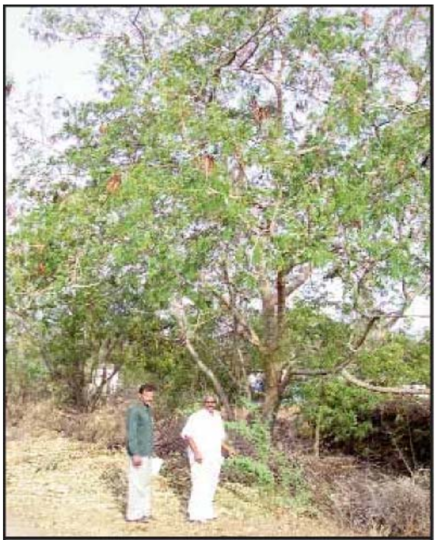
Agro-forestry Uses: FERTILIZER: Leaves are high in nitrogen and are good organic fertilizer. WINDBREAKS: Good, tall filler in windbreaks because leaf density is full yet not too thick, space ~3-4 meters apart. LIVE FENCING: Fast growth speed makes it great for live fence posts as long as animals do not eat the seedlings before they mature. WOOD: Coppiceable, dense wood good for fuel wood and pole timber. ANIMAL FORAGE: The high protein quantity and the sheer amount of leaves well into the dry season make it a great source of forage. However, it contains mimosine, an irregular amino acid, and should be fed in limited amounts to non-ruminant / single stomach animals (none at all to horses or mules). For ruminant animals (cattle, goats, sheep), it can be fed from 20-30% of the diet. Lesson 4, page 27, has more details. ALLEYCROPPING: Nitrogen fixing; can be planted on flat terrain or in contour lines on slopes, Leucaena makes great hedge rows that produce organic fertilizer, pole timber, and serve as windbreaks. FUEL: Quality fuel and charcoal.

Characteristics: Growths rates are fast, and crown shape and branch formation are all similar. It has narrow canopy up to 20 meters tall, sometimes higher. Very coppiceable. *L. colinsii* and *L. salvadorensis* have very similar properties as *L. leucocephala.*

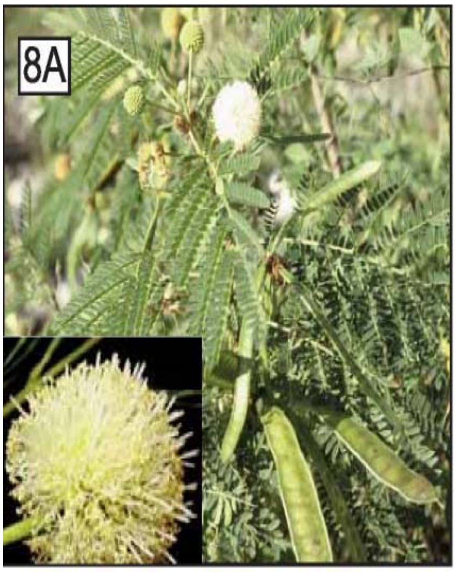
Site Requirements: Grows best in full sun, though can handle partial shade. Tolerant of many types of soil and terrain, but tends not to fare well in acidic soil. Can tolerate light frost though will likely be defoliated.
L. leucocephala: Altitude 0-1 500 m; Rainfall 650-3,000 mm L. collinsii: Altitude 100-900 m; Rainfall 500-1,000 mm L. salvadorensis: Altitude 200-1000 m; Rainfall 800-2,000 mm

Propagation: *L. leucocephala:* Soak in boiled water for 2 minutes, then add cool water. Soak for 24 to 72 hours. Another option is to scarify the seed coat. Make sure not to damage the radicle/embryo (the pointed side of the seed). *L. collinsii:* Soak in boiled water for 30 seconds, then add cool water. Soak for 24 to 72 hours. Scarification is more effective. Make sure not to damage the radicle/embryo (the pointed side of the seed). *L. salvadorensis:* No pretreatment required

Pests and Diseases: A myriad of insects, fungi, and animals attack Leucaena, yet few cause serious damage. Widespread leaf loss from psyllids in the mid-1980's is less of a concern for new, more resistant varieties. Adult trees have very few problems, though seed loss by seed weevils and flower loss by moth larva have been reported. Grazing animals are by far the greatest problem.



Leucaena tree form



Sesbania sp.(Agasthi)

Thought to be originally from Egypt, *S. sesban,* a short nitrogen fixing tree, is good for animal fodder and fuel-wood. *S. sesban* and *S. grandiflora* share many qualities, though *S. sesban* is better for drier climates.

Agroforestry Uses: Difficult to establish in highly-grazed areas because it is favored by animals. FORAGE: Leaves are a good source of protein for cattle and sheep. WOOD: Coppiceable; light wood is good for cooking; yields excellent charcoal; branches and stems used for light construction. ALLEYCROPPING: Can be intercropped with corn, beans, cotton and many other field crops. Serves as a support for grapes and black pepper. Also used as a shade tree for coffee and turmeric. Grown as a support for sugarcane, each plant bracing six canes. SOIL RECLAMATION: Planted on fallow land for soil improvement. Harvested leaves make a rich compost. WINDBREAK: Applicable around vegetable gardens, but often too short for protecting large crop fields.

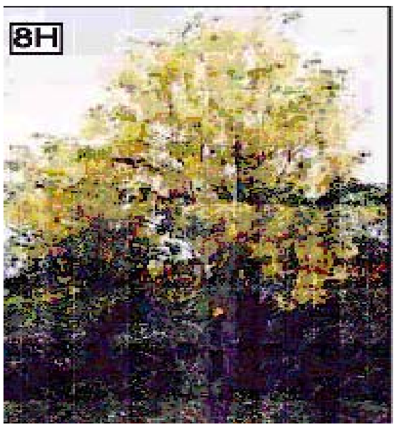
Characteristics: Fast growing, short-lived tree with many branches. Tends to develop into a shrub or small tree of about 4 to 15 meters tall. Flowers for either species can be pink, purplish, white or red.

Site Requirements: Tolerates saline, acidic, or waterlogged soils. Prefers between 500 and 2000 mm rainfall. *S. sesban* is able to grow at elevations between 100 and 2300 meters.

Propagation: SEEDS: Very susceptible to insect attack and should not be stored for over 1 year. Plant 2 seeds per sack 12 weeks before out planting. Weeding around seedlings recommended in the first month after out planting. Bare stem propagation.
S. sesban: Scarification is recommended. Make sure not to damage the radicle/embryo (the pointed side of the seed). S. grandiflora: Scarification helpful, or soak in cold water for 24 hours. Make sure not to damage the radicle/embryo (the pointed side of the seed).

Cassia and Senna species

Senna siamea is a fast growing evergreen native to Southeast Asia. It tolerates both arid lands and tropical climates. Because of its fast growth and quick regeneration from coppicing, it is applicable to many agroforestry systems. It is very popular in arid regions, particularly West Africa..



Agroforestry Uses: Leaves are high in nitrogen and great as an organic fertilizer. WINDBREAKS: Good, tall filler in windbreaks, space at 3-4 meters. LIVE FENCING: Growth speed makes great live fence posts. WOOD: Dense wood, great for fuel wood and pole timber, very coppice-able. BEE FODDER: C. fistula is popular with bees. ANIMAL FODDER: **Leaves are highly toxic to pigs** but are an excellent source of forage for ruminant animals. DISPERSED TREE: Good for shade around houses, roads, schools.

Characteristics: Rainfall as low as 500mm may inhibit growth from exceeding 5 meters, yet rainfall up to 1500mm can allow growth to 20m. Lateral roots have been reported to compete with crops in alley cropping, so should be kept out of gardens and crop fields (though makes a great windbreak/boundary planting). Seeds all year round. Produces large quantities of biomass, but does not fix nitrogen.

Site Requirements: The dry season cannot exceed 8 mos. SUN: Enjoys full sun. is sufficient, but cannot tolerate poor or skeletal soils. *C. fistula:* Altitude 0-1 200 m; Rainfall 480-2,700 mm *C. siamea:* Altitude 0-1 200 m; Rainfall 400-2,720 mm

Propagation: Be sure not to seed too deep (only ~1/2 cm deep). Seed 4-5/sack if hot soaked and 3-4/sack if scarified by hand. Keep soil moist and in a sunny place. Propagation by cuttings up to 2 meters in length is possible. Weeding is necessary for the first one or two years of growth during which they require pruning to develop a straight trunk.

Pests and Diseases: Insects are quick to attack harvested or splintered wood.

Albiza lebbeck(Siris)

Overview: Native to India, sub-tropical Africa, Asia, and northern Australia, Albizia trees are now widely cultivated throughout the tropics.

Agroforestry Uses: SOIL: Nitrogen-fixing tree, produces green manure. INTER-CROPPING: Good companion plant for coffee and tea. WINDBREAKS: Good for shelterbelts, but not in areas with little to no precipitation. FODDER: Leaves, flowers and pods make good fodder. TIMBER: Coppiceable, good for fuel wood and to work. BEE FODDER: Large 5cm-long flower heads are attractive to bees. bark used in soap-making. Good for roadside and village plantings.

Characteristics: Medium-sized deciduous tree, usually 6-12m high, fast meters in areas with high precipitation. Tolerates light frost.

Site Requirements: SUN: They grow best in full sun, but will tolerate partial shade. SOIL: Prefers loamy soils, but can grow on sandy, weathered soils. Tolerates acid and alkaline soils, as well as salt spray.

P. falcataria: Altitude 1-1 200 m; Rainfall 2,000-4,000 mm *A. lebbeck:* Altitude 0 -1,800 m; Rainfall 500-2,500 mm

Propagation: Sow 2 seeds/pot, 15-18 weeks in the nursery in partial shade before transplanting to beds at beginning of rainy season. Can be propagated by cuttings and root suckers. Bare stem propagation should be applicable. *P. falcataria:* Soak in boiling water for 3 minutes, then add cool water and soak for 24 hours.

A. lebbeck: Scarify, making sure not to damage the radicle/embryo (the pointed side of the seed) and then place in boiled water. Let water cool and soak the seeds for 24 hours.

Pests and Diseases: Susceptible to damage from high winds and from attacks by insects and rodents.

Overview: Gliricidia is a nitrogen fixing tree known through-out the Americas as "Madre de Cacao" or "Madera Negra". Because of its high output of hard wood and rich leaf litter, it can play a major role in agroforestry systems.

Agroforestry Uses: FUELWOOD: Good quality. TIMBER: Strong wood used in heavy construction, tools, posts, and furniture. BEE FODDER: Good for supporting honey production. FORAGE: Leaves not widely used for animal forage because some animals dislike the taste, but palatability improves when leaves wilt overnight . FERTILIZER/ALLEYCROPPING: Great source of green manure and leaf litter. Leaves have a high concentration of nitrogen, when submerged in water for 20 days they produce a strong natural fertilizer. Easy to establish as an alley crop. LIVING FENCE : Though lacking thorns, it is relatively easy to establish hedges, especially when propagated by cuttings. OTHER: Mix mashed seeds or boiled bark with food bait to kill rodents.

Characteristics: Very fast growth rate, possible to reach 4.5 meters in a few months from cuttings. Known to have strong lateral root system that can sometimes inhibit growth of surrounding vegetation. Flowers are usually pink .

Site Requirements: RAIN: Prefers over 1000 mm yet can survive with as little as 700 mm, not drought tolerant. SOIL: Tolerates salinity and many soil types.

Propagation: SACKS: No seed pretreatment. Seed 2 per sack 8-12 weeks before out planting. CUTTINGS: Small cuttings may be placed in sacks or directly in the ground. They may need some water during the first dry season because root structure may not be as developed as those started from seeds. Larger cuttings, 15cm wide and 2 m long, allow for fastest growth. Scrape the base of the cutting to encourage rooting. Place 2 m cuttings ½ m in the ground a couple weeks before heavy rains begin.

Pests and Diseases: Not a target of any specific pests, though reported to be one of hundreds of plants that host the pink hibiscus mealy bug, a serious (sub) tropical pest around the world.

Overview: Originally from India and Burma, this broad-leaved evergreen and cousin of mahogany is now used throughout the world .

Agroforestry Uses: WINDBREAKS: With 4m spacing, creates a great windbreak. WOOD: Begins producing timber after 5 years. Best if coppiced 1.5 or 2 meters height. Major source of straight poles. SOIL RECLAMATION: Tolerance to most soil conditions, high survival rate, and resistance to grazing animals make neem a solid pioneer tree for reforesting lands, delineating field crops, or trying to establish any type of border planting (i.e. windbreak, living fence). SHADE: Used for shade in family compounds and along roads. PESTICIDE: Submerge leaves and crushed kernels in water overnight to make a great natural pesticide. Neem has over 20 active chemicals, the most important of which is azadirachtin, which help to repel and distort the reproduction cycles of numerous insects, nematodes, fungi, bacteria, and even viruses. Solution should be applied once every week on garden vegetables, field crops, and tree nurseries. Leaves can be used when making soap to give it antimicrobial and insecticidal properties. Warning: direct sunlight on leaves will destroy the pesticide ingredient. Neem is NOT poisonous to humans. BEE FODDER: Clusters of small white flowers attract many bees. Pesticides are not present in the honey .

Characteristics: Up to 30 meters tall, trunk usually not thicker than 1 meter. Very fast growth rate, up to 6 meters in a year. Very coppiceable. Neem trees should not to be planted among gardens or alley-cropped with field crops because it absorbs a lot of water and may compete with other plants. Seeds often dispersed by birds and fruit bats that eat the sweet yellow fruit around the seed kernels.

Site Requirements: Grows almost anywhere. RAIN: Prefers 400-1200mm of rainfall but can tolerate both drought and higher rainfall. Water logging can kill trees. ALTITUDE: Sea level to 700m, and as high as ~1000m around the equator. SOIL: Neem can withstand dry, infertile soil, as well as acid soils. Slightly salt-tolerant. TEMPERATURE: Thrives in extreme heat, but dies in freezing temperatures.

Propagation: SEEDS: Normally do not store well over 6 months. Seeds should be cleaned with water to improve germination. No pretreatment necessary. Seed in sacks 12 weeks before out planting. Bare stem and direct seeding is successful. Cuttings possible, but propagation by seed is most common.

Overview: The genus Ziziphus belongs to the Rhamnaceae family, and has about 100 species of deciduous or evergreen trees and shrubs distributed in the tropical and subtropical regions of the world. The fleshy seed coats of several species are rich in sugars and vitamins, and this fact has made Ziziphus species important fruit trees for many centuries.

Agroforestry Uses: LIVE FENCING: The trees are excellent for live fencing. When coppiced, the branches grow laterally and can easily weave with neighboring branches. The sharp thorns deter most animals. SOIL STABILIZATION: Planting Ziziphus reduces the rate of desertification and soil erosion in deserts by stabilizing sandy tracts and dunes. FODDER: The leaves and twigs can be used as high nutritional fodder for livestock. WOOD: Excellent fuel-wood tree and makes a good charcoal. FOOD: Fruits of all Ziziphus species are edible . MEDICINAL USES: Fruits are applied on cuts and ulcers, employed in pulmonary ailments and fevers, and sometimes mixed with salt and chili peppers to be given for indigestion. The seeds are sedative and are taken, sometimes with buttermilk, to halt nausea, vomiting, and abdominal pains in pregnancy.

Site requirement: Ziziphus lives in a wide range on climates. ALTITUDE: It is found in altitudes between 300-1000m. RAINFALL: Prefers annual rainfall ranging from 120 to 2200mm but the tree is drought resistant and can survive salinity and water logging. SOIL: The best soils are sandy loam which may be neutral or slightly alkaline, but it will grow on a wide variety of soils. It is also able to survive injury and fire damage.

Propagation: No pretreatment is needed, but storage of seed for 4 months before sowing improves germination. The seed will germinate in 3-4 weeks if you remove fleshy seed coat and crack hard outer shell before sowing. For fastest germination, extract the internal seed from the hard shell. This is easiest done utilizing a mortar and pestle.

Pest and Disease: The greatest enemies of the jujube in India are fruit flies, *Carpomyia vesuviana* and *C. incompleta.* It has been found that treatment of the ground beneath the tree helps reduce the problem.

8.11 Recommended Spacing for Some Common Tree Sp.

S.No	Tree spp	Common name	Fruit/Seed collection period	Av. Seeds per kg	Planting distance(m)
1	*Acacia nilotica*	Babul	April-June	7000	4x2
2	*Acacia mangium*	Aust. Teak	Dec-Feb	30,000	5x5
3	*A.Lebbeck*	Siris	Sep-Oct	10,000	5x5
4	*Anacardium occidentale*	Cashew	April-June	180	7x7
5	*Azadirachta indica*	Neem	June-July	4400	5x5
6	*Dalbergia sisoo*	Sisoo	Dec-June	14,000	5x5
7	*Leucaena leucocephala*	Subabul	Nov-Dec	30,000	4x2
8	*Pongamia glabra*	Karanj	April-May	1500	5x5
9	*Tectona irandis*	Teak	Feb-March	2500	5x5
10	*Terminalia arjuna*	Arjun	April-May	200	5x5
11	*Ziziphus mauritiana*	Ber	Dec-Jan	1500	6x6
12	*Tamarindus indicus*	Tamarind	May-June	-	8x8

8.12 Estimate for Live Fencing (for 1000 rm)

S.No	Item	Unit	Unit cost	Amount (Rs)
1	Survey and alignment	5 MD	90	450
2	Earth work for bunding of 1000 rm 1000 x { (0.90+0.30)/2}x).30 m =180 cu m	180 cu m	36/ cu m	6480
3	Live posts to be planted at 3 m spacing of	333	6	2000

	size 4-6" girth and1.5 m ht with species like jatropha, ficus, gliricidia, mai etc.			
4	Collection or propagating shrubs of duranta, vitex, moringa, ipomea or kaniar etc.	1000 m	4	4000
5	Wrapping brush wood with splitted bamboo of 6 m length (one bamboo can be spitted into 6 pieces)	33 bamboo	125	4125
6	Labour cost for fencing including binding with split bamboo and binding rope	1000m	6	6000
7	Misc. cost			345
	TOTAL			**23,400**

8.13 Estimate for 1 ha Mixed Plantation (1600 plants at 2.5 mx2.5 m spacing)

S.No	Item	Unit	Unit cost	Amount (Rs)
	First year			
1	Survey and demarcation and site preparation	10 MD	90	900
2	Digging of pits 30 cm cube 1600	32 MD	90	2880
3	Cost of seedlings + 10% casuality	1760	2.50	4400
4	Transport of seedling and planting	10 MD	90	900
5	Cost of fertilizer and pesticides			1000
6	Application of fertilizer and pesticides	2MD	90	180
7	Weeding and interculture (twice)	20	90	1800
8	Watch and ward (I person per 12 ha)	30 MD	50	1500
	First year Total			**13560**
	Second Year			
1	Casualty replacement 10%	160	2.50	400
2	Labour for gap filling	2MD	90	180
3	Weeding and interculture	16MD	90	1440
4	Manuring (cost of fertilizer)			1000
5	Watch and ward	30 MD	50	1500
	Second year total			**4520**
	Third year			
1	Watch and ward	30 MD	50	1500
2	Misc. exp			100
	Third year total			**1600**
	GRAND TOTAL			**19680**

Or say Rs 20,000/ha

8.14 Model Estimate for Agro-Silvi-Horti-Pastural System (1 ha)

S.No	Item	Unit	Unit cost	Amount (Rs)
1	Survey and demarcation of site	2 MD	90	180
2	Brush wood fencing	600 r m	5	3000
3	Construction of V ditches with vegetative hedges and soil conservation measures	30MD	90	2700
4	Cost of seeds Grass 1.5 kg	1.5	80	120

	Stylo 2 kg Cowpea 2kg	2 2	80 40	160 80
5	Ploughing and leveling	5 BU	150	750
6	Peripheral ploughing	2 BU	150	300
7	Cost of bamboo seeds			400
8	Cost of sowing	2 MD	90	180
9	Cost of planting forest species Fruit species	90 50	30 60	2700 3000
10	Cost of manure and fertiliser			500
11	Watch and ward			1500
12	Misc. and unforeseen			130
	TOTAL			**15,000**

8.15 Estimate for Silvipastoral Plantation (1 ha with 625 plants at 8m x2m spacing)

S.No	Item	Unit	Unit cost	Amount (Rs)
	First year			
1	Ploughing	10 BU	150	1500
2	Sowing legume seeds at 8m strip and grasses by broadcasting	2 MD	90	180
3	Cost of pesticide/fertilizer and application			800
4	Digging pits of 30 cu cm	10 MD	90	900
5	Cost of seedlings with 10% casualty	690	2.50	1725
6	Vegetative fencing along with cost of seeds	8MD	90+ seed cost	800
7	Weeding and interculture	10MD	90	900
8	Cost of R. culture	2 kg	25	50
9	Cost of legume seeds			300
10	Watch and ward			1500
11	Misc			100
	Total of first year			**8755**
	Second year			
1	Casualty replacement 10%	1	90	90
	Cost of seedling	62	2.50	155
2	Weeding and interculture	8	90	720
3	Cost of fertilizer			400
4	Watch and ward			1500
	Total of second year			**2865**
	Third year			
1	Watch and ward			1500
2	Plant protection			500
	Total of third year			**2000**
	Grand Total			**13,620**

8.16 Estimate for Mango Plantation (1 ha with 125 plants at 9mx9m spacing. Var. Baiganpalli, Totapuri etc)

Year	Item	Unit	Unit cost	Amount (Rs)
First	Land preparation & lay out	10 MD	90	900
	Digging pits of 1mx1mx1m size	20 MD	90	1800
	Application of manure, filling pits and planting	14 MD	90	1260
	Application of pesticides	4MD	90	360
	Intercultural operations	10MD	90	900
	Temporary fencing	40 MD	90	3600
	Irrigation & watch ward	60 MD	90	5400
	Cost of grafts (10% mortality)	137	25	3425
	Organic manure/FYM	6t	300	1800
	Fertiliser(N-15kg, P-5 kg, K-15 kg)	35 kg		450
	Cost of PP chemicals			300
	Misc. expenses			100
	TOTAL			**20,295**
Second	Application of manure & fertiliser	6MD	90	540
	Weeding and interculture	10 MD	90	900
	Application of PP chemicals	4MD	90	360
	Repair to temporary fencing	8MD	90	720
	Irrigation & watching	60 MD	90	5400
	Cost of manure & fertilizer			1250
	Cost of PP Chemicals			250
	TOTAL			**9420**
3rd	Application of manure & fertilizer	6 MD	90	540
	Weeding and interculture	10 MD	90	900
	Application of pesticides	4MD	90	360
	Irrigation & Watching	60	90	5400
	Cost of manure & fertilizer			1250
	Cost of PP chemicals			250
	Misc.			385
	TOTAL			**8885**
	Grand Total			**37,600**

8.17 Nursery Management

Description: It is a place where seedlings and other planting materials are raised for field planting. Nursery practices include raising seedlings, stump planting, branch planting/cutting, root cutting, layering, budding and other grafting methods including care of planting materialsfor1-2 years.

Site: Nursery site should have easy access and convenient means of transport, availability of water and good soil.

Size: The size is determined according to the number of planting materials to be prepared. Usually one ha of nursery supports 200,000 seedlings with 25 cmx17 cm polythene bags of 150 gauge.

Components of Nursery: the components of a nursery are land, fencing, shed, propagation shed, irrigation source, water storage tank, paths, seedbeds, nursery beds, progeny plantations, pot yard, pot mixture yard and compost pits.

Garden tools: The usual tools and equipment for a nursery are secateurs, budding knife, grafting knife, HC sprayer, rose can, grass shears, hedge shears, trowels, dibblers, garden rake, trench hoe, phourah, khurpi etc.

Site preparation: The site should be cleaned during winter and weeds are to be burnt during April-May. Then the site should be ploughed up to 45 cm depth and stones and roots are to be removed. The clods are to be broken and the entire soil needs to be made smooth before rainy season.

Arrangement for irrigation: A perennial source should be made available or created. Where natural source is not available a well should be dug and lifting device may be arranged.

Soil preparation: The best soil mixture is earth, washed sand and manure in the proportion of 6:3:1.The soil should be well drained, loamy in texture, having 2.5% organic matter and pH 6.5 to 7.5. The best manure is leaf mould or quality compost.

Seedbed Preparation: The seedbeds should be 1.25 m wide with a gap of 45 cm between two beds. The long side of the bed is aligned east-west direction to capture maximum sunlight. Raised beds are preferred in high rainfall areas.

Method of propagation:

Method of propagation	Type	Tree spp.
Vegetative	Inarching, top working, veneer grafting	Mango, cashew, sapota
	Air layering	Guava, litchi
	Budding	Citrus, ber, aonla
	Stump planting	Sal, siris, cashew, arjun, sisoo, khair , teak etc.
	Cuttings	Phalsa, drum stick, mulberry, pomegranate etc.

Seeding	Direct/nursery	Teak, Acacia, Babul, Siris, Cashew, Guava, Lime, Neem, Sisoo, Arjun, Subabul, Ber, Tamarind etc.

Fencing: Provide live hedges like sisal, duranta, caesalpinia, chiller etc.Plant seeds or cuttings during July-August

Shade: Quick growing trees like sisoo, agasthi etc. may be planted in nursery.

Method of sowing: The seeds may be sown using seed drill or by dibbling at appropriate depth and covered with smooth soil or compost. The depth of cover should be equal to the minimum diameter of the seed. Seed treatment may be made using boil water for 12-24 hours for seeds with hard coat (teak, acacia), soaking in clod water or by special treatment methods. Some seeds like ber are treated by soaking in 17% salt solution for 5-6 hours and then packed in gunny bags and gradually beating with wooden rod and washing in running water to remove traces of salt. Rhizobium inoculation may be made for leguminous seeds @ 50 g per 10,000 seeds .Seeds may also be treated with thiram or captan @ 2 g/kg of seed before planting.

Time of sowing: The seeds are generally sown during January to March. Where stumps are required it should be planted during previous May-June.

Seed Quantity: The quantity of seeds is determined by using formula:

$$W = \frac{A \times D}{P \times N} \times 100$$

Where, W= weight of seeds required in gram
A= Area of bed in sq m
D= Number of plants required per sq m
P= Germination percentage expected
N = number of seed per gram

After Care: After sowing regular watering and shading is required. The germinated seedlings are transferred from the beds to the containers and carefully kept in shaded beds. Grading of seedlings is made at different stages of shifting the polypots. As and when necessary plant protection chemicals are to be used to maintain health seedlings in nursery.

8.18 Estimate for a model Nursery (Capacity 10,000 sedlings)

S.No	Items	Unit	Unit cost	Amount (Rs)
	Material cost			
1	Cost of polythene bags	15 kg	100	1500
2	Organic manure	2400 kg	0.30	720
3	Inorganic fertilizer	60 kg	10.00	600
4	Pesticides	3 litre/kg		750
5	Seeds	30 kg	40.00	1200
6	Hormones	0.5 litre	200.00	100

7	Improved seeds	5 kg	100.00	500
8	Planting material			200
9	Watering can	1	200.00	200
10	Improved potting material			1000
	Total			**6770**
	Labour cost			
1	Nursery bed preparation	2 MD	90	180
2	Fencing	4 MD	90	360
3	Soil preparation and filling	30 MD	90	2700
4	Fertilising, watering and after care	70 MD	90	6300
	Total			**9540**
	Misc & unforeseen			690
	Grand Total			**17,000**

8.19 Mixed/ Inter Cropping

Description:

Intercropping is the agricultural practice of cultivating two or more crops in the same space at the same time. An ideal inter cropping system should:

- Produce higher yields per unit area through better use of natural resources;
- Offer greater stability in production under adverse weather conditions and with disease and insect infestation;
- Meet the domestic needs of the farmer;
- Provide an equitable distribution of farm resources

Fig.8.17 Mixed / Inter Cropping

Purpose

The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop. Careful planning is required, taking into account the soil, climate, crops, and varieties. It is particularly important not to have crops competing with each other for physical space, nutrients, water, or sunlight. Examples of intercropping strategies are planting a deep-rooted crop with a shallow-rooted crop, or planting a tall crop with a shorter crop that requires partial shade.

Design

In intercropping, there is often one main crop and one or more added crops, with the main crop being the one of primary importance because of economic or food production reasons. The two or more crops used in an intercrop may be from different species and different plant families.

Types

- Mixed intercropping, as the name implies, is the most basic form in which the component crops are totally mixed in the available space.
- Row cropping involves the component crops arranged in alternate rows. This may also be called alley cropping. A variation of row cropping is strip cropping, where multiple rows (or a strip) of one crop are alternated with multiple rows of another crop.
- Intercropping also uses the practice of sowing a fast growing crop with a slow growing crop, so that the fast growing crop is harvested before the slow growing crop starts to mature. This obviously involves some temporal separation of the two crops.
- Further temporal separation is found in relay cropping, where the second crop is sown during the growth (often near the onset of reproductive development or fruiting) of the first crop, so that the first crop is harvested to make room for the full development of the second crop.

Spatial Arrangement

There are at least four basic spatial arrangements used in intercropping.

- *Row intercropping*—growing two or more crops at the same time with at least one crop planted in rows.

- *Strip intercropping*—growing two or more crops together in strips wide enough to permit separate crop production using machines but close enough for the crops to interact.
- *Mixed intercropping*—growing two or more crops together in no distinct row arrangement.
- *Relay intercropping*—planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting.

To optimize plant density, the seeding rate of each crop in the mixture is adjusted below its full rate. If full rates of each crop were planted, neither would yield well because of intense overcrowding. By reducing the seeding rates of each, the crops have a chance to yield well within the mixture. The challenge comes in knowing how much to reduce the seeding rates. Usually 60% of recommended seed rate of main crop and 40% of recommended seed rate of companion crop is used. The row arrangements differ according to the location, climate , soil, crop and cultivar used

Areas with growing season of 20-30 weeks which receive at least 800 mm rainfall are suitable for inter cropping system that will cover the risk under rain-fed situations. Inter cropping with pigeon pea + groundnut (2:5), pigeon pea + jowar (1:1), pigeon pea + rice (2:5), maize + cowpea (2:2), pigeon pea + green gram (2:6) may be taken up under upland situations during *Kharif* season where irrigation facility is not available.

8.20 Estimate for cost of cultivation of mixed (intercropping) cropping in 1 ha

Crop combination	Item	Unit	Unit cost	Amount (Rs)
Arhar+paddy	Seed cost- Arhar- 15 kg	15 kg	50	750
	Seed cost-Paddy- 45	45 kg	10	450
	Cost of fertilizer- N P-30 kg K-30 kg	60 kg 30 kg 30 kg	10 25 9	600 750 270
	Rhizobium culture	500 g	25	13
	Pesticides- Liquid Fungicide(Bavistin) Seed treating chemical	1 litre 500 g 150 g	300 500 200	300 250 30
	Total			**3413**
Arhar+ Groundnut	Seed cost- Arhar-10 kg Groundnut--90	10 kg 90 kg	50 25	500 2250
	Fertilizer- N P K	20 40 40	10 25 9	200 1000 360
	Rhizobium culture	1.5 kg	25	38
	Pesticide- Liquid Fungicide (Blitox 50) Seed treating chemical	1 litre 2.5 kg 200 g	300 250 200	300 625 40
	Total			**5313**

Chapter -9
Procedure for Check Measurement

9.1 Contour bund

i. Measure the top width
ii. Measure the depth, height
iii. Measure the length of slanting height
iv. Measure the length

9.2 Contour trench

I. Measure the top width of the trench
II. Measure the depth of the trench
III. Measure the length

9.3 Contour stone wall

I. Length
II. Height
III. Top width
IV. Slanting lengths both at u/s and d/s side

9.4 Loose boulder structures

I. Length of the structure
II. Slanting length (both upstream and downstream side)
III. Top width of the structure
IV. Height of the structure
V. Length and width of the apron
VI. Depth of boulder filling

9.5 Gabion structure

I. Length of the structure
II. Width and depth of the structure
III. Length, width and depth of the stone pitching

9.6 Brushwood structure

I. Length, width and height of structure
II. Size, spacing and height of brushwood
III. Extent of grouting (length, depth and width)

9.7 Diversion weir

I. Length of the head wall portion
II. Length of head wall extension
III. Size of openings (width and depth)
IV. Depth and width of the canal, if any
V. Length and width of individual steps/ cascades of d/s side
VI. Length and width of the apron
VII. Length, width and depth of stone pitching, if any

9.8 Check dam

I. Length of head wall
II. Height of the head wall
III. Top width of the head wall
IV. Length, top width and height of the head wall extension
V. Length, top width and height of side wall (both straight and slanting portion)
VI. Length, top width and height of the wing wall
VII. Length and width of the apron
VIII. Difference between crest of head wall and apron
IX. Length and width of both transverse and end sill
X. Level difference between top of the sill and crest of the head wall
XI. Length, width and depth of stone pitching

9.9 Farm pond/ WHS/ Irrigation tanks

I. Top width and length
II. Depth
III. Bottom width and length
IV. Length, top width, slanting length and height of embankment, if any
V. Length, top width and height of the waste weir, if any
VI. Length and width of head wall extension of the structure
VII. Length and width of the apron
VIII. Length, width and depth of stone pitching
IX. Length, width and depth of the sluice opening, if any
X. Length, width and depth of the canal system, if any
XI. Length and width of the berm, if any

XII. Difference of level between top of berm and top of dam

XIII. Slanting distance from top of the dam to berm top

9.10 Percolation tank

I. Length and width of the top

II. Depth

III. Length and width of the bottom

IV. Dimensions of waste weir, if any, as stated earlier

9.11 Dug well

I. Diameter of the well (inside and outside)

II. Depth of the well

III. Length, width and depth of the platform , if any

IV. Thickness of the stone

V. If ring well, number of rings with diameter and height

VI. Size of reinforcement

9.12 Foundation of any structure (RCC/ stone masonry/ cement concrete)

VII. Dig the side of the foundation with crowbar and then measure the depth and foundation

9.13 Cement concrete work/ RCC (If doubt comes)

I. Take a block of 5 cm X 5 cm X 5 cm and test it in the testing laboratory of Engineering college/ RRL/ PWD testing lab

II. For steel rod a sample piece may be collected and get tested in above mentioned laboratories for strength analysis (Compressive and tensile strength)

Glossary of Technical Terms

Absorption: The entrance of water into the soil or rocks by all natural processes.

Afforestation: The establishment of a tree crop on an area from which it has always or very long been absent, or the planting of open areas which are not presently in forest cover.

Agroforestry: A system of agriculture that combines traditional agriculture and forestry technologies to create a more integrated, diverse, productive, profitable, healthy and sustainable land use system

Alley cropping: An agroforestry intercropping system in which species of shrubs or trees are planted at spacing relatively close within row and wide between row, to leave room for herbaceous cropping between, that is, in the 'alleys' (syn: hedgerow intercropping).

Available Water: The portion of water in a soil that can be absorbed by plant roots, usually considered to be that water held in the soil against a tension of up to approximately 15 atmospheres.

Available Water Holding Capacity: The capacity of a soil to hold water in a form available to plants. Also, the amount of moisture held in the soil between field capacity, or about one-third atmosphere of tension, and the wilting coefficient, or about 15 atmospheres of tension.

Bund and ditch: A bund formed from excavating soil making an adjacent ditch

Climate: The sum total of the meteorological elements that characterize the average and extreme condition of the atmosphere over a long period of time at any one place or region of the earth's surface.

Conservation storage: Storage of water for later release for useful purposes such as municipal water supply, power, or irrigation in contrast with storage capacity used for flood control.

Conservation tillage: An agricultural system using tillage techniques designed to reduce soil erosion and overland flow. Most conservation tillage techniques involve less manipulation of the soil than conventional techniques, leaving more plant matter on the soil surface

Consumptive use: The quantity of water absorbed by the crop and transpired or used directly in the building of plant tissue together with that evaporated from the cropped area.

Contour cultivation: Farm operation, e.g. ploughing and planting, carried out along the contour line

Contour ploughing: A soil conservation technique involving ploughing parallel to the contour, across a slope rather than up and down it.

Contour ridging: The creation of ridges along the contour (or at a slight gradient). A series of small (15–20 cm height) structures, closely spaced. [N.B. in the southern African context they may be large 40–50 cm structures, widely spaced – termed contour bunds or banks elsewhere).

Contour tillage: Tillage (ploughing, harrowing, weeding, etc.) along the contour line

Cover cropping: Planting close growing crops to protect the soil from the impact of rain drops

Crop rotation: A soil conservation technique involving changing crops grown on a given parcel of land from year to year. Crop rotations may include fallow periods.

Cropping system: The cropping patterns used on a farm and their interaction with farm resources, other farm enterprises, and available technology which determine their cultivation (ASA, 1976). The cropping system is subsystem of a farming system (FAO, 1996).

Diversion ditch: A ditch, normally laid out at a slight gradient at the top of a plot of land, intended to intercept and divert concentrated runoff hand digging of soil up to double the normal depth in order to improve drainage, infiltration and rooting characteristics

Drainage area: The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

Drip irrigation: An irrigation method involving small pipes placed at the base of plants delivering water slowly to the plant roots.

Drought: A period of deficient precipitation or runoff extending over an indefinite number of days, but with no set standard by which to determine the amount of deficiency needed to constitute a drought.

Dry farming: Agricultural production in climatically marginal lands without the use of irrigation.

Erodibility: Susceptibility to erosion, erosion proneness.

Erosion: The wearing away of the land by running water, rainfall, wind, ice or other external agents, including such processes as detachment, entrainment, suspension, transportation and mass earth movement.

Evaporation: The process by which water is changed from the liquid or the solid state into the vapor state. In hydrology, evaporation is vaporization that takes place at a temperature below the boiling point.

Evapo-transpiration: Water withdrawn from a land area by **evaporation** from water surfaces and moist soil and plant **transpiration**

Field-moisture capacity: The quantity of water which can be permanently retained in the soil in opposition to the downward pull of gravity.

Flood: An overflow or inundation that comes from a river or other body of water .

Freeboard: the vertical space remaining in a containment structure; the vertical distance between the surface of the water and the top of a dam or dyke

Gabion: wire basket filled with rocks, used to stabilise riverbank or foot of unstable slope

Graded bund: A bund laid out on a gradient (i.e. slightly off-contour, to allow for lateral controlled disposal of runoff at non-erosive velocity) A strip of vegetation laid out on a gradient rather than the true contour

Ground water: Water in the ground that is in the **zone of saturation**, from which wells, springs, and **ground-water runoff** are supplied.

Ground-water runoff: That part of the runoff which has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.

Gully or Channel Erosion: The removal of soil by the formation of relatively large channels or gullies cut into the soil by concentrated surface runoff. In contrast to rills, gullies are too deep to be obliterated by ordinary tillage practices.

Gully: A steep-walled stream channel incised in the soil by accelerated erosion.

Hedge barrier/ barrier hedge: A dense hedge, normally of a woody species, planted on the contour to reduce soil loss through slowing surface runoff .The owner of a herd of cattle / goats / sheep, etc.

Hydrologic cycle: A convenient term to denote the circulation of water from the sea, through the atmosphere, to the land; and thence, with many delays, back to the sea by overland and subterranean routes, and in part by way of the atmosphere; also the many short circuits of the water that is returned to the atmosphere without reaching the sea.

Hydrology: The science encompassing the behavior of water as it occurs in the atmosphere, on the surface of the ground, and underground

Infiltration: The flow of a fluid into a substance through pores or small openings. It connotes flow into a substance in contradistinction to the word **percolation**, which connotes flow through a porous substance.

Intercropping: The simultaneous systems refer to the cultivation of two or more crops either intermingled or with a distinct row or strip arrangement.

Irrigation Efficiency: The percentage of water applied that can be accounted for in soil-moisture increase.

Irrigation: The controlled application of water to arable lands to supply water requirements not satisfied by rainfall.

Land Capability Classification System: A scheme used by the U.S. Natural Resource Conservation Service for assessing and classifying the productivity of land units.

Landslide: A slope Mass Earth movement where a soil or substrata mass slides over a contact surface called sliding surface.

Minimum tillage: A system whereby crops are planted into the soil with only a light and shallow tillage operation beforehand

Mixed cropping: An agricultural system in which several different crops are grown in close proximity, in a rotation system, or both.

Mulch: A natural or artificially applied layer of plant residues or other materials such as stones, sand, paper or brush on the surface of the soil.

Mulching: Spreading of organic (or other) materials on the surface of the soil around crops to reduce moisture loss, reduce erosion, inhibit weed growth, etc.

Percolation: The movement, under hydrostatic pressure, of water through the interstices of a rock or soil, except the movement through large openings such as caves.

Precipitation: As used in hydrology, precipitation is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface.

Rainfall: The quantity of water that falls as rain only. Not synonymous with **precipitation**.

Reservoir: A pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

Rill Erosion: Removal of soil by the cutting of numerous small, but conspicuous water channels or tiny rivulets by concentrated surface runoff. The marks of rill erosion may be obliterated by ordinary tillage practices.

Riparian: Pertaining to the banks of a stream.

Runoff: That part of the precipitation that appears in surface streams. It is the same as **stream flow** unaffected by **artificial diversions**, **storage**, or other works of man in or on the stream channels.

Sediment: the solid material that settles from a liquid; for example mud will sink and settle at the bottom of a river or stream because it is heavier than water

Sheet Erosion: The removal of a fairly uniform layer of soil from the land surface by runoff or wind.

Shifting cultivation: Cultivation on a piece of land which is cleared, used for a number of seasons, and then left fallow for several years to recover fertility, while the land user moves to another site

Siltation: the deposition, in a water body, of sediments (e.g. sand and clay) that appear as tiny suspended particles

Silviculture: management of timber trees to improve quality and yield, principally by pruning and thinning; can also entail seedling selection, fertilising, spraying for disease and weed control.

Silvo-pastoral system: Any agroforestry system that include trees or shrubs and pastures and animals. Related term: forest grazing

Soil cover: The vegetation (natural and planted) or human-made structures (buildings, etc.) that cover the earth's surface

Soil crusting: Process of compaction and cementation of fine soil surface particles removed and accumulated by splash and sheet erosion processes which can lead to a complete sealing of soils pores.

Soil degradation: A process which lowers the current and / or potential capability of the soil to produce goods or services (through one or more of 6 categories: water erosion; wind erosion; water logging and excess salts; chemical degradation; physical degradation; biological degradation). (FAO, 1979)

Soil erodibility: A measure of the inherent susceptibility of a soil to erosion, without regard to topography, vegetation cover, management, or weather conditions

Soil moisture: Water diffused in the soil, the upper part of the **zone of aeration** from which water is discharged by the **transpiration** of plants or by soil evaporation.

Splash/Raindrop Erosion: The spattering of soil particles caused by the impact of raindrops on the soil. The loosened particles may or may not be subsequently removed by runoff; splash erosion is an important component of sheet erosion.

Stream flow: The discharge that occurs in a natural **channel**. Although the term discharge can be applied to the flow of a canal, the word stream flow uniquely describes the discharge in a surface stream course.

Strip cropping: a form of cropping system where contour belts / bands of specific crops are alternated to improve conservation. For example an erosion-risk crop such as tobacco may be grown in bands of 10 meters along the contour which are then separated with bands of a perennial fodder grass

Strip cropping: The practice of growing crops in narrow bands along the contour in an attempt to reduce runoff, thereby preventing erosion or conserving moisture.

Stubble mulch: A soil covering composed of the unused stalks of crop plants.

Supplemental irrigation: Commonly, irrigation as carried on in humid areas. The term means that the irrigation water is supplementary to the natural rainfall rather than being the primary source of moisture as in the arid and semiarid .

Surface runoff: That part of the runoff which travels over the soil surface to the nearest stream channel. It is also defined as that part of the runoff of a drainage basin that has not passed beneath the surface since precipitation.

Terrace: A berm or discontinuous segments of a berm, in a valley at some height above the **flood plain**, representing a former abandoned flood plain of the stream.

Terracing: A soil and water conservation technique consisting of ridges on the contour, or level areas constructed on a slope.

Transpiration: The quantity of water absorbed and transpired and used directly in the building of plant tissue, in a specified time.

Tree farming: Any agroforestry practice that incorporates trees into farmland. Related term: farm forestry

Vegetation Cover: Portion of soil which is covered by the plant canopy

Water harvesting: The harvesting of runoff from a contributing (or 'catchment') area and its concentration in a collecting area. Usually for crop production in dry areas, or ponding of water for domestic / livestock use

Water table: The upper surface of a zone of saturation. No water table exists where that surface is formed by an impermeable body.

Water logging*:* Condition of land when the water table stands at or near the land surface and may be detrimental to plant growth.

Watershed: The land area that drains to a particular point or area in the landscape (i.e., to a pond, lake, river, etc.)

Weir: Overflow structure which may be used for controlling upstream water level or for measuring discharge or for both.